ENCYCLOPÆDIA BRITANNICA

Vol 28.

NEW VOLUMES

ELE.-GLA.

THE NEW VOLUMES

OF THE

ENCYCLOPÆDIA BRITANNICA

THE

NEW VOLUMES

OF THE

ENCYCLOPÆDIA BRITANNICA

CONSTITUTING

IN COMBINATION WITH THE EXISTING VOLUMES OF THE NINTH EDITION

THE TENTH EDITION

OF THAT WORK, AND ALSO SUPPLYING

A NEW, DISTINCTIVE, AND INDEPENDENT

LIBRARY OF REFERENCE

DEALING WITH RECENT EVENTS AND DEVELOPMENTS

THE FOURTH OF THE NEW VOLUMES, BEING

VOLUME XXVIII

OF THE COMPLETE WORK

PUBLISHED BY

ADAM & CHARLES BLACK, EDINBURGH & LONDON

'THE TIMES' PRINTING HOUSE SQUARE, LONDON

MCMII

THE EDITORS

SIR DONALD MACKENZIE WALLACE,
K.C.I.E., K.C.V.O.

ARTHUR T. HADLEY, LL.D.,
PRESIDENT OF YALE.

HUGH CHISHOLM, B.A.
(FORMERLY SCHOLAR OF C.C.C. OXFORD)

THE DEPARTMENTAL EDITORS

FOR LAW AND GOVERNMENT:
THE HON. SIR JOHN SCOTT, K.C.M.G., Deputy Judge-Advocate-General.

FOR MILITARY AFFAIRS:
SIR GEORGE SYDENHAM CLARKE, K.C.M.G., F.R.S.

FOR MEDICAL SCIENCE:
D. NOEL PATON, M.D., B.SC., F.R.C.P.ED.

FOR THEOLOGY:
REV. W. E. COLLINS, M.A., Prof. of Ecclesiastical Hist. at King's Coll., Lond.

FOR MINING:
HENRY M. HOWE, A.M., Prof. of Metallurgy at Columbia University.

FOR BOTANY:
D. H. SCOTT, M.A., PH.D., F.R.S., Hon. Keeper, Jodrell Laboratory, Kew.

FOR GEOGRAPHY AND STATISTICS:
J. SCOTT KELTIE, F.S.S., F.S.A.SCOT., LL.D., Sec. Roy. Geog. Soc.

FOR ASTRONOMY:
SIMON NEWCOMB, PH.D., LL.D.

FOR MATHEMATICS:
JOSEPH LARMOR, M.A., D.SC., SEC.R.S., University Lecturer in Mathematics, Cambridge.

FOR ELECTRICITY:
J. A. FLEMING, M.A., D.SC., F.R.S., Prof. of Electrical Engineering, Univ. Coll., London.

FOR ART:
M. H. SPIELMANN, Editor of the *Magazine of Art.*

FOR ZOOLOGY:
G. HERBERT FOWLER, PH.D.

FOR NAVAL AFFAIRS:
JAS. RICHARD THURSFIELD, M.A.

FOR BIOGRAPHY:
RICHARD GARNETT, C.B., LL.D.

FOR LITERATURE:
EDMUND GOSSE, LL.D.

FOR ECONOMICS:
WYNNARD HOOPER, M.A.

FOR RAILWAYS:
MAJOR HENRY G. PROUT, Editor of *Railroad Gazette*, N.Y.

FOR MUSIC:
J. A. FULLER MAITLAND, M.A., F.S.A.

FOR GAMES AND SPORTS:
ALFRED WATSON, Editor of the *Badminton Library.*

THE ASSOCIATE EDITORS

PHILIP A. ASHWORTH, DR. JUR.
H. M. ROSS, B.A.
FRANKLIN H. HOOPER, A.B.
E. H. WILLIAMS, M.D.

THE SUB-EDITORS

JAMES A. MANSON.
G. B. LYNES, A.M.

ENCYCLOPÆDIA BRITANNICA

VOLUME XXVIII (ELECTIONS—GLAMORGAN).

PRINCIPAL CONTENTS.

PREFATORY ESSAY: THE GROWTH OF TOLERATION. Sir LESLIE STEPHEN, K.C.B.

ELECTRICITY. *Electric Conduction*, J. A. FLEMING, D.Sc., F.R.S., Professor of Electrical Engineering, University College, London; *Electrolytic Conduction*, W. C. D. WHETHAM, F.R.S., Fellow of Trinity College, Cambridge; *Electric Current* and *Electric Units*, Professor J. A. FLEMING; *Electric Discharge* and *Electric Waves*, J. J. THOMSON, D.Sc., F.R.S., Cavendish Professor of Experimental Physics, Cambridge University.

ELECTRICITY SUPPLY. *General Principles* and *Lighting*, Professor J. A. FLEMING; *Traction*, LOUIS DUNCAN, Ph.D., formerly President of the American Institute of Electrical Engineers; *Industrial Developments*, EMILE GARCKE, F.S.S., Manager of the Brush Electrical Engineering Company.

ELECTRO-CHEMISTRY and ELECTRO-METALLURGY. W. G. McMILLAN, F.C.S., Secretary to the Institution of Electrical Engineers.

ELECTRO-MAGNETS. Professor J. A. FLEMING.

ELEVATORS. ROBERT H. THURSTON, LL.D., Director of Sibley College and Professor of Mechanical Engineering, Cornell University.

EMBROIDERY. LEWIS F. DAY, Examiner for Art, Board of Education.

EMBRYOLOGY. ADAM SEDGWICK, F.R.S., Fellow of Trinity College, Cambridge, and University Reader in Animal Morphology; *Physiology of Development*, HANS A. E. DRIESCH, Ph.D., Author of "Analytische Theorie der organischen Entwicklung."

EMERSON. Rev. HENRY VAN DYKE, D.D., LL.D., Professor of English Literature, Princeton University, N.J., Author of "The Poetry of Tennyson."

EMPLOYERS' LIABILITY. MAURICE HILL, Barrister-at-Law.

ENAMEL. ALEXANDER FISHER.

ENERGETICS. JOSEPH LARMOR, D.Sc., Sec. R.S., Lecturer in Mathematics, Cambridge University.

ENGINEERS, MILITARY. Colonel R. H. VETCH, C.B.

ENGINES. *Steam*, J. A. EWING, Professor of Mechanism and Applied Mechanics, Cambridge; *Gas and Oil*, DUGALD CLERK, author of "The Theory of the Gas Engine."

ENGLAND, CHURCH OF. The Rev. W. E. COLLINS, M.A., Professor of Ecclesiastical History, King's College, London, and the Rev. FREDERICK BURNSIDE, M.A., Hon. Canon of St Albans.

ENGLAND AND WALES. *Geography*, H. R. MILL, D.Sc., F.R.G.S., Editor of "Symons's Meteorological Magazine"; *Statistics*, I. P. A. RENWICK, M.A., LL.B., Assistant Editor of "The Statesman's Year-Book."

ENGLISH BIBLE. The Rev. H. HENSLEY HENSON, Canon of Westminster.

ENGLISH HISTORY. Sir SPENCER WALPOLE, K.C.B., Author of "History of England from 1815," &c.

ENGLISH LAW. F. W. MAITLAND, LL.D., D.C.L., Professor of English Law, Cambridge University.

ENGLISH LITERATURE. EDMUND GOSSE, LL.D.

ENGRAVING. *Etching*, FREDERICK WEDMORE, Author of "Etching in England," &c.; *Mezzotint*, GERALD P. ROBINSON, President of Society of Mezzotint Engravers; *Lithography*, E. F. STRANGE, National Art Library, South Kensington; *Wood* and *Line*, M. H. SPIELMANN, Editor of "The Magazine of Art."

ENTOMOSTRACA. The Rev. T. R. R. STEBBING, F.R.S., Fellow of King's College, London.

EPIDAURUS. ERNEST GARDNER, Yates Professor of Archæology, University College, London.

ERROR, LAW OF. F. Y. EDGEWORTH, D.C.L., Professor of Political Economy, Oxford University.

ESPARTERO, MARSHAL. A. E. HOUGHTON, L.C.L., Author of "Restoration of the Bourbons in Spain."

ESTABLISHMENT AND DISESTABLISHMENT. The Rev. W. E. COLLINS, M.A., Professor of Ecclesiastical History, King's College, London.

ESTATE DUTY. P. DUNCAN, Treasurer of the Transvaal Colony; *United States*, SIMEON E. BALDWIN, A.M., LL.D., Judge of the Supreme Court of Errors of Connecticut.

ETHICS. J. A. STEWART, LL.D., White's Professor of Moral Philosophy, Oxford University.

EUPHRATES. Major-General Sir C. W. WILSON, K.C.B., LL.D., F.R.S.

EUROPE. *Geography and Statistics*, G. G. CHISHOLM, Editor of "Longman's Gazetteer of the World"; *History*, Sir DONALD MACKENZIE WALLACE, K.C.I.E., K.C.V.O.

EVANGELICAL ALLIANCE. The Rev. W. E. COLLINS.

EVIDENCE. Sir COURTENAY P. ILBERT, K.C.S.I., Clerk of the House of Commons.

EVOLUTION. P. CHALMERS MITCHELL, D.Sc., F.Z.S., Lecturer on Biology at the London Hospital Medical College.

EXCHEQUER. S. E. SPRING-RICE, C.B., Principal Clerk H.M. Treasury.

EXCISE REVENUE. Sir G. H. MURRAY, K.C.B., formerly Chairman of the Board of Inland Revenue.

EXECUTIONS, CIVIL. A. WOOD RENTON, Puisne Judge of Mauritius.

EXHIBITIONS. G. C. LEVEY, C.M.G.

EXPERIMENTS ON ANIMALS. STEPHEN PAGET, M.D., F.R.C.S., Surgeon to the West London Hospital, Author of "Experiments on Animals," &c.

EXTERRITORIALITY. THOMAS BARCLAY, LL.B., Ph.D., sometime Examiner in International Law to the University of Oxford.

EXTRADITION. J. E. P. WALLIS, M.A., Advocate-General of Madras, formerly Editor "State Trials."

FACTORS. LESLIE SCOTT.

FAWCETT. THOMAS SECCOMBE, M.A., Assistant Editor of "The Dictionary of National Biography."

FENS. J. T. BEALBY.

FINANCE. C. F. BASTABLE, LL.D., Professor of Political Economy, Dublin University.

FINLAND. PRINCE KROPOTKIN.

FIRE AND FIRE EXTINCTION. *Britain*, Captain L. DE L. WELLS, R.N., Chief Officer of the Metropolitan Fire Brigade; *United States*, General A. P. ROCKWELL, Boston, Massachusetts.

FISHERIES. WALTER GARSTANG, M.A., F.Z.S., in charge of Fishery Investigations, Marine Biological Association.

FISHERY. G. G. PHILLIMORE, M.A., B.C.L., Barrister-at-Law, London.

FITZGERALD. EDMUND GOSSE, LL.D.

FLAUBERT. EDMUND GOSSE, LL.D.

FLORENCE. ENRICO CORRADINI, formerly Editor of "La Nazione," Florence.

PREFATORY ESSAY.

THE GROWTH OF TOLERATION.

By Sir Leslie Stephen, K.C.B.

AT the opening of the 20th century we might plausibly congratulate ourselves upon the increase of mutual tolerance. A marked change had taken place even within a generation. In the 'sixties there was a period of sharp controversy, which to some of the disputants seemed to herald an intellectual revolution as important as that which took place at the Reformation. Adherents of Darwinism in science, and advocates for the application of critical methods to the Bible, were denounced in a spirit recalling the ancient methods of controversial warfare. In 1902 orthodox divines could regard evolution as an established principle, and were no longer alarmed by the critical results which seemed at first sight so destructive. Whatever the meaning of this change, there is undoubtedly a gain in good temper and calmness of discussion. Perhaps we are a little inclined to exaggerate the real intensity of the previous struggle. The old phrases scarcely covered the old strength of feeling. A recent writer remarks that the Calvinistic dogmatism in which he was educated has vanished "like a nightmare and hideous dream." That may go to prove that it was not really believed even in his youth. It is exceedingly rash to infer men's genuine beliefs from their most sincere avowals. They believe themselves to hold dogmas, the plain meaning of which is neutralized by all manner of tacit reservations and unconscious interpretations. The real utility of the ostensible creed may be sapped long before it is openly abandoned; and when a doctrine vanishes rapidly, the inference is that it had already decayed at the roots. The apparent change may mean merely that men have come to avow clearly the conclusions which were already formed, though latent under various disguises. In any case, however, the general readiness to accept as harmless or obvious opinions which not long ago were regarded as dangerous and offensive is in itself a remarkable change, and may justify a few considerations as to its true nature. To understand it fully we should have to consider how it takes its place in the prolonged process by which a doctrine, universally repudiated three centuries ago, is now as universally accepted, even by some to whom the fundamental position requires a little straining to make room for it.

A remarkable change.

A full acceptance of the duty of toleration is often noticed as the most marked case of the addition of a new article to the code of morality. It seems so obvious to us now that it is necessary to recall the real obstacles by which its acceptance was impeded in order to understand more clearly the later steps in the development of the doctrine. We often look back with simple amazement at the state of mind in which the tyranny of the Inquisition or the atrocious penal laws could be reconciled by any ingenuity to the dictates of the human conscience. Considering the incapacity of the vast mass of mankind for reasoning at all, and the incapacity even of the ablest for establishing a philosophical system solid enough to survive later inquiry; and considering, too, how speedily, as the most confident dogmatists must admit, every speculation places us in front of insoluble mysteries, it seems to be not only atrocious, but grotesque, to punish men for losing their way in the labyrinth. The persecutor virtually admits, by appealing to force, that men cannot attain truth by reasoning. The obvious inference is that error is inevitable, and therefore innocent. When a heretic is punished for an honest error, honestly avowed, he is punished for doing what to him is his obvious duty. His "punishment," then, cannot have a moral quality. It is clearly paradoxical to send a man to hell for the good of his soul. It has to be admitted, in fact, that so far persecution is not moral, though it may be expedient. The heretic is damned to save the soul of his neighbours. The persecutor argues that he is not punishing a criminal, but stamping out a contagion. He is working in the interests of society at large, though inflicting a palpable wrong upon the individual. If religion be regarded as simply a philosophical creed, the absurdity of regarding error as criminal is obvious. Philosophers often hate each other pretty heartily; but they have never, I think, proposed to establish their own opinions by the stake. They have felt bound to admit that error is properly assailed by reason. But a religion is much more than a set of dogmas. It is a complex of intellectual, ethical, and social instincts. It is the bond by which a vast and elaborately organized society is held together. It means devotion to the Church as well as acceptance of certain speculative results. The persecutions of the early Christians were not intended to suppress opinions which the persecutor regarded with simple indifference or contempt, but to put down a system of secret societies, naturally objects of suspicion to the statesmen, because they enforced a discipline of their own, and might come into conflict with the authority of the State. When the empire had become Christian two great societies were fused together, and each had a direct interest in supporting, if also in limiting, the authority of the other. To rupture the unity of belief was to overthrow the authority of the Church, and intellectual dissent meant a revolt against the ties which held the whole social order together. The immediate motive of the persecutions of later days was not the love of men's souls, but the desire to support the great institution against which the heretic was rebelling. From one point of view this makes the persecution the more hideous. It meant, as the unbeliever would say, the spirit of priestcraft, that is, the instinctive hatred of the hierarchy for any one who dared to attack its privileges or dispute its power. The persecutor, however, might be sincerely convinced of the identity between the interests of the Church to all the highest interests of mankind. His motives were no doubt complex. Loyalty to the Church might spring from the purest benevolence, or from political and personal ambition, or even from the love of rich endowments. The really benevolent must always, one fancies, have felt a certain inconsistency between the estimable motive of love for men's souls, and the practical application to the individual sufferer; but presumably persecution in general was a result of the spirit which is developed more or less in all corporate bodies. Their welfare becomes an end in itself apart from the good results by which their existence is supposed to be justified. The mediæval Church was identified in so many ways with a man's whole life, and embodied his beliefs, aspirations, and interests in so many and such complex forms, that loyalty to its interests might become a second nature. The believer would require no further reason for suppressing any rebellion against its authority by the most drastic methods. From that point of view the persecuting impulse is fully intelligible, and it is easy to perceive how difficult it would be to take into account the moral objection. If it were possible to admit that a heretic was a well-meaning person avowing what he believed to be true, he was not the less a rebel against an essential part of the social order, who may be rightly put to death as we should now put to death the most sincere anarchist who applied his principles by assassination.

Obstacles to liberty of conscience.

Such obvious considerations show the difficulty of the transformation of opinion, and may indicate some which are not yet quite surmounted. To make toleration practicable in the early days, men had not only to point out the immorality of persecution, but to show how the political and ecclesiastical constitution could be reorganized. Church and State, and the systems of law which they enforced, interpenetrated each other so thoroughly at the time of the Reformation, that a complete separation of functions was inconceivable. Whether, as various disputants held, the State was properly subordinate to the Church, or the Church to the State, or they were two co-ordinate powers of equal authority, they virtually formed parts of a single organization. Each relied upon the co-operation of the other, and though the spiritual and secular sanctions might be distinct, both were required to the working of a single system. Schism involved rebellion or war. It was not a simple separation of speculative sects, but a disruption of the social structure. The Calvinist changed the ecclesiastical system, but claimed for his Church the old right to the support of the State. The Anglican Church retained the old constitution, and enforced conformity, not the less because obedience was due to the king instead of the bishop of Rome. The breach of continuity no doubt suggested some doubts as to the authority of the new system. Elizabethan statesmen sometimes repudiated the doctrine of religious persecution, and declared that Catholics were punished not as heretics, but as rebels. So long as a priest, as such, was liable to be hanged, drawn, and quartered, it made little difference to him what was the ostensible reason. But, hypocritical as the apology seems, we cannot ignore the real difficulty. The priest was, in point of fact, a drilled and subordinate member of a vast and powerful body representing a main element in the political combination which instigated domestic conspiracies and foreign invasions. Even if his immediate purpose was to administer spiritual consolation to individuals, he was necessarily also an agent of a hostile political power. Undoubtedly measures of political defence took the shape of religious persecution, and it would have been more expedient, as well as more just, to limit expression to the men who were guilty of directly treasonable purpose. The distinction, however, was difficult so long as the religious body used secular weapons. A certain reciprocity is required in international as in all morality. So long as a Catholic was bound by his dogma to be disloyal, the Protestant was strongly tempted to punish Catholicism. Meanwhile, in enforcing conformity, the State was supporting not merely certain dogmas, but the system of moral discipline in which it was essentially interested. Religion was the essence of morality, and to tolerate religious dissent was to demoralize the State. Nobody could be mere tolerant and rational in speculative matters than the excellent Baxter. But he was shocked by the claim of Independents and Quakers to "what they called liberty of conscience." It meant, he explains, liberty not only to think, but to preach and do whatever they pleased; that is, it was the plea for antinomianism and rebellion against all religious order and moral restraint.

The lesson of toleration, therefore, had to be learnt, not by logic alone—by proofs of the immorality of punishing innocent men—but also by the bitter experience won through protracted civil and international warfare. Sects found that they could live side by side when they were forced to combine against a common oppressor. Statesmen, though they had made religious differences a pretext, were most fully alive to material interests, and refused to make political aims subservient to religious bigotry. The greatest were content, like Richelieu, to make things easy for heretics on condition of submission to the secular power. The most effective persuasive to toleration, if not the most logical argument on its behalf, is the simple existence of the heretic. Ocular demonstration shows that he has not horns and hoofs, and it follows that he may be a decent person and a desirable customer. Meanwhile the endless controversies, which, instead of leading to any conclusion, branched out into countless multiplications and subdivisions of opposing theories, had an obvious lesson for the intelligence. The Catholic held that the evil was due to the rejection of the old authority, and that the only hope of restoring unity was to return to the fold. The opposite view was the scepticism which inferred that controversies which led to no result could only be concerned with chimeras. But the natural development of Protestantism was the belief that the differences were superficial, and that a common ground might be discoverable. It should be possible to draw up a list of the fundamental doctrines common to all Christians, or perhaps to all religions whatever. It might still be held that men's salvation depended upon their creed; but the creed might be so simplified and so obviously true, that very few people would have to be damned. The development of this view led to the deism of the 18th century, or to the "Religion of Nature," the truth of which was demonstrable by reason. There was ample room for controversy as to the relation of this religion to the historical religions, which might be regarded either as adding corollaries or as really superfluous. In any case, theory was naturally combined with a doctrine of toleration which is interesting by its limitations as well as its assertions.

Locke was the authorized exponent of the English revolution of 1688; and his treatise upon toleration gives the high-water mark of the advancing doctrine. He is anxious to indicate the widest practicable sphere for free thought; but he has to draw the line at two points. He excludes atheists, that is, those who disbelieve the religion of nature, and who therefore, as he holds, repudiate the only motives which form an efficient sanction of the moral law. He excludes Catholics, because their religion binds them to disloyalty. Rousseau, the apostle of the French revolutionary creed, is still at the same point of view. The citizens of his ideal state must hold the "positive" doctrine that there is a benevolent, all-wise, and omnipotent Providence; and the "negative" doctrine that salvation is not confined to the members of any sect. All who refuse these beliefs must be exiled. Every one, therefore, must be tolerated except the intolerant and those who are anti-social on principle. Now, though we have ceased in theory to make even these exceptions, the ground of exception corresponds to a practical difficulty. If, in fact, we are justified in assuming that men's conduct will be governed by their opinions, or by what we regard as the logical deduction from these opinions, toleration would clearly have to be limited. If an atheist really held that he might kill any one he pleased, we should restrain the application of his principles. "I am an atheist" would not be a sufficient plea in answer to an indictment for murder. So, if Catholicism implied actual disobedience to the constituted authorities, we should not the less put down a rebellion in the interests of Catholicism. As a matter of fact, atheists do not claim a right to murder nor modern Catholics to rebel, and no difficulty arises in regard to their conduct. Some cases may still occur in which a religious practice comes into conflict with secular laws; as when the "peculiar people" refuse to call in medical aid for their children. In practice, there is a general *de facto* agreement to obey the laws; but it must be noticed that such an agreement is a necessary condition of carrying out complete toleration, not only of opinions, but of the corresponding conduct.

The answer, in fact, to the problem which still perplexed Locke and Rousseau implies a distinction which they failed to take into account. Every one would now admit that we must attack philosophical error by reason alone, although we may find it necessary to restrain the corresponding conduct by legal coercion. Toleration of opinions, therefore, must be distinguished from toleration of practices. I may at once deny a man's right to do things and admit his full right to show that the prohibition is unreasonable. The distinction is really fundamental. A certain ambiguity still appears in popular arguments upon the question. Authority is often used in a double sense, as covering both coercion and a rational proof.

The meaning of Authority.

"Authority," as used in scientific or historical questions, means simply one kind of evidence—that kind upon which by far the greatest part of every man's knowledge is necessarily founded. I believe historical facts "on authority" when I have not been an eye-witness, but consider them to be sufficiently proved by appropriate evidence. I believe a scientific doctrine upon authority when I have not followed the reasoning or tried the experiments by which it is proved, but hold it to be established by the consent of experts and verified by the application of tests open to general observation. The discovery of Neptune was a sufficient proof of the value of astronomic theories to those who could not follow a step of the reasoning. The telegraph convinces us that electricians have real knowledge, though we may be utterly ignorant of their investigations. Such belief is, of course, perfectly reasonable; for in this sense authority means an appeal to reason. The enormous growth of scientific knowledge in modern times has made the conception of rational authority familiar. The existence of a vast body of truths, mutually consistent and corroborative, and verified at every moment by whole systems of practical application, proves not only that such belief is reasonable, but that all but an infinitesimal proportion of every individual's knowledge must be taken on trust, that is, upon reasonable authority. It would be manifestly absurd to regard authority in this sense as opposed to reason or capable of being opposed to it. Reason imperatively commands the acceptance of sufficient evidence. The only alternative to believing on authority would be to take your beliefs by chance, which is a very common but not a rational practice.

In philosophical or religious discussions, however, popular writers still oppose reason to authority, as if the words were mutually exclusive. If to believe on authority means to believe because you will be burnt for not believing, the process is clearly irrational. But it is simply rational to attach due weight to the opinions of competent inquirers. When the Protestant claimed the right of private judgment, the claim might be perfectly right or clearly preposterous. It would be right if he meant that he was to be guided by reason in choosing his guides. It would be preposterous if he meant that every ignorant man could settle for himself innumerable questions only to be answered by the combined efforts of profound critics and historical inquirers. But the absurdity would not be that he reasoned, but that he neglected the only kind of evidence which he was competent to appreciate. The argument from incompetence is not properly an argument for abandoning such reasoning power as you possess, but for respecting the opinions of your superiors, and holding your conclusions with due modesty. The two arguments, indeed, are easily confounded. An Irish peasant presumably accepts his creed without asking questions at all. It is to him a primary instinct. But if it should occur to him to inquire, it might be quite reasonable for him to hold that a creed accepted by all the wisest and best men whom he knew, and of whose competence no doubts had ever occurred to him, must have a strong presumption in its favour. If he really accepted it upon that ground, he would be as much a rationalist in principle as the free-thinking artizan who is convinced by Paine's *Age of Reason*. If, on the other hand, he accepted it because he was afraid of consequences, he would be submitting to authority of a radically irrational kind. One claim unquestionably glides very easily into the other. "Accept my creed because I am wiser" is identified with the inconsistent claim, "Accept it because I am stronger." When a man is told to absorb whole systems of dogma in regard to matters which he is totally incapable of understanding, and when his salvation is held to depend upon his accepting the orthodox view, whatever may be the grounds of his acceptance, authority ceases to mean evidence and comes to mean coercion. The superior asserts his right to be believed, and refuses to say why his authority should be accepted. The historian or the man of science may ask us to believe, because, though we cannot follow his argument, he can prove his competence. But the priest who proves the incompetence of the layman from the weakness of the reasoning faculty in general, is proving that the guide is just as incompetent as the traveller. Thus the appeal to authority comes to be essentially sceptical, and involves the assertion that as truth is unattainable, belief may be arbitrary.

To assert authority, then, in its rational or scientific sense is to admit also the obligation of proving its rationality, and, therefore, of renouncing coercion. Every scientific man admits, in theory at least, that he is bound to establish his claims, and therefore to court every kind of investigation. He does not propose to forbid even the fool to reason, but only warns him to remember that he is a fool. Every now and then some ignorant person denies an established truth; he squares the circle or invents perpetual motion. Nobody proposes to punish him except by demonstrating his error. Even his error may be useful, as an illustration of the existing state of mind. A quack remedy in medicine may do as much mischief as a theological heresy; but to suppress whatever was disapproved by the College of Physicians would be to encourage an undesirable faith in the infallibility of that eminent body. If we agree, as we do in such matters, that even incompetence supplies no ground for exercising irrational authority, the doctrine of toleration takes its widest sense. It may then be laid down absolutely that to suppress freedom of discussion is, so far, invariably bad. There is not the least necessity for trying to prevent people from thinking. They are quite ready enough to be stupid or indifferent without external inducements. The huge dead-weight of established prejudices is amply sufficient; and the authority of their defenders more likely to be over than under estimated. We may say that free thinking is not only a right, but a duty. A man, that is, is bound to be as reasonable as he can. The main condition of progress is that the intellectual activity should be stimulated by all legitimate means; not because it destroys, but because it creates a rational authority. The argument that free thought leads to scepticism is suicidal; for a doctrine which can be destroyed by exposure to argument must be a doctrine which it is irrational to believe. The great thinker is one whose mind swarms with hypotheses, and who gradually puzzles out his way through the labyrinth by trying every turn and rejecting those which end in a deadlock. A society in which speculative activity is great must abound in erroneous sects ; but the doctrine of natural selection applies, if it applies anywhere, to the world of ideas. The fittest ideas will survive, and the keener the competition the sooner they will triumph over their rivals. The tendency is not to the destruction of " authority," but to the formation of the only reasonable authority—a consistent body of doctrine which has been raised by systematic unification and is authoritative in the sense of being supported by conclusive evidence.

At this stage, the doctrine thus implies not merely passive, if one may say so, but active toleration; or that it is unconditionally desirable not only to permit but to stimulate intellectual activity. It was reached, and the essential point was stated most cogently in Mill's famous essay upon *Liberty;* and so far as he dealt with liberty of thought little can be added to his argument. He felt, however, certain difficulties when he passed from liberty of speculation to liberty of conduct. As an individual, he endeavoured to limit as much as possible the sphere of State interference ; and yet he could not deny that the State should have social aims, and therefore enforce rules, even while permitting free discussion of their underlying principles. This brings out one essential element of the problem. The accepted view of the Liberal of his time was that there should be a complete separation between Church and State. The sphere of religion was entirely separate from the sphere of political obligation. Macaulay put the case in his usual trenchant fashion in arguing against Gladstone. A State, he said, should have no more religious colouring than a railway company. The individual minister of State was, of course, bound to belong to the Church whose creed he took to be true, and so was the individual railway director. But the ministry or the directors in their corporate capacity had no concern whatever with religious questions. Religion is a matter of purely individual interest. My belief, it was said when it was desired to give a pious turn to the theory, is between myself and my God. No human being has even a right to inquire into it, and to do so is an act of gross impertinence—as Macaulay informed a constituent who had the audacity to ask the question. So long, indeed, as certain beliefs are regarded as in themselves disreputable there is some excuse for reticence. But when the duty of toleration is fully admitted and the inference drawn that a man ought to obey his own reason, I should say that an open avowal of opinion may become a duty. In any case, the theory that a man's religious opinions can have no bearing upon his political action is an assumption of fact. It is not self-evident even in the case of a railway company. If some of the shareholders believed while others denied that Sunday travelling was forbidden by the laws of God, a religious difficulty might arise in the company. Macaulay observes that Marlborough's armies included Catholics and Protestants, who were equally ready to fight, whatever their differences about transubstantiation. That, however, would not have been equally true in the time of Cromwell or Gustavus Adolphus, when Protestants or Catholics had strong motives for betraying leaders of the opposite persuasion. It is a question of fact whether loyalty to a particular Church is or is not compatible with loyalty to a given State. Both spiritual and secular powers aim at enforcing certain rules of conduct, and it is not necessarily nor always true that the two systems of legislation will be consistent. Undoubtedly in the time of Mill and Macaulay the assumption corresponded very closely to the facts. The old Puritanic ideal of a theocratic State which should regard the laws of Moses as part of the laws of England had vanished, or only left some faint traces in the desire to enforce observance of the Sabbath. The Catholic might still hold that the State ought to obey the Church, and even that under some ideal order persecution of heretics would still be right. But, in point of fact, he was as ready as his neighbours to submit to the State and to accept the principle of toleration—so long, at any rate, as he was the person to be tolerated. The question, however, remains, whether or under what conditions this separation of the two powers can be absolutely maintained. The prevalent theory of individualism, which tended to limit the legitimate action of the State to purely material interests, made the problem simple. But every Church holds that its creed embodies the essential motives for morality, whatever may be its precise theory; and unless the laws of the State have nothing to do with morality, or happen in point of fact to be in conformity with the morality approved by the Churches, some conflict must always be possible.

Religion and Politics.

If, therefore, we may develop toleration of opinion and discussion to the farthest point, and agree that intellectual activity should be not only unchecked but stimulated, there must still be a difficulty in regard to the toleration of the corresponding conduct. Coercion by physical force is essential to legal authority; and the very existence of the State implies the forcible suppression of certain modes of conduct. This again presupposes a certain moral agreement. The State does not undertake to suppress immorality as such, and leaves many forms of vice to be discouraged by other agencies. But it is equally true that no conduct should be regarded as criminal which is not also regarded as immoral. If, in the usual and very sound formula, vice cannot be put down by Act of Parliament, still, so far as it goes, the legitimate action of the State must be in harmony with the general moral convictions. Though immorality may not be directly punishable, the laws of marriage will tend to heighten or diminish the general respect for the institution, and have therefore a moral or immoral tendency, according to the doctrine accepted.

The sphere of State action has greatly extended of late years, and the theory that it should be limited to purely material interests has been more and more discredited. The question, therefore, naturally occurs, What has been the bearing of recent political changes upon the principle of toleration? If the State takes to interfere in a greater number of cases, and to interfere with a moral purpose, must not the toleration of conduct become more difficult? If the religious differences which divide sects are compatible with an agreement as to the moral issues involved, they may co-operate in suppressing the same modes of conduct; but it is a question of fact whether there is or is not such an agreement.

The question of disestablishment.

One change of modern times has a bearing upon this question. The early Radicals held that the abolition of a State Church was a simple corollary from the doctrine of toleration. At the time of the first Reform Bill, the disestablishment of the Church and the confiscation of its revenues was regarded on both sides as an inevitable result of parliamentary reform. The prediction has hitherto been falsified. Disestablishment may be still part of the genuine Radical creed; but the demand does not rouse the vehement passions of the previous generation. A State Church may be regarded as an anomaly; but we take anomalies easily, and the hostile sentiment corresponds rather to a pious aspiration for theoretical symmetry than to a deep sense of a pressing injustice. One cause is obvious. In the first quarter of the 19th century the Church was regarded by Radicals as an essential part of the great political combination by which the country was governed. Rich bishops, non-resident clergy, and indolent cathedral chapters were familiar instances of the abuses which favoured corruption, political jobbery, and all the evils of irresponsible class government. The clergy were part of the garrison, which, in alliance with the nobility, the lawyers, and the stock-jobbers, held the position to be stormed by reformers. The removal of the old abuses diminished the strength of the antagonism; and whatever may be said of bishops to-day, they are not idle sinecurists, owing their position to family claims, and trying to earn translation to the best sees by a course of political servility. At the same time the decline of the old jealousy of all Government interference has weakened one presumption in favour of a voluntary system, and favours the growth of another view. It is a disputed question whether disestablishment would really be favourable to toleration. In one way the change would clearly be more congenial to the high churchman than to his opponents. The higher the claims of the priesthood, the greater is the objection to the alliance with the State which ties the hands of the Anglican establishment. The Church, on a sacerdotalist theory, should command instead of obeying, and be able to define and interpret its own dogmas. Had the Church been "free" in the 'sixties, the high and low churchmen would each have tried to expel the other and have combined to expel the broad churchmen. Pusey and Gorham and Maurice and Colenso could hardly have been kept in one fold. The anomalous position which makes a change impossible without the consent of a body representing all other sects has preserved its external unity. If toleration implies disestablishment, it may give greater authority to the intolerant. A free Church might become more exclusive and obscurantist, or split up into separate Churches, each representing an intolerant creed. The liberty of the Church would really mean an increased power of the clergy.

A lover of toleration may prefer the Erastian view. The Church is for him a parliamentary institution, the religious department of the State, which obviously cannot claim any power of deciding what doctrines are true, but which may very well be a good comfortable institution, so regulated as to provide such services and discharge such functions as are in fact acceptable to respectable persons in general. The existence of such a sentiment implies the belief that the laity in general take very little interest in the speculative controversies by which Churches are divided.

Nobody, indeed, can say that sectarian prejudices have died out. That they can be bitter enough is proved by the controversies upon educational questions. The prejudice against State interference has been rather inverted than diminished; everybody accepts State schools in principle; and it is even laid down as self-evident that education is the business of the Government and not of the Church. If the nation were coextensive with the Church, the doctrine would seem to be rather preposterous than obvious. Education must surely be an essential function of the Church, not bare instruction in reading and writing, but inculcation of morality and the beliefs with which, according to every Church, morality is essentially connected. It is surely the most logical position that the class told off to inculcate these beliefs should control education. The acceptance of a State system implies either that religious instruction is not important or that, as a matter of fact, we are all sufficiently agreed. It is presumed that there is such a thing as "unsectarian religion," and the additional dogmas may be added by priests or such teachers as they prefer. Catholics, Anglicans, and Dissenters all accept the rule of three, and the secular teaching may be given in common, while the religious teaching is an extra. A compromise upon these lines is not acceptable to advocates of denominational schools. But even their position implies a concession. They cannot argue on the ground that their distinctive creeds are essential. There is no serious danger that the rising generation will take wrong views of apostolic succession or justification by faith or any of the speculative points upon which the Protestant Churches are divided. They must be abnormally precocious if they have any perception that any such controversies exist. The real argument is, of course, that a child may be brought up to feel a due respect for the parson or for the dissenting minister, and that the Church invested with the function may gain influence in its corporate capacity. The claim may be legitimate, and members of any Church may hold that the secret of its power depends ultimately upon its orthodoxy. But at least it is evident that the argument does not rest upon the importance of absolute purity of doctrine. The opinion that a child ought to be taught to have dogmas, because if it does not hold them it will probably be damned, is probably not held, and certainly cannot be put forward by any body. It is only held that Churches in general are useful; and that people in general believe in the great importance of religion. But, whatever may be the creed of the more devoted, it is plain that the ordinary common-sense looks with very great indifference upon the purely speculative differences even if it is aware of their existence.

Orthodoxy and Education.

Indifference to the critical distinctions is conspicuous in another direction. The controversy between socialists and their antagonists suggests profound moral questions, but it is remarkable that the religious distinctions have so little bearing upon them. Some socialist theories are indeed avowedly based upon materialism and the rejection of all theological creeds. But the most influential individualists in English politics have been also the most thoroughgoing sceptics; and complete "agnosticism" would seem to be equally capable of alliance with either form of social philosophy. On the other side, it cannot be said that the principles of orthodox Christians involve an acceptance of either alternative. The Church of England no doubt was mainly on the conservative side in general; and when "Christian Socialism" made a stir in the middle of the 19th century, its leading advocates were accused of being tacit allies of freethinkers and atheists. But we have changed all that. Perhaps staunch socialists may retain a suspicion that their patrons, if not insincere, have some tacit reservations or want of complete sympathy. But at any rate, the ecclesiastical as well as political parties seem to be anxious to accept as much, rather than as little, as they can of the socialist platform. Conservatives can argue that they are in one respect consistent. They were formerly denounced by the Radical for holding the doctrine of "paternal government." Now that he renounces or modifies individualism, he has to admit that if

Socialism and Individualism.

government should not be "paternal," it ought to be at least "fraternal." The true objection to the old theory was not to its interference, but to the hypocrisy which made a profession of interest in its governed a mere cloak for the selfishness of the ruler. When the Church appeared to the Radical to be essentially identified with a corrupt government, it shared the antipathy routed by the whole ruling class. It was one organ of a caste, and if it had remained in that position, the English Liberal would have agreed with his French contemporary that clericalism was the enemy. If the sentiment is not altogether absent on the English side of the Channel, it is far less bitter and does not connote the uncompromising animosity which instructs to intolerance. The difference might no doubt be explained by the social and intellectual differences; by the absence of the sharp division of classes and the offensive privileges which embittered the French struggle; or by the tendency to compromise which our neighbours consider to be illogical, and which we consider to be a proof of common-sense. Whatever the cause of the English attitude, the result is clearly favourable to toleration. The Church is not in solidarity with a close corporate system; and the lines which divide the orthodox from heretics or unbelievers are not coincident with vital differences upon social questions. The changes of social and political organization have been enormous, and may be described as a victory of democracy. But the democracy has not had to crush a compact and hostile body; it has rather found that the upper classes have been willing to accept its supremacy and carry out its policy. The Church, though an "appendage" of the aristocracy, has not been fitted either by its doctrines or its social position to ally itself unequivocally with the obstructive forces.

Toleration was closely associated with individualism. The most thoroughgoing individualists preached it with the greatest force and made it their most conspicuous doctrine. Yet the doctrine of individualism of the old dogmatic and absolute variety—whatever may be the explanation of that phenomenon—has certainly not led to a doctrine of practical toleration. The implication would seem to be that the individualist sentiment owed much of its strength to the antipathies generated in the prolonged struggle against a privileged class. It was not a simply "centrifugal" force, but a revolt against the claim to an artificial and unjust unity imposed for the comfort of the governing classes. It approved of voluntary associations though it objected to union by coercion. But when the old offensive claims were abandoned and government was controlled by the masses, unity could be reached spontaneously, and the distinction between voluntary and compulsory association became less important. The differences, no longer accentuated by incidental irritants, showed themselves to be less important than they had appeared. When men are brought to co-operate in common aims, whether by voluntary agreement or as members of a State organization, superficial differences show their futility; and toleration may be more acceptable when duties are discharged by public bodies than when they are left to organized sects, each propagating its own creed. Clearly, however, this presupposes a sufficient harmony in point of fact, and a certain underlying agreement between the various parties. The cause of such an agreement, so far as it exists, must be sought mainly in the intellectual development which is the correlative of the political changes.

Religion and Science.

One dominant factor in that development has of course been the vast growth of the natural sciences. The attempt to reach unity by discerning a residuum of belief common to all creeds seemed to be illusory. Atheists repudiated even the "religion of nature," and Christians declared it to be worthless. Meanwhile scientific research was suggesting a more thorough method. It took no dogma whatever for granted. It started from Descartes' principle of unlimited doubt, and accepted unequivocally the Baconian maxim of impartially interrogating nature. Its success in establishing a solid body of truth contrasted with the futility of metaphysical argumentations; and philosophers began to inquire whether the same methods might not be equally fruitful in a different sphere. History, politics, economics, and even philosophy and religion were treated by great thinkers on the precedent of the physical sciences; and, if the full constitution of the "moral sciences" is still indefinitely distant, the spirit of inquiry is at least radically changed. As historical knowledge extends and we become acquainted with the thoughts and institutions of remote races and periods, our theories have to expand. The acceptance of Newtonian astronomy, revealing the infinitesimal importance of our planet, had suggested that the universe was too big for the old-fashioned cosmogonies. The recognition that Christianity was but one of the many forms of belief which had prevailed over vast areas and indefinite periods had a similar effect upon the historical imagination. To study religions in a scientific spirit is to admit that all religions, if not equally good, spring at least from a common source. To a simple-minded missionary the likeness of Buddhism to Christianity suggested an artifice of the devil to distract his dupes by caricaturing the genuine Church. To the rational inquirer the phenomenon is an interesting illustration of his fundamental principles. The spread of investigation goes along with the rapid confrontation of all nations, which make it as impossible for the vulgar as for the scientific inquirer to identify his village with the universe and his creed with the sole revelation of the Deity. The growth of science, in short, suggested the contrast at once between rational and arbitrary authority; between fruitful methods and endless metaphysical logomachies, and between the impartial comparison of systems of belief as products of a common intellectual constitution and the assumption that one must come from God and all others from the devil.

The perception that a religion for philosophers must have some wider basis than a total tradition was of course nothing new. It was the essential contention of the old deists. Pope's "universal prayer" addressed to the "Father of all in every age, in every clime adored," gives the sentiment of the cultivated minds of his time. When Tennyson's phrase about our "little systems" which "have their day and cease to be" became at once proverbial, it implied that the thought was already congenial to far wider circles. Pope scandalized his orthodox contemporaries; Tennyson was taken to be obviously edifying. Huxley has said that Tennyson was the man of letters of his day who had most fully appreciated the tendencies of scientific thought. Anyhow he expressed most clearly a sentiment with which the more educated classes were already saturated in the first half of the century, and which it would be easy to illustrate from all the chief writers of the time. A strong religious sentiment and a belief in a sufficiently vague creed was combined with a conviction that the old dogmatic systems were effete. If the formulæ were still current, and an attempt to challenge them openly exposed an unbeliever to general disapproval, the unreality of the "little systems" was not the less felt; and the distinctions between rival sects could only interest professional divines, who had been somehow sheltered from the wider current of living thought.

The controversies which excited us in the 'sixties illustrated the state of mind. They indicated to the more thoughtful the fact that scientific theories were coming into direct collision with accepted religious creeds, and that, if philosophy was not to be, as materialists held, a simple department of physical science, it must at least conform to the established scientific base. To the ordinary mind, at first sight, it suggested simply an attack upon the first chapter of the book of Genesis. We were invited to substitute a pair of chimpanzees for Adam and Eve—the question upon which Huxley had his famous encounter with Wilberforce. The apologists had gone on arguing upon the old issue, inherited from predecessors by whom the literal truth of the whole Biblical narrative had been taken for granted as a postulate admitted on all hands. They tried for a time to maintain the old ground against Colenso and the Essayists and Reviewers as well as against the Darwinians. But it rapidly became plain that the position was an anachronism. Everything that could be called living thought had long ebbed away from its foundations. The primitive history might still be taught in schools; the old legends and the dogmas connected with them might live on as survivals; but even to ordinary common-sense it was undeniable that it was a monstrous blunder really to stake the truth of religion in general upon the possibility of maintaining the validity of the ancient record. The history or the dogma could not be independently proved; though they might, if properly rationalized, be admissible on some other authority, whether, as Catholics held, the authority were the Church, or as liberal theologians, a philosophy which might be adumbrated by imagery adapted to the prehistoric intellect. The position accordingly changed with singular rapidity. A creed must be defended, not by taking the discredited accrescences as the fulcrum of your argument, but by accepting them as incidental, useful, or perhaps needless accessories of the vital principles really embodied. The process was less one of confuting genuine beliefs than of a general awakening to the fact that many of the ostensible beliefs only lay on the surface of thought or could be abandoned without injury to deeper convictions.

The change, therefore, was clearly prepared by the whole course of speculation. It corresponds to the widening of the intellectual horizon which has made it more and more impossible to damn foreigners, heretics, and the heathen "in the lump," and shown the wickedness of the persecuting sentiment. The orthodox position must be defended, so far as defensible, upon grounds far wider than the old. The divine who now maintains the truth of Christianity no longer holds himself pledged to show the absolute falsity of the other religions which have satisfied the vast majority of the race. He argues that they are imperfect approximations to the ideal which Christianity alone can present in its manifestations of purity and the working of the same divine favour in a distracting medium. The dogmatic system must be correspondingly modified. The old controversies in which Protestants and Catholics wrangled so long and so fiercely have become hopelessly uninteresting. When the assumption that every word of the Bible is literally true disappears, the most superannuated theology can no longer appeal to isolated texts or attempt to explain the relations of man to his Creator from the details of ancient legends. Such argumentations have still a deep historical interest, but only when we come to see that that really represents the attempt to approach great moral problems with a hopelessly imperfect intellectual apparatus. Meanwhile the philosophical basis has changed as much as the historical. The old metaphysical system has been superseded by more fruitful schemes of thought, and if the dogmas are still verbally maintained, we admit that the reasoning by which they were at first elaborated was often more a juggling with words, and implied ignorance of the inevitable limits of human thought. They may be true in some sense; they may, perhaps, be imperfect versions of vitally important truths, but our belief must at least be justified by some different method. They must be regarded as corollaries from the truth of a religious system which is ultimately supported by its position in universal history or as an embodiment of a demonstrable philosophy. The modern apologist argues from the moral beauty of Christianity, not from the internal evidence. He does not base his reasoning upon the miracles, though he is prepared to accept them as congenial incidents. The sceptic might be right in rejecting the supernatural, if an isolated interference with the order of nature were made an ultimate ground of belief. But the supernatural becomes in a sense natural, if we regard it as a manifestation of the divine power which underlies all phenomena. The apologist must appeal to history; not to a particular narrative or to an isolated series of events, but to the whole history of mankind as becoming intelligible when we regard the Christian revelation as the central event to which all other history converges.

Widening of the intellectual horizon.

The agnostic of course holds that the implied concession is fatal to the creed defended. The dogmas have to be interpreted so as to lose all significance; and to accept a genuine historical method is to abandon any really supernatural element. The divine is virtually surrendering when he tries an impossible conciliation. Still a certain approximation is implied as to the method of inquiry and the criterion of truth. The acceptance by divines of evolutionist theories, to which I referred at starting, is no doubt perfectly sincere, and has obvious recommendations. When the first alarm subsided, it became evident that some such theory was congenial to the philosophical needs of the time as well as to scientific tendencies. The order of nature had to be regarded as a continuous process stretching indefinitely backwards and forwards, and every conception of an abrupt beginning or ending had to be banished. The barriers between species were not absolute and impassable gulfs, but implied a common origin, and the slow elaboration by antagonism or association of a consistent order. This change in the natural sciences corresponded to the demands already made in a different sphere by the growth of more philosophical conceptions of the history of mankind. If man himself had to take his place among other living beings, and the impassable gulf to be obliterated, the religious creeds must be regarded as varying products of the instincts common to all men. They could not be simply false, and might contain elements capable of incorporation in superior form of belief. Authority could not be in any single body laying down absolute decrees, but can only be claimed by the creed which submits to the test of the freest discussion, and is elaborated by the gradual convergence of reasonable thought. This, again, is to assert the essential principle of toleration, to which men's minds had been slowly awakening through the whole course of modern speculation. It expressed the ideal of all the more liberal divines who had seen the necessity of basing a tenable creed upon doctrines wide enough to correspond to all the results of inquiry in every department of human knowledge; and the general sentiment even of popular audiences was already on their side. An arbitrary dogmatism, working by threats instead of argument, had grown to be hateful and contemptible, and it had become obvious that the identification of religions with adherence to a particular legend was not a support, but a fatal limitation to its credibility.

The same tendency, we may hope, is apparent in the sphere of politics. Popular orators, no doubt, have still to denounce each other pretty heartily, and to represent Toryism or Liberalism as an emanation from the good or evil principle. Still, some advance has been made in the last century. Democrats used to regard kings and priests as responsible for all the evils that afflict mankind, and aristocrats to denounce revolutionists as directly inspired by the devil. The antagonism is hardly so internecine, and the change, we may hope, is due to a more philosophical mode of thought. A revolution, it has been said, always justifies itself, because it can only be brought about by profound grievances. This is perfectly true in the same sense in which it is true that the resistance to evolution has always some justification. There must have been some cause for the attachment to the old order. The line between good and evil is never precisely identical with the line between parties; and the first condition of sound reasoning on such matters is to attempt to understand your adversary, instead of simply denouncing him. The doctrine applies to those social questions which still arouse the bitterest antipathies. Capitalists and labourers may regard each other as simply children of the devil. Still, so far as newer scientific methods of thought gain acceptance, this pleasing assumption is modified. The old method of settling the question by laying down absolute principles of right is seen to be absurd. In place of it we have to try to understand the mode in which the complex order has been developed, to admit that the fact of its existence implied that it satisfied some general requirements, and that it must be modified tentatively and gradually, so as to approximate to a more widely satisfactory state. A tempting short-cut to the solution of problems was offered by the assumption that justice requires the enforcement of equality, or that it requires that every man should have an absolute right to improve his own position. Each doctrine may be stated plausibly, but when they come into collision we see that neither can be laid down absolutely. We have to consider the conditions by which each is limited, and how far it is applicable. That can only be done by understanding the real nature of the existing system, studying the way in which it has grown, and the functions which have been discharged by its constituent facts. The change which has come over the methods of political economists corresponds to a growing perception of the necessity of this as the only scientific treatment. So far as it is accepted, we are agreed as to the method to be pursued and the criterion which is to be decisive. It supposes not the triumph of one of two contradictory principles, but the gradual elaboration of a comprehensive theory which will do justice to both. The authority to which it appeals is that of impartial and laborious investigation of facts; and that is the kind of authority which rests upon free discussion, and therefore implies toleration in the widest sense.

Political tolerance.

One other conclusion follows. The existence of any creed or institution is a *prima facie* ground of justification. Some, it may be, are simply pernicious. But they must have had some cause; and the longer they have thriven, the greater the presumption that they have had some utility. The scientific spirit, therefore, implies that explanation should precede, and will probably qualify, denunciation. The Darwinian assumes that the survival of a species proves its fitness to its conditions; and for that reason the evolutionist theory has commended itself to the orthodox. Undoubtedly it supplies the strongest argument in their favour. If they cannot safely appeal to any arbitrary authority, or to a purely dialectical proof, they can point to undeniable facts. That religious institutions have played an enormous part in the history of civilization, and that at the present day, in spite of all intellectual revolutions, the religious instinct in some shape represents a

Scientific presumptions in favour of religion.

social force of enormous power, is obviously undeniable. If the particular dogmatic systems have ceased to correspond to genuine beliefs, we must ask to what cause we attribute the enduring vitality of the sects and the loyal devotion which they command. The old explanations are no longer available. We cannot set down religious beliefs as simply the product of priestly imposture. That short and easy method has become obsolete along with the claims to which it was opposed. Nor is it easy to admit the proposition that religious beliefs as a whole represent simply a stupendous misunderstanding generated by the blunders of primitive savages, a set of simply erroneous superstitions, which can be eliminated without difficulty from the general system of thought. Unless they had been more deeply rooted in human nature, they would have died out before the newer lights of intellectual advance. The truth indeed may be that the view which identifies a religion with its avowed creed, and supposes that a man first persuades himself of the truth of certain tenets and then deduces rules for conduct, inverts the true process. A religion in the full sense is a product of the whole social, imaginative, and emotional nature, and the dogmatic system represents a congenial construction which has to use for its materials the prevalent conceptions of the period. When the dogma become incredible to the more intelligent the underlying instincts do not lose strength, but cannot be fully satisfied until some more simple system is worked out. Meanwhile men are often contented with the old scheme of belief, subject to certain tacit reservations instead of open repudiation. The problem of replacing the old synthesis remains, and those who reject the old creeds most completely, and are most convinced of the duty of expressing their dissent, may be most aware of the extreme difficulty of the task.

What institutions, if any, are to take the place of the old churches, and how the emotions which found expression in times of the old belief are to find satisfactory utterance in terms reconcilable to scientific knowledge, is our present problem, which has not been attacked with much success, and must be the work of many generations. The believer who admits, as he is forced to admit, that the old language is obsolete, but that it yet contains a pure essence of truth, has still to define what that truth may be. To me it appears that he will not find the problem of easy solution; but, so far as I am here concerned, I need only note that the tendencies which I have attempted to describe imply a growth of mutual toleration. There is at least an agreement that a simple creed must be tested upon the widest appreciation of the whole process of intellectual development; that the only authority which can permanently demand assent is the gradual convergence of belief under the freest possible play of thought, and that every honest phase of opinion has a right to a fair hearing, and may be of some use even if only by provoking the exposure of its own fallacy.

ENCYCLOPÆDIA BRITANNICA

NEW VOLUMES.

ELECTIONS

Elections.—*United Kingdom.*—Considerable alterations have been made in recent years in the law of Great Britain and Ireland relating to the procedure at parliamentary and municipal elections, and to election petitions. The Local Government Acts have also introduced new classes of voters (county and parochial electors), and have extended to the elections in which they take part the rules applicable to municipal elections.

As regards parliamentary elections, the most important of the amending statutes is the Corrupt and Illegal Practices Act, 1883. This Act, and the Parliamentary Elections Act, 1868, as amended by it, and other enactments dealing with corrupt practices, are temporary Acts requiring annual renewal. As regards municipal elections, the Corrupt Practices (Municipal Elections) Act, 1872, has been repealed by the Municipal Corporations Act, 1882, for England, and by the Local Government (Ireland) Act, 1898, for Ireland. The governing enactments for England are now the Municipal Corporations Act, 1882, part iv., and the Municipal Elections (Corrupt and Illegal Practices) Act, 1884, the latter annually renewable. The provisions of these enactments have been applied with necessary modifications to municipal and other local government elections in Ireland by orders of the Irish Local Government Board made under powers conferred by the Local Government (Ireland) Act, 1898. In Scotland the law regulating municipal and other local government elections is now to be found in the Elections (Scotland) (Corrupt and Illegal Practices) Act, 1890.

The alterations in the law have been in the direction of greater strictness in regard to the conduct of elections, and increased control in the public interest over the proceedings on election petitions. Various acts and payments which were previously lawful in the absence of any corrupt bargain or motive are now altogether forbidden under the name of "illegal practices" as distinguished from "corrupt practices." Failure on the part of a parliamentary candidate or his election agent to comply with the requirements of the law in any particular is sufficient to invalidate the return. Certain relaxations are, however, allowed in consideration of the difficulty of absolutely avoiding all deviation from the strict rules laid down. Thus, where the judges who try an election petition report that there has been treating, undue influence, or any illegal practice by the candidate or his election agent, but that it was trivial, unimportant, and of a limited character, and contrary to the orders and without the sanction or connivance of the candidate or his election agent, and that the candidate and his election agent took all reasonable means for preventing corrupt and illegal practices, and that the election was otherwise free from such practices on their part, the election will not be avoided. The court has also the power to relieve from the consequences of certain innocent contraventions of the law caused by inadvertence or miscalculation.

Election petitions.

The jurisdiction in regard to election petitions formerly exercised by the Court of Common Pleas was on the abolition of that court by the Judicature Act, 1873, transferred to the Common Pleas Division, and again on the abolition of that division was transferred to the King's Bench Division, in whom it is now vested. The rota of judges for the trial of election petitions is also supplied by the King's Bench Division. The trial now takes place before two judges instead of one; and, when necessary, the number of judges on the rota may be increased. Both the judges who try a petition are to sign the certificates to be made to the Speaker. If they differ as to the validity of a return, they are to state such difference in their certificate, and the return is to be held good; if they differ as to a report on any other matter, they are to certify their difference and make no report on such matter. The director of public prosecutions attends the trial personally or by representative. It is his duty to watch the proceedings in the public interest, to issue summonses to witnesses whose evidence is desired by the court, and to prosecute before the Election Court or elsewhere those persons whom he thinks to have been guilty of corrupt or illegal practices at the election in question. If an application is made for leave to withdraw a petition, copies of the affidavits in support are to be delivered to him; and he is entitled to be heard and to call evidence in opposition to such application. Witnesses are not excused from answering criminating questions; but their evidence cannot be used against them in any proceedings except criminal proceedings for perjury in respect of that evidence. If a witness answers truly all questions which he is required by the court to answer, he is entitled to receive a certificate of indemnity, which will save him from all proceedings for any offence under the Corrupt Practices Acts committed by him before the date of the certificate at or in relation to the election, except proceedings to enforce any incapacity incurred by such offence. An application for leave to withdraw a petition must be supported by affidavits from all the parties to the petition and their solicitors, and by the election agents of all of the parties who were candidates at the election. Each of these affidavits is to state that to the best of the deponent's knowledge and belief there has been no agreement and no terms or undertaking made or entered into as to the withdrawal, or, if any agreement has been made, shall state its terms. The applicant and his solicitor are also to state in their affidavits the grounds on which the petition is sought to be withdrawn. If any person makes an agreement for the withdrawal of a petition in consideration of a money payment, or of the promise that the seat shall be vacated or another petition withdrawn, or omits to state in his affidavit that he has made an agreement, lawful or unlawful, for the withdrawal, he is guilty of an indictable misdemeanour. The report of the judges to the Speaker is to contain particulars as to illegal practices similar to those previously required as to corrupt practices; and they are to report further whether any candidate has been guilty by his agents of an illegal practice, and whether certificates of indemnity have been given to persons reported guilty of corrupt or illegal practices.

The Corrupt Practices Acts apply, with necessary variations in details, to parliamentary elections in Scotland and Ireland.

The amendments in the law as to municipal elections are generally similar to those which have been made in parliamentary election law. The procedure on trial of petitions is substantially the same, and wherever no other provision is made by the Acts or rules the procedure on the trial of parliamentary election petitions is to be followed. The commissioner who tries a petition sends to the High Court a certificate of the result, together with reports as to corrupt and illegal practices, &c., similar to those made to the Speaker by the judges who try a parliamentary election petition. The Municipal Elections (Corrupt and Illegal Practices) Act, 1884, applies to school board elections subject to certain variations, and has been extended by the Local Government Act, 1888, to County Council elections, and by the Local Government Act, 1894, to elections by parochial electors. The law in Scotland is on the same lines, and extends to all non-parliamentary elections, and, as has been stated, the English statutes have been applied with adaptations to all municipal and local government elections in Ireland. (L. L. S.)

United States.—Elections are much more frequent in the United States than they are in Great Britain, and they are also more complicated. The terms of elective officers are shorter; and as there are also more offices to be filled, the number of persons to be voted for is necessarily much greater. In the year of a presidential election the citizen may be called upon to vote at one time for all of the following:—(1) National candidates—President and Vice-President (indirectly through the electoral college) and members of the House of Representatives; (2) state candidates—governor, members of the state legislature, attorney-general, treasurer, &c.; (3) county candidates—sheriff, county judges, district attorney, &c.; (4) municipal or town candidates—mayor, aldermen, selectmen, &c. The number of persons actually voted for may therefore be ten or a dozen, or it may be many more. In addition, the citizen is often called upon to vote yea or nay on questions such as amendments to the state constitutions, granting of licences, and approval or disapproval of new municipal undertakings. As there may be, and generally is, more than one candidate for each office, and as all elections are now, and have been for many years, conducted by ballot, the total number of names to appear on the ballot may be one hundred or may be several hundred. These names are arranged in different ways, according to the laws of the different states. Under the Massachusetts law, which is considered the best by reformers, the names of candidates for each office are arranged alphabetically on a "blanket" ballot, as it is called from its size, and the elector places a mark opposite the names of such candidates as he may wish to vote for. Other states, New York for example, have the blanket system, but the names of the candidates are arranged in party columns. Still other states allow the grouping on one ballot of all the candidates of a single party, and there would be therefore as many separate ballots in such states as there were parties in the field.

The qualifications for voting, while varying in the different states in details, are in their main features the same throughout the Union. A residence in the state is required of from three months to two years. Residence is also necessary, but for a shorter period, in the county, city or town, or voting precinct. A few states require the payment of a poll tax. Some require that the voter shall be able to read and understand the Constitution. This latter qualification has been introduced into several of the Southern states as a means of disqualifying the ignorant coloured voters. In all, or practically all, the states idiots, convicts, and the insane are disqualified; in some states paupers; and in some of the Western states the Chinese. In some states women are allowed to vote on certain questions, or for the candidates for certain offices, especially school commissioners; and in a few of the Western states women have the same rights of suffrage as men. The number of those who are qualified to vote, but do not avail themselves of the right, varies greatly in the different states and according to the interest taken in the election. As a general rule, but subject to exceptions, the national elections call out the largest number, the state elections next, and the local elections the smallest number of voters. In an exciting national election between 80 and 90 per cent. of the qualified voters actually vote, a proportion considerably greater than in Great Britain or Germany.

The tendency of recent years has been towards a decrease both in the number and in the frequency of elections. A President and Vice-President are voted for every fourth year, in the years divisible by four, on the first Tuesday following the first Monday of November. Members of the national House of Representatives are chosen for two years on the even-numbered years. State and local elections take place in accordance with state laws, and may or may not be on the same day as the national elections. Originally the rule was for the states to hold annual elections; in fact, so strongly did the feeling prevail of the need in a democratic country for frequent elections, that the maxim "where annual elections end, tyranny begins," became a political proverb. But opinion gradually changed even in the older or Eastern states, and in 1901 Massachusetts and Rhode Island were the only states in the Union holding annual elections for governor and both houses of the state legislature. In the Western states especially state officers are chosen for longer terms—in the case of the governor often for four years—and the number of elections has correspondingly decreased. Another cause of the decrease in the number of elections is the growing practice of holding all the elections of any year on one and the same day. Before the Civil War the state of Pennsylvania, for instance, held its state elections several months before the national elections in November. Similarly, Ohio and Indiana, until within the last few years, held their state elections early in October. The selection of one day in the year for all elections held in that year has resulted in a considerable decrease in the total number.

Another tendency of recent years, but not so pronounced, is to hold local elections in what is known as the "off" year; that is, on the odd-numbered year, when no national election is held. The object of this reform is to encourage independent voting. The average American citizen is only too prone to carry his national political predilections into local elections, and to vote for the local nominees of his party, without regard to the question of fitness of candidates and the fundamental difference of issues involved. This tendency to vote the entire party ticket is the more pronounced because under the system of voting in use in many of the states all the candidates of the party are arranged on one ticket, and it is much easier to vote a straight or unaltered ticket than to change or "scratch" it. Again, the voter, especially the ignorant one, refrains from scratching his ticket, lest in some way he should fail to comply with the technicalities of the law and his vote be lost. On the other hand, if local elections are held on the "off" or odd-year, and there be no national or state candidates, the voter feels much more free to select only those candidates whom he considers best qualified for the various offices.

On the important question of the purity of elections it is difficult to speak with precision. In many of the states, especially those with an enlightened public spirit, such as most of the New England states and many of the North-Western, the elections are fairly conducted, there being no intimidation at all, little or no bribery, and an honest count. It can safely be said that through the Union as a whole the tendency of recent years has been decidedly towards greater honesty of elections. This is owing to a number of causes: (1) The selection of a single day for all elections, and the consequent immense number voting on that day. Some years ago, when for instance the Ohio and Indiana elections were held a few weeks before the general election, each party strained every nerve to carry them, for the sake of prestige and the influence on other states. In fact, presidential elections were often felt to turn on the result in these early voting states, and the party managers were none too scrupulous in the means employed to carry them. Bribery has decreased in such states since the change of election day to that of the rest of the country. (2) The enactment in most of the states (the number in 1901 being 40 out of the 45) of the Australian or secret ballot laws. These have led to the secrecy of the ballot, and hence to a greater or less extent have prevented intimidation and bribery. (3) Educational or other such test, more particularly in the Southern states, the object of which is to exclude the coloured, and especially the ignorant coloured, voters from the polls. In those Southern states in which the coloured vote was large, and still more in those in which it was the majority, it was felt among the whites that intimidation or ballot-box stuffing was justified by the necessity of white supremacy. With the elimination of the coloured vote by educational or other tests the honesty of elections has increased. (4) The enactment of new and more stringent registration laws. Under these laws only those persons are allowed to vote whose names have been placed on the rolls a certain number of days or months before election. These rolls are open to public inspection, and the names may be challenged at the polls, and "colonization" or repeating is therefore almost impossible. (5) The reform of the civil service and the gradual elimination of the vicious principle of "to the victors belong the spoils." With the reform of the civil service elections become less a scramble for office and more a contest of political or economic principle. They bring into the field, therefore, a better class of candidates. (6) The enactment in a number of states of various other laws for the prevention of corrupt practices, for the publication of campaign expenses, and for the prohibition of party workers from coming within a certain specified distance of the polls. In the state of Massachusetts, for instance, an Act passed in 1892, and subsequently amended, provides that political committees shall file a full statement, duly sworn to, of all campaign expenditures made by them. The Act applies to all public elections except that of town officers, and also covers nominations by caucuses and conventions as well. Apart from his personal expenses such as postage, travelling expenses, &c., a candidate is prohibited from spending anything himself to promote either his nomination or his election, but he is allowed to contribute to the treasury of the political committee. The law places no limit on the amount that these committees may spend. The reform sought by the law is through publicity, and not only are details of receipts and expenditures to be published, but the names of contributors and the amount of their contributions. In the state of New York the Act which seeks to prevent corrupt practices, relies in like manner on the efficacy of publicity, but it is less effective than the Massachusetts law in that it provides simply for the filing by the candidates themselves of sworn statements of their own expenses. There is nothing to prevent their contributing to political committees, and the financial methods and the amounts expended by such committees are not made public. But behind all these causes that have led to more honest elections lies the still greater one of a healthier public spirit. In the reaction following the Civil War all reforms halted. In recent years, however, a new and healthier interest has sprung up in things political; and one result of this improved civic spirit is seen in the various laws for purification of elections. It may now be safely affirmed that in the majority of states the elections are honestly conducted; that intimidation, bribery, stuffing of the ballot boxes or other forms of corruption, when they exist, are owing in large measure to temporary or local causes; and that the tendency of recent years has been towards a decrease in all forms of corruption.

The expenses connected with elections, such as the renting and preparing of the polling-places, the payment of the clerks and other officers who conduct the elections and count the vote, are borne by the community. A candidate, therefore, is not, as far as the law is concerned, liable to any expense whatever. As a matter of fact he does commonly contribute to the party treasury, though in the case of certain candidates, particularly those for the presidency and for judicial offices, financial contributions are not general. The amount of a candidate's contribution varies greatly, according to the office sought, the state in which he lives, and his private wealth. On one occasion, in a district in New York, a candidate for Congress is credibly believed to have spent at one election $50,000. On the other hand, in a Congressional election in a certain district in Massachusetts, the only expenditure of one of the candidates was for the two-cent stamp placed on his letter of acceptance. No estimate of the average amount expended can be made. It is, however, the conclusion of Mr Bryce, in his *American Commonwealth*, that as a rule a seat in Congress costs the candidate less than a seat for a county division in the House of Commons. (See also BALLOT.) (F. H. H.)

ELECTRICITY.

UNDER the general heading of ELECTRICITY we place the following articles on electric theory, which are given in the order named :—

I. ELECTRIC CONDUCTION.
II. ELECTROLYTIC CONDUCTION.
III. ELECTRIC CURRENT.
IV. ELECTRIC UNITS.
V. ELECTRIC DISCHARGE THROUGH GASES.
VI. ELECTRIC WAVES.

In addition to these articles, the following, dealing with allied questions, practical and scientific, will be found under separate headings, to which reference must be made :— ACCUMULATORS; ATMOSPHERIC ELECTRICITY; DYNAMO; ELECTRICITY SUPPLY (1. General Principles; 2. Lighting; 3. Traction; 4. Industrial Development); ELECTRO-CHEMISTRY; ELECTROMAGNET; ELECTRO-METALLURGY; MAGNETISM; MAGNETISM, TERRESTRIAL; MAGNETO-OPTICS; MEASURING INSTRUMENTS, ELECTRIC; POWER TRANSMISSION, ELECTRIC; TELEGRAPH; TELEPHONE; THERMO-ELECTRICITY; TRANSFORMERS; WELDING, ELECTRIC.

I. ELECTRIC CONDUCTION.

The *Electric Conductivity* of a substance is that property in virtue of which all its parts come spontaneously to the same electric potential if the substance is kept free from the operation of electric force. Accordingly, the reciprocal quality, *Electric Resistivity*, may be defined as a quality of a substance in virtue of which a difference of potential can exist between different portions of the body when these are in contact with some constant source of electromotive force, in such a manner as to form part of an electric circuit. Deferring more exact quantitative definitions for a moment, we may say that all material substances possess in some degree, large or small, Electric Conductivity, and may for the sake of convenience be broadly divided into five classes in this respect. Between these, however, there is no sharply-marked dividing line, and the classification must therefore be accepted as a more or less arbitrary one. These divisions are: (1) Metallic Conductors, (2) Non-Metallic Conductors, (3) Electrolytic Conductors, (4) Dielectric Conductors, (5) Gaseous Conductors. The first class comprises all metallic substances, and those mixtures or combinations of metallic substances known as alloys. The second includes such non-metallic bodies as carbon, silicon, many of the oxides and peroxides of the metals, and probably also some oxides, sulphides, and selenides. Many of these substances, for instance carbon and silicon, are well known to have the property of existing in several allotropic forms, and in some of these conditions, so far from being fairly good conductors, they may be almost perfect non-conductors. An example of this is seen in the case of carbon in its three allotropic conditions, charcoal, graphite, and diamond. As charcoal it possesses a fairly well-marked but not very high conductivity in comparison with metals; as graphite, a conductivity about one-four-hundredth of that of iron; but as diamond, so little conductivity that the substance is included amongst insulators or non-conductors. The third class, namely, the Electrolytic Conductors, comprises all those substances which undergo chemical decomposition when they form part of an electric circuit traversed by an electric current. The whole subject of Electrolytic Conduction has of late years acquired an immense importance from its bearing on chemical theory, and it is considered separately under the next heading (see II. ELECTROLYTIC CONDUCTION). The fourth class includes those substances which are generally called Insulators or Non-Conductors, but which are better denominated Dielectric Conductors; it comprises such solid substances as mica, ebonite, shellac, indiarubber, gutta-percha, paraffin, and a large number of liquids, chiefly hydrocarbons. These substances differ greatly in insulating power, and according as the conductivity is more or less marked, they are spoken of as bad or good insulators. Amongst the latter many of the liquid gases hold a high position. Thus, liquid oxygen and liquid air have been shown by J. Dewar to be almost perfect non-conductors of electricity, but their absolute resistivity has not yet been numerically determined. The fifth and last class of Conductors includes the Gases. The conditions under which this class of substance becomes possessed of electric conductivity are considered more in detail below (see V. ELECTRIC DISCHARGE). In connexion with metallic conductors, it is a fact of great interest and considerable practical importance, that although the majority of metals when in a finely divided or powdered condition are practically non-conductors, a mass of metallic powder or filings may be made to pass suddenly into a conductive condition by being exposed to the influence of an electric wave. The same is true of the loose contact of two metallic conductors. Thus if a steel point, such as a needle, presses very lightly against a metallic plate, say of aluminium, it is found that this metallic contact, if carefully adjusted, is non-conductive, but that if an electric wave (see VI. ELECTRIC WAVES) is created anywhere in the neighbourhood, this non-conducting contact passes into a conductive state.[1]

Standard Ohm.

Electric conductivity is measured by making a comparison with the conductivity of a known mass of a standard substance taken in a stated form. The practical unit of conductivity is the conductivity of a column of pure mercury at 0° C. having a uniform cross-section, a length of 106·3 centimetres, and a mass of 14·4521 grammes. The practical unit of electric resistance, to which was given legal definition in Great Britain by the authority of the Queen in Council in 1894, is defined to be the "resistance offered to an invariable electric current by a column of mercury at the temperature of melting ice, 14·4521 grammes in mass, of a constant cross-sectional area, and a length 106·3 centimetres." This has been legalized as a standard in Great Britain, France, Germany, and the United States, and is denominated "The International or Standard Ohm." It is intended to represent as nearly as possible a resistance equal to 10^9 absolute C.G.S. units of electric resistance. Convenient multiples and subdivisions of the ohm are the microhm and the megohm, the former being a millionth part of an ohm, and the latter a million ohms. The resistivity of substances is then numerically expressed by stating the resistance of one cubic centimetre of the substance taken between opposed faces, and expressed in ohms, microhms, or megohms, as may be most convenient. The reciprocal of the ohm is called the mho, which is the unit of conductivity, and is defined as the conductivity of a substance whose resistance is one ohm. The absolute unit of conductivity is the conductivity of a substance whose resistivity is one absolute C.G.S. unit, or one-thousandth-millionth part of an ohm. Resistivity is a quality in which material substances differ very widely. The metals and alloys, broadly speaking, are good conductors, and their resistivity is conveniently expressed in microhms per cubic centimetre, or in absolute C.G.S. units. Very small differences in density and in chemical purity make, however, immense differences in electric resistivity; hence the values given by different experimentalists for the resistivity of known metals differ to a considerable extent.

It is found convenient to express the resistivity of metals in two different ways: (1) We may state the resistivity of one cubic centimetre of the material in microhms or absolute units taken between opposed faces. This is called the *Volume-Resistivity*. (2) We may ex-

[1] This fact, investigated and discovered independently by Hughes, Onesti, Branly, Lodge, and others, is applied in the construction of the "Coherer," or sensitive tube employed as a detector or receiver in that form of "wireless telegraphy" chiefly developed by Marconi.

press the resistivity by stating the resistance in ohms offered by a wire of the material of uniform cross-section, one metre in length, and one gramme in weight. This numerical measure of the resistivity is called the *Mass-Resistivity*. The mass-resistivity of a body is connected with its volume-resistivity and the density of the material in the following manner:—The mass-resistivity, expressed in microhms per metre-gramme, divided by 10 times the density is numerically equal to the volume-resistivity per centimetre-cube in absolute C.G.S. units. The mass-resistivity per metre-gramme can always be obtained by measuring the resistance and the mass of any wire of uniform cross-section of which the length is known, and if the density of the substance is then measured, the volume-resistivity can be immediately calculated.

If R is the resistance in ohms of a wire of length l, uniform cross-section s, and density d, then taking ρ for the volume-resistivity we have

$$10^9 R = \rho \frac{l}{s}\text{; but } lsd = M$$

where M is the mass of the wire. Hence

$$10^9 R = \rho d \frac{l^2}{M}.$$

If $l=100$ and $M=1$, then $R=\rho^1=$ resistivity in ohms per metre-gramme and $10^9 \rho^1 = 10{,}000 d\rho$,

or $\rho = 10^5 \rho^1 / d$

and $\rho^1 = 10{,}000 MR/l^2$.

The following rules, therefore, are useful in connexion with these measurements. To obtain the mass-resistivity per metre-gramme of a substance in the form of a uniform metallic wire:—Multiply together 10,000 times the mass in grammes, and the total resistance in ohms, and then divide by the square of the length in centimetres. Again, to obtain the volume-resistivity in C.G.S. units per centimetre-cube, the rule is to multiply the mass-resistivity in ohms by 100,000 and divide by the density. These rules, of course, apply only to wires of uniform cross-section. In the following Tables I., II., and III. are given the mass and volume resistivity of ordinary metals and certain alloys expressed in terms of the Standard Ohm or the absolute C.G.S. unit of resistance, the values being calculated from the experiments of Matthiessen between 1860 and 1865, and from later results obtained by Fleming and Dewar in 1893.

TABLE I. *Electric Mass-Resistivity of Various Metals at* 0° *C., or Resistance per Metre-gramme in Standard Ohms at* 0° *C.* (Matthiessen.)

Metal.	Resistance at 0° C. in Standard Ohms of a Wire 1 Metre long and Weighing 1 Gramme.	Approximate Temperature Coefficient near 20° C.
Silver (annealed)	·1523	0·00377
Silver (hard-drawn)	·1657	
Copper (annealed)	·1421	0·00388
Copper (hard-drawn)	·1449 (Matthiessen's Standard)	
Gold (annealed)	·4025	0·00365
Gold (hard-drawn)	·4094	...
Aluminium (annealed)	·0757	...
Zinc (pressed)	·4013	...
Platinum (annealed)	1·9337	...
Iron (annealed)	·765	...
Nickel (annealed)	1·058 [1]	...
Tin (pressed)	·9618	0·00365
Lead (pressed)	2·2268	0·00387
Antimony (pressed)	2·3787	0·00389
Bismuth (pressed	12·8554 [2]	0·00354
Mercury (liquid)	12·885 [3]	0·00072

[1] and [2] The values for nickel and bismuth given in the table are much higher than more recent values obtained with pure electrolytic nickel and bismuth.

[3] The value here given, namely, 12·885, for the electric mass-resistivity of liquid mercury as determined by Matthiessen is now known to be too high by nearly one per cent. The value at present accepted is 12·789 ohms per metre-gramme at 0° C.

TABLE II. *Electric Volume-Resistivity of Various Metals at* 0° *C., or Resistance per Centimetre-cube in C.G.S. Units at* 0° *C.*

This table is calculated from the results of experiments made by Matthiessen, employing the values given by Fleeming Jenkin in his Cantor Lectures (Soc. of Arts, 1866) for the resistance in B.A. units of a uniform circular-sectioned wire of the metal, one metre long and one millimetre in diameter taken at 0° C. The figures given by Jenkin have been reduced to Standard Ohms and C.G.S. units by multiplying by $\frac{\pi}{4} \times \cdot 9866 \times 10^5 = 77{,}485$.

Metal.	Volume-Resistivity at 0° C. in C.G.S. Units.
Silver (annealed)	1,502
Silver (hard-drawn)	1,629
Copper (annealed)	1,594
Copper (hard-drawn)	1,630 [1]
Gold (annealed)	2,052
Gold (hard-drawn)	2,090
Aluminium (annealed)	3,006
Zinc (pressed)	5,621
Platinum (annealed)	9,035
Iron (annealed)	10,568
Nickel (annealed)	12,429 [2]
Tin (pressed)	13,178
Lead (pressed)	19,580
Antimony (pressed)	35,418
Bismuth (pressed)	130,872
Mercury (liquid)	94,896 [3]

[1] The value (1630) here given for hard-drawn copper is about one-quarter per cent. higher than the value now adopted, namely, 1626. The difference is due to the fact that either Jenkin or Matthiessen did not employ precisely the value at present employed for the density of hard-drawn and annealed copper in calculating the volume-resistivities from the mass-resistivities.

[2] Matthiessen's value for nickel is much greater than that obtained in more recent researches. (See Matthiessen and Vogt, *Phil. Trans. Roy. Soc.*, 1863, and J. A. Fleming, *Proc. Roy. Soc.*, Dec. 1899.)

[3] Matthiessen's value for mercury is nearly one per cent. greater than the value adopted at present as the mean of the best results, namely, 94,070.

TABLE III. *Electric Volume-Resistivity of Various Metals at* 0° *C., or Resistance per Centimetre-cube at* 0° *C. in C.G.S. Units.* (Fleming and Dewar, *Phil. Mag.*, Sept. 1893.)

Metal.	Resistance at 0° C. per Centimetre-cube in C.G.S. Units.	Mean Temperature Coefficient between 0° C. and 100° C.
Silver (electrolytic and well annealed) [1]	1,468	0·00400
Copper (electrolytic and well annealed) [1]	1,561	0·00428
Gold (annealed)	2,197	0·00377
Aluminium (annealed)	2,665	0·00435
Magnesium (pressed)	4,355	0·00381
Zinc	5,751	0·00406
Nickel (electrolytic) [1]	6,935	0·00618
Iron (annealed)	9,065	0·00625
Cadmium	10,023	0·00419
Palladium	10,219	0·00354
Platinum (annealed)	10,917	0·003669
Tin (pressed)	13,048	0·00440
Thallium (pressed)	17,633	0·00398
Lead (pressed)	20,380	0·00411
Bismuth (electrolytic) [2]	110,000	0·00433

[1] The samples of silver, copper, and nickel employed for these tests were prepared electrolytically by Mr J. W. Swan, F.R.S., and were exceedingly pure and soft. The value for volume-resistivity of nickel as given in the above table (from experiments by J. A. Fleming, *Proc. Roy. Soc.*, Dec. 1899) is much less (nearly 40 per cent.) than the value given by Matthiessen's researches.

[2] The electrolytic bismuth here used was prepared by Messrs Hartmann and Braun, and the resistivity taken by J. A. Fleming. The value is nearly 20 per cent. less than that given by Matthiessen.

The volume-resistivity of pure mercury is a very important electric constant, and during the last two decades many of the most competent experimentalists have directed their attention to the determination of its value. The experimental process has usually been to fill a glass tube of known dimensions, having large cup-like extensions at the ends, with pure mercury, and determine the absolute resistance of this column of metal. For the practical details of this method the following references may be consulted:—"The Specific Resistance of Mercury," Lord Rayleigh and Mrs Sidgwick, *Phil. Trans. Roy. Soc.*, 1883, part i. p. 173, and

R. T. Glazebrook, *Phil. Mag.*, October 1885; "On the Specific Resistance of Mercury," R. T. Glazebrook and T. C. Fitzpatrick, *Phil. Trans. Roy. Soc.*, June 1888, or *Proc. Roy. Soc.* vol. xliv. No. 270, or *Electrician*, vol. xxi. p. 538, 1888; "Recent Determinations of the Absolute Resistance of Mercury," R. T. Glazebrook, *Electrician*, vol. xxv. pp. 543, 588, 1890. Also see Professor J. V. Jones, "On the Determination of the Specific Resistance of Mercury in Absolute Measure," *Phil. Trans. Roy. Soc.*, 1891, A, p. 2. The Table IV. below gives the values of the volume-resistivity of mercury as determined by various observers, the constant being expressed (*a*) in terms of the resistance in ohms of a column of mercury one millimetre in cross-section and 100 centimetres in length, taken at 0° C.; and (*b*) in terms of the length in centimetres of a column of mercury one square millimetre in cross-section taken at 0° C. The result of all the most careful determinations has been to show that the resistivity of pure mercury at 0° C. is about 94,070 C.G.S. electromagnetic units of resistance, and that a column of mercury 106·3 centimetres in length having a cross-sectional area of one square millimetre would have a resistance at 0° C. of one Standard Ohm. These values have accordingly been accepted as the official and recognized values for the specific resistance of mercury, and the definition of the ohm. The Table also states the methods which have been adopted by the different observers for obtaining the absolute value of the resistance of a known column of mercury, or of a resistance coil afterwards compared with a known column of mercury. A column of figures is added showing the value in fractions of a Standard Ohm of the British Association Unit (B.A.U.), formerly supposed to represent the true ohm. The real value of the B.A.U. is now taken as ·9866 of a Standard Ohm.

TABLE IV. *Determinations of the Absolute Value of the Volume-Resistivity of Mercury and the Mercury Equivalent of the Ohm.*

Observer.	Date.	Method.	Value of B.A.U. in Ohms.	Value of 100 Centimetres of Mercury in Ohms.	Value of Ohm in Centimetres of Mercury.
Lord Rayleigh .	1882	Rotating coil	·98651	·94133	106·24
Lord Rayleigh .	1883	Lorenz method	·98677	...	106·21
G. Wiedemann .	1884	Rotation through 180°	...	...	106·19
Mascart . . .	1884	Iuduced current	·98611	·94096	106·33
Rowland . .	1887	Mean of several methods	·98644	·94071	106·32
Kohlrausch . .	1887	Damping of magnets	·98660	·94061	106·32
Glazebrook . .	1882 / 1888	Induced currents	·98665	·94074	106·29
Wuilleumeier .	1890		·98686	·94077	106·27
Duncan and Wilkes	1890	Lorenz	·98634	·94067	106·34
Jones . . .	1891	Lorenz	...	·94067	106·31
		Mean value	·98653		
Streker . . .	1885	An absolute determination of resistance was not made. The value ·98656 has been used		·94056	106·32
Hutchinson . .	1888			·94074	106·30
Salvioni . . .	1890			·94054	106·33
,, ...	...			·94076	106·30
			Mean value	·94076	106·29
H. F. Weber . .	1884	Induced current	Absolute measurements compared with German silver wire coils issued by Siemens and Streker		105·37
H. F. Weber . .	...	Rotating coil			106·16
Roiti . . .	1884	Mean effect of induced current			105·89
Himstedt . .	1885				105·98
Dorn . . .	1889	Damping of a magnet			106·24
Wild . . .	1883	Damping of a magnet			106·03
Lorenz . . .	1885	Lorenz method			105·93

For a critical discussion of the methods which have been adopted in the absolute determination of the resistivity of mercury, and the value of the British Association unit of resistance, the reader may be referred to the *British Association Reports* for 1890 and 1892 (*Report of Electrical Standards Committee*), and to the *Electrician*, vol. xxv. p. 456, and vol. xxix. p. 462. A discussion of the relative value of the results obtained between 1882 and 1890 was given by Mr R. T. Glazebrook in a paper presented to the British Association at Leeds, 1890.

In connexion with electro-technical work the determination of the conductivity or resistivity values of annealed and hard-drawn

Standard for copper.

copper wire at standard temperatures is a very important matter. Matthiessen devoted considerable attention to this subject between the years 1860 and 1864, and since that time much additional work has been carried out. Matthiessen's value, known as *Matthiessen's Standard*, for the mass-resistivity of pure hard-drawn copper wire, expressed in Standard Ohms, is the resistance of a wire of pure hard-drawn copper one metre long and weighing one gramme = ·14493 Standard Ohms at 0° C. For many purposes it is convenient to express temperature in Fahrenheit degrees, and the recommendation of the 1899 Committee on Copper Conductors[1] is as follows:—"Matthiessen's standard for hard-drawn conductivity commercial copper shall be considered to be a wire of pure hard-drawn copper one metre long, weighing one gramme, the resistance of which at 60° F. is ·153858 Standard Ohms." Matthiessen also measured the mass-resistivity of annealed copper, and found that its conductivity is greater than that of hard-drawn copper by about 2·25 per cent. to 2·5 per cent. As annealed copper may vary considerably in its state of annealing, and is always somewhat hardened by bending and winding, it is found in practice that the resistivity of commercial annealed copper is about 1¼ per cent. less than that of hard-drawn copper. The standard now accepted for such copper, on the recommendation of the 1899 Committee, is a wire of pure annealed copper one metre long, weighing one gramme, whose resistance at 0° C. is ·1421 Standard Ohms, or at 60° F., ·150822 Standard Ohms. The specific gravity of copper varies from about 8·89 to 8·95, and the standard value accepted for high conductivity commercial copper is 8·912, corresponding to a weight of 555 lb per cubic foot at 60° F. Hence the volume-resistivity of pure annealed copper at 0° C. is 1·594 microhms per c.c., or 1594 C.G.S. units, and that of pure hard-drawn copper at 0° C. is 1·626 microhms per c.c., or 1626 C.G.S. units. Since Matthiessen's researches, the most careful scientific investigation on the conductivity of copper is that of Mr T. C. Fitzpatrick, carried out in 1890. Mr Fitzpatrick confirmed Matthiessen's chief result, and obtained values for the resistivity of hard-drawn copper which, when corrected for temperature variation, are in entire agreement with those of Matthiessen at the same temperature.

The volume-resistivity of alloys is, generally speaking, much higher than that of pure metals. A Table (V.) is given below showing the volume-resistivity at 0° C. of a number of well-known

TABLE V. *Volume-Resistivity of Alloys of known Composition at 0° C in C.G.S. Units per Centimetre-cube. Mean Temperature Coefficients taken at 15° C.* (Fleming and Dewar.)

Alloys.	Resistivity at 0° C.	Temperature Coefficient at 15° C.	Composition in per cents:
Platinum-silver .	31,582	·000243	Pt 33 %, Ag 66 %
Platinum-iridium .	30,896	·000822	Pt 80 %, Ir 20 %
Platinum-rhodium .	21,142	·00143	Pt 90 %, Rd 10 %
Gold-silver . .	6,280	·00124	Au 90 %, Ag 10 %
Manganese-steel .	67,148	·00127	Mn 12 %, Fe 78 %
Nickel-steel . .	29,452	·00201	Ni 4·35 %, remaining percentage chiefly iron, but uncertain.
German silver . .	29,982	·000273	$Cu_5Zn_3Ni_2$
Platinoid[2] . .	41,731	·00031	
Manganin . .	46,678	0000	Cu 84 %, Mn 12%, Ni 4 %
Aluminium-silver .	4,641	·00238	Al 94 %, Ag 6 %
Aluminium-copper .	2,904	·00381	Al 94 %, Cu 6 %
Copper-aluminium .	8,847	·000897	Cu 97 %, Al 3 %
Copper-nickel-aluminium.	14,912	·000645	Cu 87 %, Ni 6·5 %, Al 6·5 %
Titanium-aluminium	3,887	·00290	

alloys, with their chemical composition. Generally speaking, an alloy having high resistivity has poor mechanical qualities, that is to say, its tensile strength and ductility are small. It is possible to form alloys having a resistivity as high as 100 microhms per cubic centimetre; but, on the other hand, the value of an alloy for electro-technical purposes is judged not merely by its resistivity, but also by the degree to which its resistivity varies with temperature, and by its capability of being easily drawn into fine wire of

[1] In 1899 a Committee was formed of representatives from eight of the leading manufacturers of insulated copper cables, and delegates from the Post Office and Institution of Electrical Engineers, to consider the question of the values to be assigned to the resistivity of hard-drawn and annealed copper. The sittings of the Committee were held in London, the secretary being Mr A. H. Howard. The values given in the above paragraphs are in accordance with the decision of this Committee, and its recommendations have been accepted by the General Post Office and the leading manufacturers of insulated copper wire and cables.

[2] Platinoid is an alloy introduced by Martino, said to be similar in composition to German silver, but with a little tungsten added. It varies a good deal in composition according to manufacture, and the resistivity of different specimens is not identical. Its electric properties were first made known by J. T. Bottomley, in a paper read at the Royal Society, May 5, 1885.

not very small tensile strength. Some pure metals when alloyed with a small proportion of another metal do not suffer much change in resistivity, but in other cases the resultant alloy has a much higher resistivity. Thus an alloy of pure copper with 3 per cent. of aluminium has a resistivity about 5½ times that of copper; but if pure aluminium is alloyed with 6 per. cent. of copper, the resistivity of the product is not more than 20 per cent. greater than that of pure aluminium. The presence of a very small proportion of a non-metallic element in a metallic mass, such as oxygen, sulphur, or phosphorus, has a very great effect in increasing the resistivity. Certain metallic elements also have the same power; thus platinoid has a resistivity 30 per cent. greater than German silver, though it differs from it merely in containing a trace of tungsten.

The resistivity of non-metallic conductors is in all cases higher than that of any pure metal. The resistivity of carbon, for instance, in the forms of charcoal or carbonized organic material and graphite, varies from 600 to 6000 microhms per cubic centimetre, as shown in the following Table VI.:—

TABLE VI. *Electric Volume-Resistivity in Microhms per Centimetre-cube of Various Forms of Carbon at 15° C.*

Substance.	Resistivity.
Arc lamp carbon rod	8000
Jablochkoff candle carbon	4000
Carré carbon	3400
Carbonized bamboo	6000
Carbonized parchmentized thread	4000 to 5000
Ordinary carbon filament from glow-lamp "treated" or flashed	2400 to 2500
Deposited or secondary carbon	600 to 900
Graphite	400 to 500

The resistivity of liquids is, generally speaking, much higher than that of any metals, metallic alloys, or non-metallic conductors. Thus fused plumbic chloride, one of the best conducting liquids, has a resistivity in its fused condition of 0·376 ohm per centimetre-cube, or 376,000 microhms per centimetre-cube, whereas that of metallic alloys only in few cases exceeds 100 microhms per centimetre-cube. The resistivity of solutions of metallic salts also varies very largely with the proportion of the diluent or solvent, and in some instances, as in the aqueous solutions of mineral acids, there is a maximum conductivity corresponding to a certain dilution. The resistivity of many liquids, such as alcohol, ether, benzine, and pure water, is so high, in other words, their conductivity is so small, that they are practically insulators, and the resistivity can only be appropriately expressed in megohms per centimetre-cube.

In Table VII. are given the names of a few of these badly-conducting liquids, with the values of their volume-resistivity in megohms per centimetre-cube:—

TABLE VII. *Electric Volume-Resistivity of Various Badly-Conducting Liquids in Megohms per Centimetre-cube.*

Substance.	Resistivity in Megohms per c.c.	Observer.
Ethylic alcohol	0·5	Pfeiffer.
Ethylic ether	1·175 to 3·760	W. Kohlrausch.
Benzine	4·700	
Absolutely pure water approximates probably to	25·0 at 18° C.	Value estimated by Kohlrausch and Heydweiler.
All very dilute aqueous salt solutions having a concentration of about 0·00001 of an equivalent gramme molecule[1] per litre approximate to	1·00 at 18° C.	From results by F. Kohlrausch and others.

[1] An equivalent gramme molecule is a weight in grammes equal numerically to the chemical equivalent of the salt. For instance, one equivalent gramme molecule of sodic chloride is a mass of 58·5 grammes. NaCl = 58·5.

The resistivity of all those substances which are generally called dielectrics or insulators is also so high that it can only be appropriately expressed in millions of megohms per centimetre-cube, or in megohms per quadrant-cube, the quadrant being a cube the side of which is 10^9 cms. (see Table VIII.).

TABLE VIII. *Electric Volume-Resistivity of Dielectrics reckoned in Millions of Megohms (Mega-megohms) per Centimetre-cube, and in Megohms per Quadrant-cube,* i.e., *a Cube whose Side is* 10 *cms.*

Substance.	Resistivity.		Temperature Cent.
	Mega-megohms per c.c.	Megohms per Quadrant-cube.	
Bohemian glass	61	·061	60°
Mica	84	·084	20°
Gutta-percha	450	·45	24°
Flint glass	1,020	1·02	60°
Glover's vulcanized indiarubber	1,630	1·63	15°
Siemens' ordinary pure vulcanized indiarubber	2,280	2·28	15°
Shellac	9,000	9·0	28°
Indiarubber	10,900	10·9	24°
Siemens' high-insulating fibrous material	11,900	11·9	15°
Siemens' special high-insulating indiarubber	16,170	16·17	15°
Flint glass	20,000	20·0	20°
Ebonite	28,000	28·	46°
Paraffin	34,000	34·	46°

Effects of heat.

Temperature affects in various degrees the resistivity of these different classes of conductors. In all cases, so far as is yet known, the resistivity of pure metal is increased if its temperature is raised, and decreased if the temperature is lowered so that if it could be brought to the absolute zero of temperature (−273° C.) its conductivity would probably become perfect or its resistivity would vanish, or at least arrive at a very small minimum value. With metallic alloys, however, rise of temperature does not always increase resistivity; it sometimes diminishes it, so that many alloys are known which have a maximum resistivity corresponding to a certain temperature, and at or near this point they vary very little in resistance with temperature. Such alloys have, therefore, a negative temperature-variation of resistance at and above fixed temperatures. Prominent amongst these metallic compounds are certain alloys of iron, manganese, nickel, and copper. Some of these were discovered by Mr Weston, in the United States. One well-known alloy of copper, manganese and nickel, now called manganin, which was brought to the notice of electricians by the careful investigations made at the Berlin Physikalisch-Technische Reichsanstalt, is characterized by having a zero temperature coefficient at or about a certain temperature in the neighbourhood of 15° C. Hence within a certain range of temperature on either side of this critical value the resistivity of manganin is hardly affected at all by temperature. Similar alloys can be produced from copper and ferromanganese. An alloy formed of 80 per cent. copper and 20 per cent. manganese in an annealed condition has a nearly zero temperature-variation of resistance between 20° C. and 100° C. In the case of non-metals the action of temperature is generally to diminish the resistivity as temperature rises, though this is not universally so. The interesting observation has been recorded by Mr J. W. Howell, that "treated" carbon filaments, and also graphite, are substances which have a minimum resistance corresponding to a certain temperature approaching red heat (*Electrician*, vol. xxxviii. p. 835). At and beyond this temperature increased heating appears to increase their resistivity; this phenomenon may, however, be accompanied by a molecular change and not be a true temperature variation. In the case of dielectric conductors, and of electrolytes, the action of rising temperature is to reduce resistivity. Many of the so-called insulators, such as mica, ebonite, indiarubber, and the insulating oils, paraffin, &c., decrease in resistivity with great rapidity as the temperature rises. With gutta-percha a rise in temperature from 0° C. to 24° C. is sufficient to reduce the resistivity to one-twentieth part of its value at 0° C., and the resistivity of flint glass at 140° C. is only one-hundredth of what it is at 60° C.

A definition may here be given of the meaning of the term *Temperature Coefficient.* If, in the first place, we suppose that the resistivity (ρ_t) at any temperature ($t°$) is a simple linear function of the resistivity (ρ_0) at 0° C., then we can write

$$\rho_t = \rho_0 (1 + \alpha t),$$

or

$$\alpha = \frac{\rho_t - \rho_0}{\rho_0} \frac{1}{t}.$$

The quantity α is then called the temperature-coefficient, and its reciprocal is the temperature at which the resistivity would become zero. By an extension of this notion we can call the quantity $d\rho/\rho dt$ the temperature coefficient corresponding to any temperature t at which the resistivity is ρ. In all cases the relation between the resistivity of a substance and the temperature is best set out in the form of a curve called a temperature-resistance curve. If a series of such curves are drawn for various pure metals, temperature being taken as abscissa and resistance as ordinate, and if the temperature range extends from the absolute zero of temperature upwards, then it is found that these temperature-resistance lines are curved lines having their convexity either upwards or downwards. In other words, the second differential coefficient of resistance with respect to temperature is either a positive or negative quantity. An extensive series of observations concerning the form of the resistivity curves for various pure metals over a range of temperature extending from −200° C. to +200° C. was carried out in 1892 and 1893 by Fleming and Dewar (*Phil. Mag.*, Oct. 1892 and Sept. 1893). The resistance observations were taken with resistance coils constructed with wires of various metals obtained in a state of great chemical purity. The lengths and mean diameters of the wires were carefully measured, and their resistance was then taken at certain known temperatures obtained by immersing the coils in boiling aniline, boiling water, melting ice, melting carbonic acid in ether, and boiling liquid oxygen, the temperatures thus given being +184°·5 C., +100° C., 0° C., −78°·2 C., and −182°·5 C. The resistivities of the various metals were then calculated and set out in terms of the temperature. From these data a chart was prepared showing the temperature-resistance curves of these metals throughout a range of 400 degrees. The exact form of these curves through the region of temperature lying between −200° C. and −273° C. is not yet known. As shown on the chart, the curves evidently do not converge to precisely the same point. It is, however, much less probable that the resistance of any metal should vanish at a temperature above the absolute zero than at the absolute zero itself, and the precise path of these curves at their lower ends cannot be delineated until means are found for fixing independently the temperature of some regions in which the resistance of metallic wires can be measured.

The resistivity curves of the magnetic metals are also remarkable for the change of curvature they exhibit at the magnetic critical temperature. Thus J. Hopkinson and D. K. Morris (*Phil. Mag.*, September 1897, p. 213) observed the remarkable alteration that takes place in the iron resistance temperature curve in the neighbourhood of 780° C. At that temperature the direction of the curvature of the curve changes so that it becomes convex upwards instead of convex downwards, and in addition the value of the temperature coefficient undergoes a great reduction. The mean temperature coefficient of iron in the neighbourhood of 0° C. is ·0057; at 765° C. it rises to a maximum value ·0204; but at 1000° C. it falls again to a lower value, ·00244. A similar rise to a maximum value and subsequent fall is also noted in the case of the specific heat of iron. The changes in the curvature of the resistivity curves are undoubtedly connected with the molecular changes that occur in the magnetic metals at their critical temperatures.

A fact of considerable interest in connexion with resistivity is the influence exerted by a strong magnetic field in the case of some metals, notably bismuth. It was discovered by Righi and confirmed by Leduc (*Journal de Physique*, vol. v. p. 116, and vol. vi. p. 189), that if a pure bismuth wire is placed in a magnetic field transversely to the direction of the magnetic field, its resistance is considerably increased (see MAGNETISM). This increase is greatly affected by the temperature of the metal (Dewar and Fleming, *Proc. Roy. Soc.* vol. lx. p. 427).

Time effects.

In the case of dielectric conductors, commonly called insulators, such as indiarubber, gutta-percha, glass, and mica, the electric resistivity is not only a function of the temperature but also of the time during which the electromotive force employed to measure it is imposed. Thus if an indiarubber-covered cable is immersed in water and the resistance of the dielectric between the copper conductor and the water measured by ascertaining the current which can be caused to flow through it by an electromotive force, this current is found to vary very rapidly with the time during which the electromotive force is applied. Apart from the small initial effect due to the electrostatic capacity of the cable, the application of an electromotive force to the dielectric produces a current through it which rapidly falls in value, as if the electric resistance of the dielectric were increasing. The current, however, does not fall continuously but tends to a limiting value, and it appears that if the electromotive force is kept applied to the cable for a prolonged time, a small and nearly constant current will ultimately be found flowing through it. It is customary in electro-technical work to consider the resistivity of the dielectric as the value it has after the electromotive force has been applied for one minute, the standard temperature being 75° F. This, however, is a purely conventional proceeding, and the number so obtained does not necessarily represent the true or ohmic resistance of the dielectric. If the electromotive force is increased, in the case of a large number of ordinary dielectrics the apparent resistance at the end of one minute's electrification decreases as the electromotive force increases.

Practical standards.

The practical measurement of resistivity involves many processes and instruments (see MEASURING INSTRUMENTS, ELECTRIC). Broadly speaking, the processes are divided into *Comparison Methods* and *Absolute Methods*. In the former a comparison is effected between the resistance of a material in a known form and some standard resistance. In the *Absolute Methods* the resistivity is determined without reference to any other substance, but with reference only to the fundamental standards of length, mass, and time. Immense labour has been expended during the last twenty years in investigations concerned with the production of a standard of resistance and its evaluation in absolute measure. In some cases the absolute standard is constructed by filling a carefully-calibrated tube of glass with mercury, in order to realise in a material form the official definition of the ohm; in this manner most of the principal national physical laboratories have been provided with standard mercury ohms. (For a full description of the standard mercury ohm of the Berlin Physikalisch-Technische Reichsanstalt, see the *Electrician*, vol. xxxvii. p. 569.) For practical purposes it is more convenient to employ a standard of resistance made of wire.

Opinion is not yet perfectly settled on the question whether a wire made of any alloy can be considered to be a perfectly unalterable standard of resistance, but experience has shown that a platinum-silver alloy (66 per cent. silver, 33 per cent. platinum), and also the alloy called manganin, seem to possess the qualities of permanence essential for a wire-resistance standard. A comparison made in 1892 and 1894 of all the manganin wire copies of the ohm made at the Reichsanstalt in Berlin, showed that these standards had remained constant for two years to within one or two parts in 100,000. It appears, however, that in order that manganin may remain constant in resistivity when used in the manufacture of a resistance coil, it is necessary that the alloy should be *aged* by heating it to a temperature of 140° C. for ten hours; and to prevent subsequent changes in resistivity, solders containing zinc must be avoided, and a silver solder containing 75 per cent. of silver employed in soldering the manganin wire to its connexions.

The authorities of the Berlin Reichsanstalt have devoted considerable attention to the question of the best form for a wire standard of electric resistance. In that now adopted the resistance wire is carefully insulated and wound on a brass cylinder, being doubled on itself to annul inductance as much as possible. In the coil two wires are wound on in parallel, one being much finer than the other, and the final adjustment of the coil to an exact value is made by shortening the finer of the two. A standard of resistance for use in a laboratory now generally consists of a wire of manganin or platinum-silver carefully insulated and enclosed in a brass case. Thick copper rods are connected to the terminals of the wire in the interior of the case, and brought to the outside, being carefully insulated at the same time from one another and from the case. The coil so constructed can be placed under water or paraffin oil, the temperature of which can be exactly observed during the process of taking a resistance measurement. Equalization of the temperature of the surrounding medium is effected by the employment of a stirrer, worked by hand or by a small electric motor. The construction of a standard of electrical resistance consisting of mercury in a glass tube is an operation requiring considerable precautions, and only to be undertaken by those experienced in the matter. Opinions are divided on the question whether greater permanence in resistance can be secured by mercury-in-glass standards of resistance or by wire standards, but the latter are at least more portable and less fragile.

A full description of the construction of a standard wire-resistance coil on the plan adopted by the Berlin Physikalisch-Technische Reichsanstalt is given in the Report of the British Association Committee on Electrical Standards, presented at the Edinburgh Meeting in 1892. For the design and construction of standards of electric resistances adapted for employment in the comparison and measurement of very low or very high resistances, the reader may be referred to standard treatises on electric measurements.

(J. A. F.)

II. Electrolytic Conduction.

Many of the phenomena which accompany the passage of electricity through fused salts and solutions have been described in the articles Electricity and Electrolysis (*Ency. Brit.*, 9th ed.), in which the nomenclature of the subject is defined. But since the date of those articles much additional knowledge has been obtained: the discharge of electricity through gases has been proved to depend largely on electrolytic conduction, and the explanation both of this process and of the passage of a current through liquids has been extended on the lines of the theory of moving particles of matter, called ions, associated with definite electric charges. In this article we are concerned only with liquid electrolytes, the conduction of gases being treated under Electric Discharge (see V., below). The new developments of this section of the subject depend experimentally on the measurement of electrolytic resistance. The fundamental problems underlying such experiments have been considered in the article Electricity (*Ency. Brit.*, 9th ed.).

In determining the electrical resistance of solutions, Kohlrausch's method of eliminating the effects of polarization by the use of alternating currents (see as above) is now universally employed. The currents, usually obtained from a *small* induction coil, or from an alternating current supply reduced by a transformer to a low voltage, are led to a Wheatstone's bridge, in one arm of which is placed the solution to be investigated. Instead of a galvanometer, which cannot indicate alternating currents, a telephone is used. A sound is heard when alternating currents pass through this instrument, and the bridge is adjusted till silence is obtained. A modification of the method, which eliminates several disturbing causes, consists in alternating the current from a galvanic battery by means of a commutator revolving at a uniform speed, which at the same time alternates the connexions of the indicator. The differential current of the bridge thus again becomes direct, and a galvanometer, preferably of the moving coil type (see III. Electric Current, below), can be employed (Whetham, *Phil. Trans. Roy. Soc.*, A, 1900). The solutions are usually placed in glass vessels, the shape of which depends on the order of the resistance to be measured. The platinum electrodes are coated with platinum black, in order to obtain a surface of very large area and thus diminish the effects of polarization. The determination of the conductivity of a liquid in absolute units involves a knowledge of the "cell constant" or "resistance capacity" of the vessel containing it. This can be found if we already know the absolute conductivity of any definite solution. Kohlrausch has compared the specific resistance of many solutions with that of mercury, and from his results a cell constant can be calculated. The following numbers may be used for this purpose: a solution of potassium chloride, containing one-tenth of a gram-equivalent of salt per litre, has at 18° C. a specific resistance of 89·37 ohms per cubic centimetre, or a conductivity of $1{\cdot}119 \times 10^{-13}$ in C.G.S. units.

As in the case of the other properties of solutions, the phenomena are much more simple when the concentration is small than when it is great, and a study of dilute solutions is therefore the best way of getting an insight into the essential principles of the subject. The foundation of our knowledge was laid by Kohlrausch, who expresses his results in terms of "equivalent conductivity," that is, the conductivity (k) of the solution divided by the number (m) of gram-equivalents of electrolyte per litre. He finds that, as the concentration diminishes, the value of k/m approaches a limit, and eventually becomes constant, that is to say, at great dilution the conductivity is proportional to the concentration. Kohlrausch first prepared very pure water by repeated distillation, and found that its resistance continually increased as the process of purification proceeded. The conductivity of the water, and of the slight impurities which must always remain, was subtracted from that of the solution made with it, and the result, divided by m, gave the equivalent conductivity of the substance dissolved. This procedure appears justifiable, for as long as conductivity is proportional to concentration it is evident that each part of the dissolved matter produces its own independent effect, so that the total conductivity is the sum of the conductivities of the parts; when this ceases to hold, the concentration of the solution has in general become so great that the conductivity of the solvent may be neglected. The general result of these experiments can be graphically represented by plotting k/m as ordinates and $m^{\frac{1}{3}}$ as abscissæ, $m^{\frac{1}{3}}$ being a number proportional to the reciprocal of the average distance between the molecules, to which it seems likely that the molecular conductivity may be related. The general types of curve for a neutral salt and for a caustic alkali or acid are shown in Fig. 1. The curve for the neutral salt comes to a limiting value; that for the acid attains a maximum at a certain very small concentration, and falls again when the dilution is carried to an extreme. It has usually been considered that this destruction of conductivity is due to chemical action between the acid and the residual impurities in the water. At such great dilution these impurities are present in quantities comparable with the amount of acid, which they convert into a less highly conducting neutral salt. In the case of acids, then, the maximum must be taken as the limiting value. The decrease in equivalent conductivity at great dilution is, however, so constant that this explanation seems insuffi-

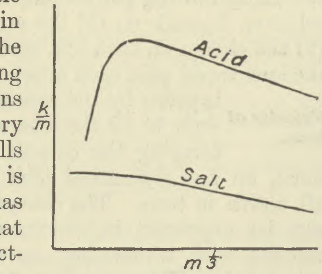


Fig. 1.

cient. The true cause of the phenomenon may perhaps be connected with the fact that the bodies in which it occurs, acids and alkalis, contain the ions, hydrogen in the one case, hydroxyl in the other, which are present in the solvent, water, and have, perhaps because of this relation, velocities higher than those of any other ions. The values of the molecular conductivities of all neutral salts are, at great dilution, of the same order of magnitude, while those of acids at their maxima are about three times as large. The influence of increasing concentration is greater in the case of salts containing divalent ions, and greatest of all in such cases as solutions of ammonia and acetic acid, which are substances of very low conductivity.

Kohlrausch found that, when the polarization at the electrodes was eliminated, the resistance of a solution was constant however determined, and thus established Ohm's Law for electrolytes, which was confirmed in the case of strong currents by Fitzgerald and Trouton (*B. A. Report*, 1886, p. 312). Now, Ohm's Law implies that no work is done by the current in overcoming reversible electromotive forces such as those of polarization. Thus the molecular interchange of ions, which must occur in order that the products may be able to work their way through the liquid and appear at the electrodes, continues throughout the solution whether a current is flowing or not. The influence of the current on the ions is merely directive, and when it flows, streams of electrified ions travel in opposite directions, and, if the applied electromotive force is enough to overcome the local polarization, give up their charges to the electrodes. We may therefore represent the facts by considering the process of electrolysis to be a kind of convection. Faraday's classical experiments proved that when a current flows through an electrolyte the quantity of substance liberated at each electrode is proportional to its chemical equivalent weight, and to the total amount of electricity passed. Accurate determinations have since shown that the mass of an ion deposited by one electromagnetic unit of electricity, *i.e.*, its electrochemical equivalent, is $1{\cdot}036 \times 10^{-4} \times$ its chemical equivalent weight. Thus the amount of electricity associated with one gram-equivalent of any ion is $\frac{10^4}{1{\cdot}036} = 9653$ units. Each monovalent ion must therefore be associated with a certain definite charge, which we may take to be a natural unit of electricity; a divalent ion carries two such units, and so on. A cation, *i.e.*, an ion giving up its charge at the cathode, as the electrode at which the current leaves the solution is called, carries a positive charge of electricity; an anion, travelling in the opposite direction, carries a negative charge. It will now be seen that the quantity of electricity flowing per second, *i.e.*, the current through the solution, depends on (1) the number of the ions concerned, (2) the charge on each ion, and (3) the velocity with which the ions travel past each other. Now, the number of ions is given by the concentration of the solution, for even if all the ions are not actively engaged in carrying the current at the same instant, they must, on any dynamical idea of chemical equilibrium, be all active in turn. The charge on each, as we have seen, can be expressed in absolute units, and therefore the velocity with which they move past each other can be calculated. This was first done by Kohlrausch[1] about 1879.

Theory of ions.

Velocity of ions.

In order to develop Kohlrausch's theory, let us take, as an example, the case of an aqueous solution of potassium chloride, of concentration n gram-equivalents per cubic centimetre. There will then be n gram-equivalents of potassium ions and the same number of chlorine ions in this volume. Let us suppose that on each gram-equivalent of potassium there reside $+e$ units of electricity, and on each gram-equivalent of chlorine ions $-e$ units. If u denotes the average velocity of the potassium ions, the positive charge carried per second across unit area normal to the flow is neu. Similarly, if v be the average velocity of the chlorine ions, the negative charge carried in the opposite direction is nev. But positive electricity moving in one direction is equivalent to negative electricity moving in the other, so that, before changes in concentration sensibly supervene, the total current, C, is $ne(u+v)$. Now let us consider the amounts of potassium and chlorine liberated at the electrodes by this current. At the cathode, if the chlorine ions were at rest, the excess of potassium ions would be simply those arriving in one second, namely, nu. But since the chlorine ions move also, a further separation occurs, and nv potassium ions are left without partners. The total number of gram-equivalents liberated is therefore $n(u+v)$. By Faraday's law, the number of *grams* liberated is equal to the product of the current and the electro-chemical equivalent of the ion; the number of gram-equivalents therefore must be equal to ηC, where η denotes the electro-chemical equivalent of hydrogen in C.G.S. units. Thus we get

$$n(u+v)=\eta C=\eta ne(u+v),$$

and it follows that the charge, e, on 1 gram-equivalent of each kind of ion is equal to $1/\eta$. We know that Ohm's Law holds good for electrolytes, so that the current C is also given by $k \cdot dP/dx$, where k denotes the conductivity of the solution, and dP/dx the potential gradient, *i.e.*, the change in potential per unit length along the lines of current flow. Thus

$$\frac{n}{\eta}(u+v)=k \cdot dP/dx;$$

therefore
$$u+v=\eta\frac{k}{n}\cdot\frac{dP}{dx}$$

Now η is $1{\cdot}036+10^{-4}$, and the concentration of a solution is usually expressed in terms of the number, m, of gram-equivalents per litre instead of per cubic centimetre. Therefore

$$u+v = 1{\cdot}036 \times 10^{-1}\frac{k}{m}\cdot\frac{dP}{dx}.$$

When the potential gradient is one volt (10^8 C.G.S. units) per centimetre this becomes

$$u+v=1{\cdot}036\times 10^{-7}\times k/m.$$

Thus by measuring the value of k/m, which is known as the equivalent conductivity of the solution, we can at once find $u+v$, the velocity of the ions relative to each other. For instance, the equivalent conductivity of a solution of potassium chloride containing one-tenth of a gram-equivalent per litre is 1113×10^{-13} C.G.S. units at 18° C. Therefore

$$u+v=1{\cdot}036\times 10^{7}\times 1113\times 10^{-13}$$
$$=1{\cdot}153\times 10^{-3}=0{\cdot}001153 \text{ cm. per sec.}$$

In order to obtain the absolute velocities u and v, we must find some other relation between them. Let us resolve u into $\frac{1}{2}(u+v)$ in one direction, say to the right, and $\frac{1}{2}(u-v)$ to the left. Similarly, v can be resolved into $\frac{1}{2}(v+u)$ to the left and $\frac{1}{2}(v-u)$ to the right. On pairing these velocities we have a combined movement of the ions to the right, with a speed of $\frac{1}{2}(u-v)$ and a drift right and left, past each other, each ion travelling with a speed of $\frac{1}{2}(u+v)$, constituting the electrolytic separation. If u is greater than v, the combined movement involves a concentration of salt at the cathode, and a corresponding dilution at the anode, and *vice versâ*. The rate at which salt is electrolysed, and thus removed from the solution at each electrode, is $\frac{1}{2}(u+v)$. Thus the total loss of salt at the cathode is $\frac{1}{2}(u+v)-\frac{1}{2}(u-v)$, or v, and at the anode, $\frac{1}{2}(v+u)-\frac{1}{2}(v-u)$, or u. Therefore, by measuring the dilution of the liquid round the electrodes when a current passed, Hittorf[2] deduced the ratio of the two velocities. Many further experiments have been made on the subject.[3]

By combining the results thus obtained with the sum of the velocities, as determined from the conductivities, Kohlrausch calculated the absolute velocities of different ions under stated conditions. Thus, in the case of the solution of potassium chloride considered above, Hittorf's experiments show us that the ratio of the velocity of the anion to that of the cation in this solution is ·51 : ·49. The absolute velocity of the potassium ion under unit potential gradient is therefore 0·000564 cm. per sec., and that of the chlorine ion 0·000589 cm. per sec. Similar calculations can be made for solutions of other concentrations, and of different substances.

The following table shows Kohlrausch's latest values for the ionic velocities of three chlorides of alkali metals at 18° C., calculated for a potential gradient of 1 volt per

[1] *Leitvermogen den Elektrolyte*, Leipzig, 1898.

[2] *Pogg. Ann.* vol. lxxxix. p. 177; xcviii. p. 1; ciii. p. 1; cvi. pp. 337, 513, 1853–59.

[3] Kuschel, *Wied. Ann.* vol. xiii. p. 289, 1881, and Löb and Nernst, *Zeits. f. physik. Chem.* vol. ii. p. 948, 1888; for other references see *Electrolytic Conduction*, ed. by H. M. Goodwin (New York, 1899).

cm.; the numbers are in terms of a unit equal to 10^{-6} cm. per sec. :—

TABLE IX.

	KCl			NaCl			LiCl		
m	*u+v*	*u*	*v*	*u+v*	*u*	*v*	*u+v*	*u*	*v*
0	1350	660	690	1140	450	690	1050	360	690
0·0001	1335	654	681	1129	448	681	1037	356	681
·001	1313	643	670	1110	440	670	1013	343	670
·01	1263	619	644	1059	415	644	962	318	644
·03	1218	597	621	1013	390	623	917	298	619
·1	1153	564	589	952	360	592	853	259	594
·3	1088	531	557	876	324	552	774	217	557
1·0	1011	491	520	765	278	487	651	169	482
3·0	911	442	469	582	206	376	463	115	348
5·0				438	153	285	334	80	254
10·0							117	25	92

These numbers clearly show that there is an increase in ionic velocity as the dilution proceeds. Moreover, if we compare the values for the chlorine ion obtained from observations on these three different salts, we see that as the concentrations diminish the velocity of the chlorine ion becomes the same in all of them. A similar relation appears in other cases, and, in general, we may say that at great dilution the velocity of an ion is independent of the nature of the other ion present. This at once introduces the conception of specific ionic velocities, for which some values at 18° C. are given by Kohlrausch in the following table :—

TABLE X.

K	. 66 × 10^{-5} cms. per sec.	Cl	. 69 × 10^{-5} cms. per sec.
Na	. 45 ,, ,,	I	. 69 ,, ,,
Li	. 36 ,, ,,	NO_3	. 64 ,, ,,
NH_4	. 66 ,, ,,	OH	. 162 ,, ,,
H	. 320 ,, ,,	$C_2H_3O_2$	36 ,, ,,
Ag	. 57 ,, ,,	$C_3H_5O_2$	33 ,, ,,

Having obtained these numbers we can deduce the conductivity of the dilute solution of any salt, and the comparison of the calculated with the observed values furnished the first confirmation of Kohlrausch's theory. Some exceptions, however, are known. Thus acetic acid and ammonia give solutions of much lower conductivity than is indicated by the sum of the specific ionic velocities of their ions as determined from other compounds. An attempt to find in Kohlrausch's theory some explanation of this discrepancy shows that it could be due to one of two causes. Either the velocities of the ions must be much less in these solutions than in others, or else only a fractional part of the number of molecules present can be actively concerned in conveying the current. We shall return to this point later.

Friction on the Ions.—It is interesting to calculate the magnitude of the forces required to drive the ions with a certain velocity. If we have a potential gradient of 1 volt per centimetre the electric force is 10^8 in C.G.S. units. The charge of electricity on 1 gram-equivalent of any ion is 1/·0001036 = 9653 units, hence the mechanical force acting on this mass is 9653 × 10^8 dynes. This, let us say, produces a velocity u; then the force required to produce unit velocity is $P_A = \frac{9{\cdot}653 \times 10^{11}}{u}$ dynes $= \frac{9{\cdot}84 \times 10^5}{u}$ kilograms-weight. If the ion have an equivalent weight A, the force producing unit velocity when acting on 1 gram is $P_1 = 9{\cdot}84 \times \frac{10^5}{Au}$ kilograms-weight. Thus the aggregate force required to drive 1 gram of potassium ions with a velocity of 1 centimetre per second through a very dilute solution must be equal to the weight of 38 million kilograms.

TABLE XI.

	Kilograms-weight.			Kilograms-weight.	
	P_A	P_1		P_A	P_1
K .	. 15 × 10^8	38 × 10^6	Cl .	. 14 × 10^8	40 × 10^6
Na .	. 22 ,,	95 ,,	I .	. 14 ,,	11 ,,
Li .	. 27 ,,	390 ,,	NO_3	. 15 ,,	25 ,,
NH_4	. 15 ,,	83 ,,	OH .	. 5·4 ,,	32 ,,
H .	. 3·1 ,,	310 ,,	$C_2H_3O_2$	. 27 ,,	46 ,,
Ag .	. 17 ,,	16 ,,	$C_3H_5O_2$	. 30 ,,	41 ,,

Since the ions move with uniform velocity, the frictional resistances brought into play must be equal and opposite to the driving forces, and therefore these numbers also represent the ionic friction coefficients in very dilute solutions at 18° C.

Direct Measurement of Ionic Velocities.—Oliver Lodge was the first to directly measure the velocity of an ion (*B. A. Report*, 1886, p. 389). In a horizontal glass tube connecting two vessels filled with dilute sulphuric acid he placed a solution of sodium chloride in solid agar-agar jelly. This solid solution was made alkaline with a trace of caustic soda in order to bring out the red colour of a little phenol-phthalein added as indicator. An electric current was then passed from one vessel to the other. The hydrogen ions from the anode vessel of acid were thus carried along the tube, forming hydrochloric acid as they travelled, which decolorized the phenol-phthalein. By this method the velocity of the hydrogen ion through a jelly solution under a known potential gradient was observed to be about 0·0026 cms. per sec., a number of the same order as that required by Kohlrausch's theory. Direct determinations of the velocities of a few other ions have been made by W. C. D. Whetham (*Phil. Trans. Roy. Soc.* vol. clxxxiv., A, p. 337; vol. clxxxvi., A, p. 507; *Phil. Mag.*, October 1894). Two solutions, having one ion in common, of equivalent concentrations, different densities, different colours, and nearly equal specific resistances, were placed one over the other in a vertical glass tube. In one case, for example, decinormal solutions of potassium carbonate and potassium bichromate were used. The colour of the latter is due to the presence of the bichromate group, Cr_2O_7. When a current was passed across the junction, the anions Cl and Cr_2O_7 travelled in the direction opposite to that of the current, and their velocity could be determined by measuring the rate at which the colour boundary moved. Similar experiments were made with alcoholic solutions of cobalt salts, in which the velocities of the ions were found to be much less than in water. The behaviour of agar jelly was then investigated, and the velocity of an ion through a solid jelly was shown to be very little less than in an ordinary liquid solution. The velocities could therefore be measured by tracing the change in colour of an indicator or the formation of a precipitate. Thus decinormal jelly solutions of barium chloride and sodium chloride, the latter containing a trace of sodium sulphate, were placed in contact. Under the influence of an electromotive force the barium ions moved up the tube, disclosing their presence by the trace of insoluble barium sulphate formed. Again, a measurement of the velocity of the hydrogen ion, when travelling through the solution of an acetate, showed that its velocity was then only about the one-fortieth part of that found during its passage through chlorides. From this, as from the measurements on alcohol solutions, it is clear that where the equivalent conductivities are very low the effective velocities of the ions are reduced in the same proportion.

Another series of direct measurements has been made by Orme Masson (*Phil. Trans. Roy. Soc.* vol. cxcii., A, p. 331). He placed the gelatine solution of a salt, potassium chloride, for example, in a horizontal glass tube, and found the rate of migration of the potassium and chlorine ions by observing the speed at which they were replaced when a coloured anion, say, the Cr_2O_7 from a solution of potassium bichromate, entered the tube at one end, and a coloured cation, say, the Cu from copper sulphate, at the other.

Kohlrausch's theory.

All the direct measurements which have been made agree with Kohlrausch's results within the limits of experimental error. His theory therefore probably holds good in every case, whatever be the solvent, if the proper values are given to the ionic velocities, *i.e.*, the values expressing the velocities with which the ions actually move in the solution of the strength taken, and under the conditions of the experiment. If we know the specific velocity of any one ion, we can, from the conductivity of very dilute solutions, at once deduce the velocity of any other ion with which it may be associated, a proceeding which does not involve the difficult task of determining the migration constant of the compound. Thus, taking the specific ionic velocity of hydrogen as 0·00032 cm. per second, we can, by determining the conductivity of dilute solutions of any acid, at once find the specific velocity of the acid radicle involved. Or again, since we know the specific velocity of silver, we can find the velocities of a series of acid radicles at great dilution by measuring the conductivity of their silver salts.

By such methods Ostwald, Bredig, and other observers have found the specific velocities of many ions both of inorganic and organic compounds, and examined the relation between constitution and ionic velocity.[1] The velocity of elementary ions is found to be a periodic function of the atomic weight, similar elements lying on corresponding portions of a curve drawn to express the relation between these two properties. Such a curve much resembles that giving the relation between atomic weight and viscosity in solution. For complex ions the velocity is largely an additive property; to a continuous additive change in the composition of the ion corresponds a continuous but decreasing change in the velocity. The following table gives Ostwald's results for the formic acid series:—

TABLE XII.

		Velocity.	Difference for CH_2.
Formic acid . . .	HCO_2	51·2	...
Acetic ,, . . .	$H_2C_2O_2$	38·3	−12·9
Propionic ,, . . .	$H_5C_3O_2$	34·3	− 4·0
Butyric ,, . . .	$H_7C_4O_2$	30·8	− 3·5
Valeric ,, . . .	$H_9C_5O_2$	28·8	− 2·0
Caprionic ,, . . .	$H_{11}C_6O_2$	27·4	− 1·4

Nature of electrolytes.

We have as yet said nothing about the fundamental cause of electrolytic activity, nor considered why, for example, a solution of potassium chloride is a good conductor, while a solution of sugar allows practically no current to pass All the preceding account of the subject is, then, independent of any view we may take of the nature of electrolytes, and stands on the basis of direct experiment. Nevertheless, the facts considered point to a very definite conclusion. The specific velocity of an ion is independent of the nature of the opposite ion present, and this at once suggests that the ions themselves, while travelling through the liquid, are dissociated from each other. Further evidence, pointing in the same direction, is furnished by the fact that since the conductivity is proportional to the concentration at great dilution, the equivalent-conductivity, and therefore the ionic velocity, is independent of it. The importance of this relation will be seen by considering the alternative to the dissociation hypothesis. If the ions are not permanently free from each other their mobility as parts of the dissolved molecules must be secured by continual interchanges. The velocity with which they work their way through the liquid must then increase as such molecular rearrangements become more frequent, and will therefore depend on the number of solute molecules, *i.e.*, on the concentration. On this supposition the observed constancy of velocity would be impossible. We shall therefore adopt as a working hypothesis the theory, confirmed by other phenomena to be described later, that an electrolyte consists of dissociated ions. It is necessary to point out that the dissociated ions of such a body as potassium chloride are not in the same condition as potassium and chlorine in the free state. The ions are associated with very large electric charges, and, whatever their exact relations with those charges may be, it is certain that the energy of a system in such a state must be different from its energy when unelectrified. It is not unlikely, therefore, that even a compound as stable in the solid form as potassium chloride should be thus dissociated when dissolved. Again, water, the best electrolytic solvent known, is also the body of the highest specific inductive capacity (di-electric constant), and this property, to whatever cause it may be due, will reduce the forces between electric charges in the neighbourhood, and may therefore enable two ions to separate.[2]

Dissociation theory.

This view of the nature of electrolytic solutions, which we owe to Arrhenius,[2] at once explains many well-known phenomena. Other physical properties of these solutions, such as density, colour, optical rotatory power, &c., like the conductivities, are *additive*, *i.e.*, can be calculated by adding together the corresponding properties of the parts. This again suggests that these parts are independent of each other. For instance, the colour of a salt solution is the colour obtained by the superposition of the colours of the ions and the colour of any undissociated salt that may be present. All copper salts in dilute solution are blue, which is therefore the colour of the copper ion. Solid copper chloride is brown or yellow, so that its concentrated solution, which contains both ions and undissociated molecules, is green, but changes to blue as water is added and the ionization becomes complete. A series of equivalent solutions all containing the same coloured ion have absorption spectra which, when photographed, show identical absorption bands of exactly equal intensity.[3] The colour changes shown by many substances which are used as indicators of acids or alkalis can be explained in a similar way. Thus para-nitro-phenol has colourless molecules, but an intensely yellow negative ion. In neutral, and still more in acid solutions, the dissociation of the indicator is practically nothing, and the liquid is colourless. If an alkali is added, however, a highly dissociated salt of para-nitro-phenol is formed, and the yellow colour is at once evident. In other cases, such as that of litmus, both the ion and the undissociated molecule are coloured, but in different ways.

Electrolytes possess the power of coagulating solutions of colloids such as albumen and arsenious sulphide. The mean values of the relative coagulative powers of sulphates of mono-, di-, and trivalent metals have been shown experimentally to be approximately in the ratios 1 : 35 : 1023. The dissociation theory refers this to the action of electric charges carried by the free ions. If a certain minimum charge must be collected in order to start coagulation, it will need the conjunction of $6n$ monovalent, or $3n$ divalent, to equal the effect of $2n$ trivalent ions. The ratios of the coagulative powers can thus be calculated to be $1 : x : x^2$, and putting $x=32$ we get 1 : 32 : 1024, a satisfactory explanation of the facts.[4]

Osmotic pressure.

The dissociation of electrolytes in solution is also suggested by other phenomena. If a solution be separated from a volume of its pure solvent by a membrane permeable to the solvent but not to the solution, the solvent passes through until a definite excess of pressure, called osmotic pressure, exists. By experiments on non-conducting solutions in water and other solvents, it has been found that this osmotic pressure shows the same volume and temperature relations as gaseous pressure, and has the same absolute value. Solutions of electrolytes, however, have abnormally high osmotic pressures, and we are thus led to conclude that, in their case, either the usual laws fail, or else that the number of molecules is greater than the chemical molecular weight and the concentration

[1] Data collected in a paper by Bredig, *Zeits. f. physikal. Chemie*, 1894, vol. xiii. p. 191.

[2] *Mém. p. à l'Acad. des Sciences de Suède*, 1883. Abstract in *B. A. Report*, 1886, p. 357. *Zeits. f. physikal. Chemie*, 1887, vol. i. p. 631.

[3] Ostwald, *Zeits. physikal. Chemie*, 1892, vol. ix. p. 579; Ewan, *Phil. Mag.* (5), 1892, vol. xxxiii. p. 317; Liveing, *Cambridge Phil. Trans.*, 1900, vol. xviii. p. 298.

[4] See Hardy, *Journal of Physiology*, 1899, vol. xxiv. p. 288; and Whetham, *Phil. Mag.*, November 1899.

of the solution would lead us to expect. Similar relations hold for the lowering of the vapour pressure and the depression of the freezing-point of a solvent caused by dissolving some substance in it. Both these effects are related to the osmotic pressure, and can be calculated from it, and the values of both are abnormally great for electrolytes. We may conclude, then, that the cause of the electrolytic property is also the cause of the increase in the osmotic pressure effects, and the phenomena are at once explained if we assume that the number of effective particles in solution is abnormally great in the case of electrolytes, that is, that electrolytes are partially or completely dissociated into their ions. It will be noticed that such a supposition does not commit us to any definite view as to the nature of solution or the cause of osmotic pressure. If solution be a purely physical process, analogous to evaporation, and the osmotic pressure be due to the impact of the dissolved molecules, the extra pressure of electrolytes is caused by similar impacts of the ions. If solution, on the other hand, be due to chemical action, and osmotic pressure be caused by chemical affinity of solvent for solute, then the same affinity, acting between the ions and the solvent, explains the properties of electrolytes. All that the dissociation theory demands is the freedom of the ions from each other; they may or may not be united with solvent molecules.

Freezing-points are easier to determine than osmotic or vapour pressures, and are therefore more suitable for the experimental investigation of this relation. The connexion between freezing-point and conductivity is well shown by Arrhenius' original table, the following short extract from which will serve our present purpose. The last two columns, headed *i*, give the ratio of the total number of dissolved particles to the number which would exist if all the molecules were undissociated. In column II. the ratio is calculated from Raoult's experiments on the freezing-points, and in column III., from the measurements of Kohlrausch, Ostwald, and others on the electrical conductivities. The first column, showing the ionization (dissociation) coefficients, is also calculated from these latter results.

Freezing-points.

TABLE XIII.

Non-Conductors.		I.	II.	III.
		a	*i*	*i*
Ethyl alcohol	C_2H_5OH	0·00	0·94	1·00
Cane sugar	$C_{12}H_{22}O_{11}$	0·00	1·00	1·00
Acetone	C_3H_6O	0·00	0·92	1·00
Bases, Acids, and Salts.				
Sodium hydroxide	NaOH	0·88	1·96	1·88
Ammonia	NH_3	0·01	1·03	1·01
Hydrochloric acid	HCl	0·90	1·98	1·90
Nitric acid	HNO_3	0·92	1·94	1·92
Sulphuric acid	H_2SO_4	0·60	2·06	2·19
Phosphoric acid	H_3PO_4	0·08	2·32	1·24
Acetic acid	CH_3COOH	0·01	1·03	1·01
Potassium chloride	KCl	0·86	1·82	1·86
Sodium chloride	NaCl	0·82	1·90	1·82
Potassium sulphate	K_2SO_4	0·67	2·11	2·33
Copper sulphate	$CuSO_4$	0·35	0·97	1·35

The remarkable general agreement of these numbers is broken by a few exceptions, such as those seen in the cases of phosphoric acid and copper sulphate. More recent work has not succeeded in finally establishing the strict accuracy of this relation, but its approximate truth seems undoubted. The chief experimental difficulty consists in the precise determination of the very small temperature differences between the freezing-point of the solvent and that of very dilute solutions.

An interesting relation appears when the electrolytic conductivity of solutions is compared with their chemical activity. The readiness and speed with which electrolytes react are in sharp contrast with the difficulty experienced in the case of non-electrolytes. Moreover, a study of the chemical relations of electrolytes indicates that it is always the electrolytic ions that are concerned in their reactions. The tests for a salt, potassium nitrate, for example, are the tests not for KNO_3, but for its ions K and NO_3, and in cases of double decomposition it is always these ions that are exchanged for those of other substances. If an element is present in a compound otherwise than as an ion it is not interchangeable, and cannot be recognized by the usual tests. Thus neither a chlorate, which contains the ion ClO_3, nor monochloracetic acid, shows the reactions of chlorine, though it is, of course, present in both substances; again, the sulphates do not answer to the usual tests which indicate the presence of sulphur as sulphide. The chemical activity of a substance being independent of the reaction in which it is concerned, it is possible to assign to each body a specific coefficient of affinity. Arrhenius has pointed out that the coefficient of affinity of an acid is proportional to its electrolytic ionization.

Chemical activity.

The affinities of acids have been compared in several ways. Ostwald (*Lehrbuch der allg. Chemie*, vol. ii., Leipzig, 1893) investigated the relative affinities of acids for potash, soda, and ammonia, and proved them to be independent of the base used. The method employed was to measure the changes in volume caused by the action. His results are given in column I. of the following table, the affinity of hydrochloric acid being taken as one hundred. Another method is to allow an acid to act on an insoluble salt, and to measure the quantity which goes into solution. Determinations have been made with calcium oxalate, $CaC_2O_4 + H_2O$, which is easily decomposed by acids, oxalic acid and a soluble calcium salt being formed. The affinities of acids relative to that of oxalic acid are thus found, so that the acids can be compared among themselves (column II.). If an aqueous solution of methyl acetate is allowed to stand, a slow decomposition goes on. This is much quickened by the presence of a little dilute acid, though the acid itself remains unchanged. It is found that the influence of different acids on this action is proportional to their specific coefficients of affinity. The results of this method are given in column III. Finally, in column IV. the electrical conductivities of normal solutions of the acids have been tabulated. A better basis of comparison would be the ratio of the actual to the limiting conductivity, but since the conductivity of acids is chiefly due to the mobility of the hydrogen ions, its limiting value is nearly the same for all, and the general result of the comparison would be unchanged.

TABLE XIV.

Acid.	I.	II.	III.	IV.
Hydrochloric	100	100	100	100
Nitric	102	110	92	99·6
Sulphuric	68	67	74	65·1
Formic	4·0	2·5	1·3	1·7
Acetic	1·2	1·0	0·3	0·4
Propionic	1·1	...	0·3	0·3
Monochloracetic	7·2	5·1	4·3	4·9
Dichloracetic	34	18	23·0	25·3
Trichloracetic	82	63	68·2	62·3
Malic	3·0	5·0	1·2	1·3
Tartaric	5·3	6·3	2·3	2·3
Succinic	0·1	0·2	0·5	0·6

It must be remembered that, the solutions not being of quite the same strength, these numbers are not strictly comparable, and that the experimental difficulties involved in the chemical measurements are considerable. Nevertheless, the remarkable general agreement of the numbers in the four columns is quite enough to show the intimate connexion between chemical activity and electrical conductivity. We may take it, then, that only that portion of a body is chemically active which is electrolytically active—that ionization is necessary for chemical activity just as it is necessary for electrolytic conductivity.

The ordinary laws of chemical equilibrium have been applied to the case of the dissociation of a substance into its ions. Let x be the number of molecules which dissociate per second when the number of undissociated molecules in unit volume is unity, then xp is the number when the concentration is p. Recombination can only occur when two ions meet, and since the frequency with which this will happen is proportional to the square of the ionic concentration, we shall get for the number of molecules re-formed in one second yq^2 where q is the number of dissociated molecules in one cubic centimetre. When there is equilibrium, $xp=yq^2$. If μ be the molecular conductivity, and μ_∞ its value at infinite dilution, the fractional number of molecules dissociated is μ/μ_∞, which we may write as α. The number of undissociated molecules is then $1-\alpha$, so that if V is the volume of the solution containing 1 gram-molecule of the dissolved substance, we get

$$q=\frac{1}{V}\alpha \text{ and } p=\frac{1}{V}(1-\alpha),$$

$$\therefore\ \frac{x}{V}(1-\alpha)=\frac{y}{V^2}\alpha^2,$$

$$\therefore\ \frac{\alpha^2}{V(1-\alpha)}=\frac{x}{y}=\text{constant}=k.$$

This constant k gives a numerical value for the chemical affinity, and the equation should represent the effect of dilution on the molecular conductivity of binary electrolytes. Ostwald has confirmed it by observation on an enormous number of weak acids (*Zeits. f. physikal. Chemie*, 1888, ii. p. 278; 1889, iii. pp. 170, 241, 369). Thus in the case of cyanacetic acid, while the volume V changed by doubling from 16 to 1024 litres, the values of k were 0′00(376, 373, 374, 361, 362, 361, 368). The mean values of k for other common acids were — formic, 0·0000214; acetic, 0·0000180; monochloracetic, 0·00155; dichloracetic, 0·051; trichloracetic, 1·21; propionic, 0·0000134. From these numbers we can, by help of the equation, calculate the conductivity of the acids for any dilution. In the case of substances like ammonia and acetic acid, where the dissociation is very small, $1-\alpha$ is nearly equal to unity, and only varies slowly with dilution. The equation then becomes

$$\frac{\alpha^2}{V}=k,$$

or

$$\alpha=\sqrt{Vk}, \qquad . \quad . \quad . \quad (31)$$

so that the molecular conductivity is proportional to the square root of the dilution. The value of k, however, does not keep so satisfactorily constant in the case of highly dissociated substances, and empirical formulæ have been constructed to represent the effect of dilution on them. Thus the values of the expressions $\frac{\alpha^2}{1-\alpha\sqrt{V}}$ (Rudolphi, *Zeits. physikal. Chem.*, 1895, vol. xvii. p. 385) and $\frac{\alpha^3}{(1-\alpha)^2V}$ (Van't Hoff, *ibid.*, 1895, vol. xviii. p. 300) are found to keep constant as V changes. Van't Hoff's formula is equivalent to taking the frequency of dissociation as proportional to the square of the concentration of the molecules, and the frequency of recombination as proportional to the cube of the concentration of the ions. No good explanation of the failure of the usual dilution law in these cases has yet been given.

When the solutions of two substances are mixed, similar considerations to those given above enable us to calculate the resultant changes in dissociation. (See Arrhenius, *loc. cit.*) The simplest and most important case is that of two electrolytes having one ion in common, such as two acids. It is evident that the undissociated part of each acid must eventually be in equilibrium with the free hydrogen ions, and if the concentrations are not such as to secure this condition, readjustment must occur. In order that there should be no change in the states of dissociation on mixing, it is necessary, therefore, that the concentration of the hydrogen ions should be the same in each separate solution. Such solutions were called by Arrhenius, "isohydric." The two solutions, then, will so act on each other when mixed that they become isohydric. Suppose we have one very active acid like hydrochloric, in which dissociation is nearly complete, and another like acetic, in which it is very small. In order that the solutions of these should be isohydric and the concentrations of the hydrogen ions the same, we must have a very large quantity of the feebly dissociated acetic acid, and a very small quantity of the strongly dissociated hydrochloric, and in such proportions alone will equilibrium be possible. This explains the action of a strong acid on the salt of a weak acid. Let us allow dilute sodium acetate to react with dilute hydrochloric acid. Some acetic acid is formed, and this process will go on till the solutions of the two acids are isohydric: that is, till the dissociated hydrogen ions are in equilibrium with both. In order that this should hold, we have seen that a considerable quantity of acetic acid must be present, so that a corresponding amount of the salt will be decomposed, the quantity being greater the less the acid is dissociated. This "replacement" of a "weak" acid by a "strong" one is a matter of common observation in the chemical laboratory. Similar investigations applied to the general case of chemical equilibrium lead to an expression of exactly the same form as that given by Guldberg and Waage, which is universally accepted as an accurate representation of the facts.

The temperature coefficient of conductivity has approximately the same value for most aqueous salt solutions. It decreases both as the temperature is raised and as the concentration is increased, ranging from about 3·5 per cent. per degree for extremely dilute solutions (*i.e.*, practically pure water) at 0° to about 1·5 for concentrated solutions at 18°. For acids its value is usually rather less than for salts at equivalent concentrations. The influence of temperature on the conductivity of solutions depends on (1) the ionization, and (2) the frictional resistance of the liquid to the passage of the ions, the reciprocal of which is called the ionic fluidity. At extreme dilution, when the ionization is complete, a variation in temperature cannot change its amount. The rise of conductivity with temperature, therefore, shows that the fluidity becomes greater when the solution is heated. As the concentration is increased and un-ionized molecules are formed, a change in temperature begins to affect the ionization as well as the fluidity. But the temperature coefficient of conductivity is now generally less than before; thus the effect of temperature on ionization must be of opposite sign to its effect on fluidity. The ionization of a solution, then, is usually diminished by raising the temperature, the rise in conductivity being due to the greater increase in fluidity. Nevertheless, in certain cases, the temperature coefficient of conductivity becomes negative at high temperatures, a solution of phosphoric acid, for example, reaching a maximum conductivity at 75° centigrade.

Thermal phenomena.

The dissociation theory gives an immediate explanation of the fact that, in general, no heat-change occurs when two neutral salt solutions are mixed. Since the salts, both before and after mixture, exist mainly as dissociated ions, it is obvious that large thermal effects can only appear when the state of dissociation of the products is very different from that of the reagents. Let us consider the case of the neutralization of a base by an acid in the light of the dissociation theory. In dilute solution such substances as hydrochloric acid and potash are almost completely dissociated, so that, instead of representing the reaction as

$$HCl + KOH = KCl + H_2O,$$

we must write

$$\overset{+}{H} + \overset{-}{Cl} + \overset{+}{K} + \overset{-}{OH} = \overset{+}{K} + \overset{-}{Cl} + H_2O.$$

The ions K and Cl suffer no change, but the hydrogen of the acid and the hydroxyl (OH) of the potash unite to form water, which is only very slightly dissociated. The heat liberated, then, is almost exclusively that produced by the formation of water from its ions. An exactly similar process occurs when any strongly dissociated acid acts on any strongly dissociated base, so that *in all such cases the heat evolution should be approximately the same.* This is fully borne out by the experiments of Thomsen, who found that the heat of neutralization of one gram-molecule of a strong base by an equivalent quantity of a strong acid was nearly constant, and equal to 13,700 or 13,800 calories. In the case of weaker acids, the dissociation of which is less complete, divergences from this constant value will occur, for some of the molecules have to be separated into their ions. For instance, sulphuric acid, which in the fairly strong solutions used by Thomsen is only about half dissociated, gives a higher value for the heat of neutralization, so that heat must be evolved when it is ionized. The heat of formation of a substance from its ions is, of course, very different from that evolved when it is formed from its elements in the usual way, since the energy associated with an ion is different from that possessed by the atoms of the element in their normal state. We can calculate the heat of formation from its ions for any substance *dissolved in a given liquid*, from a knowledge of the temperature coefficient of ionization, by means of an application of the well-known thermodynamical process, which also gives the latent heat of evaporation of a liquid when the temperature coefficient of its vapour pressure is known. The heats of formation thus obtained may be either positive or negative, and by using them to supplement the heat of formation of water, Arrhenius calculated the total heats of neutralization of soda by different acids, some of them only slightly dissociated, and found values agreeing well with observation (*Zeits. f. physikal. Chemie*, 1889, vol. iv. p. 96; and 1892, vol. ix. p. 339).

Diffusion of Electrolytes.—An application of the theory of ionic velocity due to Nernst[1] and Planck[2] enables us to calculate the diffusion constant of dissolved electrolytes. According to the molecular theory, diffusion is due to the motion of the molecules of the dissolved substance through the liquid. When the dissolved molecules are uniformly distributed, the osmotic pressure will be the same everywhere throughout the solution, but if the concentration varies from point to point the pressure will vary also. There must, then, be a relation between the rate of change of the concentration and the osmotic pressure gradient, and thus we may consider the osmotic pressure gradient as a force driving the solute through a viscous medium. In the case of non-electrolytes and of all non-ionized molecules this analogy completely represents the facts, and the phenomena of diffusion can be deduced from it alone. But the ions of an electrolytic solution can move independently through the liquid, even when no current flows, as the consequences of Ohm's Law indicate. The ions will therefore diffuse independently, and the faster ion will travel quicker into pure water in contact with a solution. The ions carry their charges with them, and, as a matter of fact, it is found that water in contact with a solution takes with respect to it a positive or negative potential, according as the positive or negative ion travels the faster. This process will go on until the simultaneous separation of electric charges produces an electrostatic force strong enough to prevent further separation of ions. We can therefore calculate the rate at which the salt as a whole will diffuse by examining the conditions for a steady transfer, in which the ions diffuse at an equal rate, the faster one being restrained and the slower one urged forward by the electric forces. In this manner the diffusion constant can be calculated in absolute units ($HCl=2\cdot49$, $HNO_3=2\cdot27$, $NaCl=1\cdot12$), the unit of time being the day. By experiments on diffusion this constant has been found by Scheffer, and the numbers observed agree with those calculated ($HCl=2\cdot30$, $HNO_3=2\cdot22$, $NaCl=1\cdot11$).

Contact Difference of Potential.—As we have seen above, when a solution is placed in contact with water the water will take a positive or negative potential with regard to the solution, according as the cation or anion has the greater specific velocity, and therefore the greater initial rate of diffusion. This idea can be developed to explain the difference of potential at the surface of contact of two solutions. If e is the electric charge on each ion, and dP/dx the potential gradient, the electrical force on each ion is $e\,dP/dx$. Again, if dp/dx denote the osmotic pressure gradient, the osmotic force on one of the ions in a small cylindrical space Adx is the force on the whole element shared among the total number of ions, that is, $\frac{Adp}{nAdx}$, or $\frac{1}{n}\cdot\frac{dp}{dx}$ when n is the number of ions in unit volume. We have called u and v the velocities of the cation and anion under unit potential gradient, so that their velocities under unit force will be u/e and v/e. Now, let us write down the velocities under the actual forces, and equate them, as the condition of the final state of steady transfer.

$$\frac{u}{e}\left(\frac{1}{n}\cdot\frac{dp}{dx}+e\frac{dP}{dx}\right)=\frac{v}{e}\left(\frac{1}{n}\frac{dp}{dx}-e\frac{dP}{dx}\right),$$

or

$$\frac{dP}{dx}=\frac{1}{ne}\cdot\frac{v-u}{v+u}\cdot\frac{dp}{dx}.$$

Osmotic pressure, as we have said, shows the same volume and temperature relations as gaseous pressure, and has the same absolute value. We can therefore apply to it the usual equation for a mass M of gas at an absolute temperature T, $p\times\text{volume}=MRT$, where R is a characteristic constant. Putting $M/\text{volume}=\text{density}=mn$, where m is the mass of each ion, we have $dp=mRTdn$, at constant temperature. Then, substituting in our equation, and integrating, we get

$$P_2-P_1=\frac{m}{e}RT\frac{v-u}{v+u}\log\frac{n_2}{n_1}$$

as the difference of potential between two solutions in contact, which differ in concentration, m/e denoting the electro-chemical equivalents. In the case of a galvanic cell, we must also consider the metal-liquid functions. Ions from the zinc plate enter the liquid, but no acid anions enter the zinc; thus at the anode, $v=0$. So also at the cathode, $u=0$, and the equation for the total electromotive force becomes

$$F=\frac{m}{e}RT\left(\log\frac{N_1}{n_1}+\frac{v-u}{v+u}\log\frac{n_2}{n_1}+\log\frac{n_2}{N_2}\right),$$

N_1 and N_2 denoting the concentrations of cations and anions in the substance of the anode and cathode respectively. In common forms of cells, where different metals are used, our ignorance of the meaning of these constants prevents the application of the formula, but galvanic cells can be constructed with two electrodes of the same metal placed in solutions of different substances, or even of the same substance at different concentrations. In these cases, since the unknown contribution from the metal is the same at the opposite electrodes, we can calculate the total electromotive force of the cell, for the equation becomes

$$E=\frac{m}{e}RT\frac{2v}{v+u}\log\frac{n_2}{n_1},$$

where everything is known in absolute measure. The values calculated for such "concentration cells" (usually of the order of 0·05 volt) agree well with observation. As the equation shows, the electromotive force will be greater if the concentration of the ions of the metal in the solution round one electrode is made very small. This can easily be done by placing the electrode in a solution which precipitates the metal. Thus Ostwald found that a cell with silver electrodes, one of which was surrounded by a chloride, had an electromotive force of 0·51 volt, Nernst's formula indicating a theoretical value of 0·52 volt. By placing copper in the solution of a cyanide it can even be made electropositive with regard to zinc, and the cell arranged in accordance with the scheme.

$$Zn/ZnSo_4/K_2So_4/KCN/Cu$$

has a reverse electromotive force, the current outside the cell passing from zinc to copper. Similar ideas have been used to explain the potential difference between a metal and a liquid. Nernst ascribes to each metal a solution pressure with regard to water, which depends on the value of N used above, and tends to drive the metal into solution in the form of positively electrified ions. This process will electrify the liquid positively, and leave the metal negatively charged. Whether this last extension of the theory can be justified or not is still a subject of discussion.[3]

Function of the solvent.

In the early development of the present theory of the subject no attention was paid to the part played by the solvent. It was looked on simply as furnishing a space into which the dissolving solid could diffuse, and, in the case of electrolytes, as providing a screen for separating the ions from one another. The very different power of various solvents, both in dissolving substances and in enabling them to conduct electricity when dissolved, directed attention to the general question of their influence, and measurements of conductivity of the same salt in water and alcohol were made by Fitzpatrick,[4] Völlmer,[5] and others. The problem of the cause of solubility still remains unsettled, but towards the explanation of ionizing power some advance has been made. If the forces holding the ions together in a molecule are electrical in their nature (as is quite possible), it follows that they will be much weakened by immersing the molecule in a medium of high specific

[1] *Zeits. physikal. Chem.* vol. ii. p. 613.
[2] *Wied. Ann.*, 1890, vol. xl. p. 561.

[3] See Lodge, *Phil. Mag.*, 1900; and Lehfeldt, *Phil. Mag.*, Nov. 1899.
[4] *B. A. Report*, 1886, p. 328; and *Phil. Mag.*, 1887, xxiv. p. 378.
[5] *Wied. Ann.*, 1894, lii. p. 328.

inductive capacity like water. This may explain the differences observed in the molecular conductivities of the same salt dissolved in different solvents, such as water and alcohol, for example, for, other conditions being the same, the effect of solvents in loosening the connexion between two ions, *i.e.*, their relative ionization powers, will depend on their specific inductive capacities. Some experimental evidence which, as far as it goes, confirms this idea has been obtained (Whetham, *Phil. Mag.*, 1894, p. 392; and 1897, p. 1). Kohlrausch's experiments have shown that the conductivity of pure water is exceedingly small, indicating only a slight amount of dissociation. But this is what we should expect, for the concentration is so great and the molecules are so crowded together that no dissociation can be permanent. Nevertheless, there are many indications that even chemically pure water would, if it could be prepared, be slightly dissociated and possess some conducting power (see Kohlrausch and Heydweiler, *Zeits. f. physikal. Chemie*, 1893, p. 492). Allied to this subject is the question of the nature of electrolytic conduction in fused salts. Here, however, the small amount of experimental work makes further consideration premature.

Electrons.

With regard to the fundamental principles of electrolytic conduction, it seems possible that a great step in advance may be made by the application of ideas obtained from the study of electric discharge through gases (*q.v.*). J. J. Thomson has shown (*Phil. Mag.*, 1897, vol. xliv. p. 293, 1898; vol. xlvi. p. 528, 1899; vol. xlviii. p. 547. *Summary in Reports of the Physical Congress at Paris*, 1900, vol. iii. p. 138) that the negative ions in certain cases of discharge are enormously more mobile than the positive ones, and that their mass is only about the one-thousandth part of that of the hydrogen molecule. These negative ions perhaps realize the conception of electrons due to Lorentz and Larmor (*Phil. Trans. Roy. Soc.*, 1895, vol. clxxxvi., A, p. 695, and 1898, vol. cxc., A, p. 205), and may be the ultimate particles of which, in varying number, different atoms are composed. A body containing an excess of these corpuscles is negatively charged, but positively when some of them have been removed. A current consists in the motion of electrons; in the case of gases, the electron particles sometimes travel alone, but in liquid electrolytes they cannot be detached from atoms, and hence their movement involves chemical action. An atom *plus* an electron is a monovalent anion, an atom *minus* an electron, a monovalent cation. In metallic conductors the electrons can pass from one atom to the next, and thus allow a current to flow without chemical decomposition.

Most of the new work on the subject, which does not appear in the general physical and chemical journals, is published in the *Zeitschrift für physikalische Chemie*, Leipzig, the *Zeitschrift für Elektrochemie*, Halle, or the *Journal of Physical Chemistry*, Cornell University, Ithaca, New York State. In these periodicals abstracts of papers published elsewhere will be found. Reference may also be made to the following:—ARRHENIUS. *Récherches sur la conductivité galvanique des Electrolytes.* Stockholm, 1883.—GOODWIN. *The Fundamental Laws of Electrolytic Conduction* (Memoirs of Faraday, Hittorf, and Kohlrausch). New York and London, 1899.—JONES. *The Modern Theory of Solution* (Memoirs by Pfeffer, Van't Hoff, Arrhenius, and Raoult). New York and London, 1899.—KOHLRAUSCH and HOLBORN. *Leitvermogen der Elektrolyte.* Leipzig, 1898.—LARMOR. *Æther and Matter.* Cambridge, 1900.—LEHFELDT. *Text-Book of Physical Chemistry.* London, 1899.—LODGE. *Reports on Electrolysis.* Brit. Ass. 1886; "Address to the Physical Society of London," *Phil. Mag.*, 1900.—LÜPKE. *Grundzüge der Elektrochemie.* Berlin, 1896. Translation by Muir. London, 1897.—NERNST. *Theoretische Chemie*, 2te Aufl. Stuttgart, 1898.—OSTWALD, *Lehrbuch der Allgemeinen Chemie.* Leipzig, 1893.—SHAW. *Report on Electrolysis*, Brit. Ass. 1890.—WALKER. *Introduction to Physical Chemistry.* London, 1899.—WHETHAM. *Solution and Electrolysis.* Cambridge, 1895. *Report on Electrolysis*, Brit. Ass., 1897.

(W. C. D. W.)

III. ELECTRIC CURRENT.

When a conductor is connected to two other conductors maintained at different electric potentials (see I. ELECTRIC CONDUCTION, above) it immediately exhibits physical qualities which are commonly described by stating that an electric current flows through it. We are in ignorance whether this effect involves any actual flow or circulation of a material or medium in the conductor, and the term is, therefore, to be understood only as a comprehensive and convenient expression for all the physical actions taking place in and near the conductor which determines the locality of the current. These actions are chiefly the production of a magnetic field or of magnetic force in and around the conductor, and the generation of heat in its mass. An electric current considered as a mathematical quantity has direction as well as magnitude, and belongs to that class of quantities called *circuital quantities*, because they can only exist at all when they exist simultaneously everywhere along a completely closed circuit. The path of electric current is, therefore, called an *electric circuit*, and may be made up partly of conductors, metallic or electrolytic, or partly of those substances known as insulators, or better, as dielectric conductors. Energy is associated with every circuit traversed by a current, and the continual dissipation of this energy causes the conducting circuit to become heated. Three qualities of a circuit determine the amount of the electric kinetic energy and potential energy which can be connected with it, and the rate at which it dissipates electric energy; these are its *Inductance* (L), its *Capacity* (C), and its *Resistance* (R). If a portion of the circuit is an electrolyte (see II. ELECTROLYTIC CONDUCTION), chemical decomposition of the electrolyte takes place. A magnetic field or magnetic flux is always associated with the circuit conveying a current, and the lines of this magnetic flux are always closed loops embracing or linked with the electric circuit. The principal facts connected with the electric circuit are: (1) the magnetic force at any point outside a conducting circuit which is traversed by an unvarying electric current is proportional to the chemical decomposition produced per second by the current in an electrolyte forming part of the circuit, provided that no ferromagnetic material is in the neighbourhood of the circuit; (2) the rate of dissipation of energy in any circuit traversed by an electric current is proportional to the square of the current, and varies inversely as the conductivity of the circuit—(this assertion is a statement of Joule's Law, and applies not only to the circuit as a whole but to any part of it); (3) if two points on an electric circuit, not including an active electromotive force, are selected and the difference of their electric potential measured, the current in the circuit is proportional to this difference of potential and to the conductivity of the circuit between these two points.

Measurement.

The magnitude or strength of an electric current may be estimated either by the *electrolytic* or the *magnetic* method. In the first case a standard electrolyte is selected, and a unit current defined as the unvarying current which, when passed through this standard electrolyte, liberates from it on the electrodes a certain mass of ions. It has been agreed that the standard electrolyte for this purpose shall be a neutral solution of nitrate of silver in water, and that the ion which shall be considered is the silver deposited on the cathode. The process of making an electrolytic measurement, therefore, of the strength of an electric current uniform in direction and unvarying in magnitude, consists in passing it through a neutral solution of nitrate of silver contained in a platinum bowl, the anode being a plate of pure silver. The direction of the current is defined to be the direction in which the silver ion moves. For the performance of this experiment the British Board of Trade have issued a particular specification. The practical unit of current is called the *ampere*, which in Great Britain is legally defined as the "unvarying electric current which, when passed through a solution of nitrate of silver made according to a certain specification, deposits silver on the cathode at the rate of ·001118 of a gramme per second." The ampere is intended to reproduce one-tenth of an absolute electromagnetic unit of current. The magnetic method of measuring an electric current is as follows:—Let a thin wire be bent into a circle of unit radius (1 cm.), and let it be supposed to be traversed by a uniform unvarying current; then at the centre of this circular conductor there will be a magnetic force perpendicular to the plane of the circuit. At that point imagine a unit magnetic pole to be placed (see IV. ELECTRIC UNITS), belonging to a thin uniformly magnetized filament of great length; the magnetic field due to this current will then exert a mechanical force on the unit pole. Let the current be adjusted until this mechanical force is $2\pi/10$ dynes. The unvarying current so regulated is one-tenth part of an absolute C.G.S. electromagnetic unit of current. The direction of the current is conventionally defined by the following rule:—Let the circular circuit be supposed to be placed horizontally on the ground, and a watch or clock placed, face upwards, at the centre; then if the magnetic pole is a North-seeking or marked pole, and the force on it tends to raise the pole, the current is said to flow round the circuit in the opposite direction to that in which the hands of the clock or watch move. There are reasons for believing that the practical unit of current as recovered electrolytically by the Board of Trade specification differs from the true ampere as defined electromagnetically by about one part in 1100; that is to say, if the ampere were defined as the unvarying current which would deposit in one second ·001119 of a gramme of silver, it would reconcile the two definitions more completely than at present. The two definitions were originally intended to define one and the same unit current, but as a matter of fact the Board of Trade ampere is probably about one-tenth per cent. smaller than the electromagnetic ampere defined as one-tenth part of the absolute electromagnetic unit in the C.G.S. system.

Periodic currents.

If an electric current is not unvarying, it may be *irregular* or *periodic*. If periodic, it may pass through a cycle of values from a maximum value in one direction to an equal value in the opposite direction, and is in this case also called an *alternating* current. Such a current is measured by the heating effect it produces, and is said to have an effective value of one ampere if it produces the same total heat per unit of time in any given conductor as an unvarying current of one ampere measured electrolytically or magnetically. If a current is periodic or alternating, we have to consider also the law of its variation, and we are concerned first with its *instantaneous* value (i), its *maximum* value (I), its *true mean* value (T.M.), and its *root-mean-square* value (R.M.S.), the two latter quantities being respectively the mean of the instantaneous values taken at numerous equidistant intervals of time during the cycle, and the square root of the mean of the squares of the instantaneous values so taken. Lastly, many of the properties of a periodic current depend upon the manner in which its variations in instantaneous magnitude take place. It is convenient to delineate the mode of variation of a periodic or irregular current by a curve. This may be of such nature that either the ordinates or radii represent the instantaneous values of the periodic current, and it may be therefore either a *wave curve*,—that is, one so drawn that the ordinates represent the instantaneous values and the abscissæ represent the flow of time; or a *polar curve*, in which radii represent instantaneous values, and angles round a point represent time, the complete periodic time of the variable being represented by four right-angles. If a current is periodic, the *frequency* (n) is the number of cycles per second, which is usually denoted by the symbol $\sim$. The periodic time (T) is the duration of one cycle, and the frequency obviously varies inversely as the periodic time. In the case of periodic currents we have to consider also another quantity called the *form factor* (f), which is defined as the ratio between the root-mean-square (R.M.S.) value of the periodic current and its true mean (T.M.) value, or $f=\frac{\text{R.M.S. value}}{\text{T.M. value}}$. Alternating or periodic currents may be also subdivided into *single phase* and *polyphase*, the latter depending upon the union of two or more circuits traversed by currents having certain relative differences of phase. Two periodic currents are said to differ in phase when their zero values do not happen at the same instant. In this case one current is said to *lag* behind the other. We have, therefore, the following classification of electric currents:—

1. Unvarying and uni-directional currents.
2. Irregular currents.
3. Periodic or alternating currents, including
   (*a*) Single phase currents,
   (*b*) Polyphase currents.

The relation between the instantaneous value (i) of the current and the impressed electromotive force (e) acting in the circuit, and the constants of the circuit, namely, the Inductance (L), Resistance (R), and the Capacity (C), is expressed by a *current equation.* Consider first the simplest case, namely, when L and R are constant quantities and C is zero, the electromotive force having a constant value E. Then the current equation is formed by equating the impressed electromotive force to the sum of the effective electromotive forces, which is always the product Ri, and the electromotive force positive or negative which is created by the inductance or capacity of the circuit. In a circuit of constant inductance this electromotive force is a counter electromotive force and is numerically equal to L di/dt. Hence the differential current equation for a circuit of constant inductance and resistance acted upon by a constant electromotive force E is

$$E=Ri+L\frac{di}{dt}. \qquad (1)$$

The solution of this equation is

$$i=\frac{E}{R}\left(1-\epsilon^{-Rt/L}\right) \qquad (2)$$

where ϵ is the base of the Napierian logarithms.

Hence as the time (t), reckoned from the instant when the electromotive force is first applied, increases indefinitely, the value of the current (i) approximates to E/R, or to the value given by Ohm's Law. The ratio L/R which occurs in the equation (2) is of the dimensions of a time, and is called the *time-constant* of the circuit.

Consider next the case when the impressed electromotive force is not constant but periodic, and is a simple sine function having a periodic time T and a frequency n. Let $2\pi n$ be called p. Then the electromotive force at any instant has a value $e=E\sin pt$, where E is the maximum value of e. The current equation for a circuit of constant resistance and inductance is

$$e=E\sin pt=Ri+L\frac{di}{dt}, \qquad (3)$$

and the solution for i is

$$i=\frac{E\sin(pt-\theta)}{\sqrt{R^2+p^2L^2}}+C', \qquad (4)$$

where $\theta=\tan^{-1}Lp/R$, and C′ is an exponential function of t which diminishes to zero as t increases indefinitely. The quantity $\sqrt{R^2+p^2L^2}$ is called the *Impedance* of the circuit.

If we have a condenser of capacity C in series with a conducting circuit possessing an inductance L, and capacity R, then the back electromotive force due to the accumulation of electric charge in the condenser is equal to the quotient of the total electric quantity in the condenser divided by its capacity. Hence if i is the current at any instant flowing into the condenser at the time t, the total electric charge of the condenser is

$C\int_0^t idt$, and the counter electromotive force created by that charge is

$\frac{1}{C}\int_0^t idt$. Hence the differential current equation in the case of a circuit formed of a circuit having impedance, in series with a condenser having capacity, and acted upon by a simple periodic electromotive force $e = \mathrm{E} \sin pt$, is

$$e = \mathrm{R}i + \mathrm{L}\frac{di}{dt} + \frac{1}{\mathrm{C}}\int_0^t idt. \tag{5}$$

The solution of this equation for i is

$$i = \frac{\mathrm{E}}{\sqrt{\mathrm{R}^2 + (\mathrm{L}p - (\mathrm{C}p)^{-1})^2}} \sin (pt - \theta) + \mathrm{C}^1, \tag{6}$$

where θ is a constant phase angle, and C^1 is a function of t which dies out rapidly as the time t continually increases. The equation (2) shows that if a constant unidirectional electromotive force is applied to an inductive circuit, the current does not immediately attain its full strength, but beginning at zero gradually rises up towards a constant value E/R at a rate which depends upon the rate of increase of the quantity $\epsilon^{-\mathrm{R}t/\mathrm{L}}$ towards unity. The larger the value of the inductance L, the slower is the rate of growth. Accordingly, in an inductive circuit it is not possible to make very rapid changes in current strength. If the circuit has a variable inductance, such for instance as the circuit of an electromagnet, in which coils of wire are wrapped round an iron core, the inductance L is a function of the exciting current i, and the differential equations cannot be solved unless the form of the function is known.

In the case of simple periodic currents it is interesting to study the initial effects in a circuit of constant inductance L which take place on first bringing an alternating electromotive force into operation on the circuit. To obtain the complete solution of the differential current equation

$$\mathrm{E} \sin pt = e = \mathrm{R}i + \mathrm{L}\frac{di}{dt}, \tag{7}$$

we differentiate the equation twice to eliminate E sin pt, and arrive at a linear differential equation of the third order, namely,

$$\mathrm{L}\frac{d^3i}{dt^3} + \mathrm{R}\frac{d^2i}{dt^2} + p^2\mathrm{L}\frac{di}{dt} + p^2\mathrm{R}i = 0. \tag{8}$$

The solution of the above equation is

$$i = \mathrm{A}\,\epsilon^{-\mathrm{R}t/\mathrm{L}} + \mathrm{B} \sin pt + \mathrm{B}^1 \cos pt \tag{9}$$

where A, B, and B^1 are constants. This may be written

$$i = \mathrm{A}\,\epsilon^{-\mathrm{R}t/\mathrm{L}} + \mathrm{I} \sin (pt - \phi) \tag{10}$$

where I is the maximum value of the periodic current and ϕ is a constant angle, called the *angle of lag.* To find the value of the constant A we note that at the instant of closing, the circuit i must be zero. Let this closure happen at a time t^1 reckoned from the instant when the electromotive force is zero, then we have

$$i = \mathrm{I} \sin (pt - \phi) + \mathrm{I} \sin (pt^1 - \phi)\,\epsilon^{-\mathrm{R}(t - t^1)/\mathrm{L}}$$

as the complete solution of the above differential current equation. We notice that the solution for i is made up of a simple periodic function added to an exponential function of which the initial value is I sin $(pt^1 - \phi)$. The complete graph of the solution of the current equation is therefore a curve similar to the dotted curve in Fig 2, the ordinates of which are equal to the sum of the ordinates of the (firm line) periodic curve and the (firm line) exponential curve. The initial value of the exponential curve depends upon the phase of the electromotive force when the circuit is closed. We are therefore led to the conclusion that if a simple periodic electromotive force is applied suddenly to an inductive circuit, there may be a short period of time during which the current curve is lop-sided, and more current flows in one direction than in the other. The occurrence of this initial stage depends upon the phase of the electromotive force when the circuit is closed.

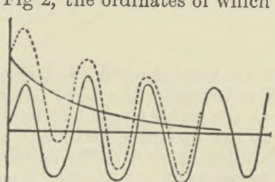


Fig. 2

In the above equations ϕ is the angle by which the current when steady lags behind the electromotive force. Hence $\tan \phi = \mathrm{L}p/\mathrm{R}$. We may in the same manner discuss the initial conditions when a periodic electromotive force is suddenly applied to an inductive circuit having a condenser in series with it, and arrive at a solution of the form

$$i = \mathrm{I} \sin (pt - \theta) + \mathrm{A}\,\epsilon^{-\mathrm{R}t/\mathrm{L}} \sin (pt - \phi)$$

where I is the maximum value of the current during the cycle in the steady state and A and q are constants. The solution shows us that the physical operations which take place when a condenser in series with an inductive circuit suddenly has a simple periodic electromotive force applied to it is as follows :—Before the oscillations of current settle down into a steady periodic state, a second set of oscillations of current is superimposed on the steady set, the latter having possibly a frequency and amplitude different from those which ultimately survive. The simultaneous existence of these oscillations may give rise to variations of electromotive force acting on the condenser which are much greater in amplitude than those which take place in the steady state. The extent to which these superimposed oscillations of current occur, depends upon the phase of the electromotive force when the current is closed.

In dealing with problems connected with electric currents we have to consider the laws which govern the flow of currents in linear conductors (wires), in plane conductors (sheets), and throughout the mass of a material conductor. In the first case consider the collocation of a number of linear conductors, such as rods or wires of metal, joined at their ends to form a *network of conductors.* The network consists of a number of conductors joining certain points and forming meshes. In each conductor a current may exist, and along each conductor there is a fall of potential, or an active electromotive force may be acting in it. Each conductor has a certain resistance. To find the current in each conductor when the individual resistances and electromotive forces are given, proceed as follows :—Consider any one mesh. The sum of all the electromotive forces which exist in the branches bounding that mesh must be equal to the sum of all the products of the resistances into the currents flowing along them, or $\Sigma(\mathrm{E}) = \Sigma(\mathrm{C.R.})$. Hence if we consider each mesh as traversed by imaginary currents all circulating in the same direction, the real currents are the sums or differences of these imaginary cyclic currents in each branch. Hence we may assign to each mesh a cycle symbol x, y, z, &c., and form a cycle equation. Write down the cycle symbol for a mesh and prefix as coefficient the sum of all the resistances which bound that cycle, then subtract the cycle symbols of each adjacent cycle, each multiplied by the value of the bounding or common resistances, and equate this sum to the total electromotive force acting round the cycle. Thus if x y z are the cycle currents, and a b c the resistances bounding the mesh x, and b and c those separating it from the meshes y and z, and E an electromotive force in the branch a, then we have formed the cycle equation $x\,(a + b + c)\,x - by - cz = \mathrm{E}$. For each mesh a similar equation may be formed. Hence we have as many linear equations as there are meshes, and we can obtain the solution for each cycle symbol, and therefore for the current in each branch. The solution giving the current in such branch of the network is therefore always in the form of the quotient of two determinants. The solution of the well-known problem of finding the current in the galvanometer circuit of the arrangement of linear conductors called Wheatstone's Bridge is thus easily obtained. For if we call the cycles (see Fig. 3) $(x+y)$, y and z, and the resistances P, Q, R, S, G, and B, and if E be the electromotive force in the battery circuit, we have the cycle equations

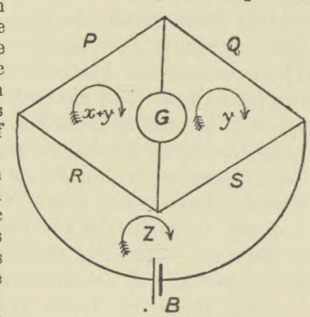


Fig. 3.

$$(\mathrm{P} + \mathrm{G} + \mathrm{R})\,\overline{x + y} - \mathrm{G}y - \mathrm{R}z = 0.$$
$$(\mathrm{Q} + \mathrm{G} + \mathrm{S})\,y - \mathrm{G}\overline{x + y} - \mathrm{S}z = 0.$$
$$(\mathrm{R} + \mathrm{S} + \mathrm{B})\,z - \mathrm{R}\overline{x + y} - \mathrm{S}y = \mathrm{E}.$$

From these we can easily obtain the solution for $\overline{x + y} - y = x$, which is the current through the galvanometer circuit in the form

$$x = \mathrm{E}\delta/\Delta,$$

where δ and Δ are two determinants. (Fleming, "Problems on the Distribution of Electric Currents in Networks of Conductors," *Phil. Mag.*, Sept. 1885.)

In the case of current flow in plane sheets, we have to consider certain points called *sources* at which the current flows into the sheet, and certain points called *sinks* at which it leaves. We may investigate, first, the simple case of one source and one sink in an infinite plane sheet of thickness δ, and conductivity k. Take any point P in the plane at distances R and r from the source and sink respectively. The potential V at P is obviously given by

$$\mathrm{V} = \frac{\mathrm{Q}}{2\pi k\delta} \log \frac{r_1}{r_2},$$

where Q is the quantity of electricity supplied by the source per second. Hence the equation to the equipotential curve is $r_1 r_2 = \mathrm{Const.}$

If we take a point half-way between the sink and the source as the origin of a system of rectangular co-ordinates, and if the distance between sink and source is equal to p, and the line joining them is taken as the axis of x, then the equation to the equipotential line is

$$\frac{y^2 + \overline{x + p}^2}{y^2 + (x - p)^2} = \mathrm{Const.}$$

This is the equation of a family of circles having the axis of y for a common radical axis, one set of circles surrounding the sink and another set of circles surrounding the source. In order to discover the form of the stream of current lines we have to determine the orthogonal trajectories to this family of coaxial circles. It is easy to show that the orthogonal trajectory of the system of circles is another system of circles all passing through the sink and the source, and as a corollary of this fact, that the electric resistance of a circular disc of uniform thickness is the same between any two points taken anywhere on its circumference as sink and source. These equipotential lines may be delineated experimentally by attaching the terminals of a battery or batteries to small wires which touch at various places a sheet of tinfoil. Two wires attached to a galvanometer may then be placed on the tinfoil, and one may be kept stationary and the other may be moved about, so that the galvanometer is not traversed by any current. The moving terminal then traces out an equipotential curve. If there are n sinks and sources in a plane conducting sheet, and if r, r', r'', be the distances of any point from the sinks, and r, r', r'', the distances of the source, then

$$\frac{r\ r'\ r''\ \ldots}{r\ r'\ r''\ \ldots} = \text{a constant},$$

is the equation to the equipotential lines. The orthogonal trajectories or stream lines have the equation[1]

$$\Sigma\,(\theta - \theta') = \text{a constant},$$

where θ and θ' are the angles which the lines drawn from any point in the plane to the sink and corresponding source make with the line joining that sink and source. Generally it may be shown that if there are any number of sinks and sources in an infinite plane-conducting sheet, and if r, θ are the polar co-ordinates of any one, then the equation to the equipotential surfaces is given by the equation

$$\Sigma\,(\text{A} \log r) = \text{a constant},$$

where A is a constant; and the equation to the stream or current lines is

$$\Sigma\,(\theta) = \text{a constant}.$$

In the case of electric flow in three dimensions the electric potential must satisfy Laplace's equation, and a solution is therefore found in the form $\Sigma\left(\frac{\text{A}}{r}\right) = \text{a constant}$, as the equation to an equipotential surface, where r is the distance of any point on that surface from a source or sink.

Practical instruments. The practical measurement of electric current involves the use of instruments which are variously called *galvanoscopes*, *galvanometers*, *amperemeters* or *ampere-balances*. The most frequently-recurring operation in electric work is the determination of the presence or the absence of an electric current in a circuit. For this purpose we may employ galvanoscopes when a mere qualitative determination is required, indicating in a general way the presence of a current, without any reference to its strength. On the other hand, if a current has to be measured in terms of the unit current, then a galvanometer or amperemeter must be made use of. Current measuring instruments may be constructed by taking advantage of any measurable effect due to the presence of a current in a conductor. Hence we may classify them as: 1. *Electromagnetic*; 2. *Electrodynamic*; 3. *Electrothermal*; 3. *Electro-optic*; 5. *Electrochemical*, according as they depend in principle upon the magnetic, electrodynamic, thermal, optical, or chemical effects which are associated with an electric circuit when traversed by a current. The majority of instruments in use depend upon the properties of the magnetic field round a circuit through which a current is flowing, and such instruments may be classified into: (i.) *movable needle and fixed coil instruments*; (ii.) *movable coil and fixed magnet instruments*; (iii.) *movable iron and fixed coil instruments*. In the first class a magnetic needle is suspended in or near a coil which is traversed by the current to be measured. The magnetic field due to this current brings into existence a magnetic torque or couple which causes the needle to tend to set in a certain direction, and this movement is resisted by some opposing couple called the *control*.

Of this type are many forms of galvanometer, such as the simple needle, the mirror galvanometer, the tangent galvanometer in various forms. In the mirror instrument the movement of a single magnetic needle or of an astatic system is detected by attaching to the needle system a light concave mirror on which a ray of light is thrown from a lamp. The mirror reflects the ray upon a scale, where it is made to form the sharp image of the source of light or of an opening through which it passes. The scale is generally placed at a distance of one metre from the mirror. A convenient method for obtaining a sharp image is to focus on the screen the image of a portion of a filament of an incandescent electric lamp. If the scale is semi-transparent, the bright line of light so formed can be read from the other side, and its position determined with great accuracy. The *sensibility* of the galvanometer is expressed by stating the deflection of the spot of light in millimetres on the scale when the mirror is at a distance of one metre from the scale, and when a known fraction of an ampere, say a microampere, is passing through the galvanometer. In the movable coil instruments a current passes through the light suspended coil of wire, the current entering and leaving the coil by a fine suspension wire, generally composed of phosphor-bronze. This coil is placed in the field of a strong permanent magnet, so arranged that the direction of the plane of the coil is parallel to the lines of flux of the field. The coil thus stands in a very intense field; and if a feeble current is passed through it, a couple is brought into operation, tending to twist it round so that its plane becomes inclined to the field. A small movement of the coil can be detected by attaching to it a mirror, and reflecting therefrom a ray of light upon a scale. Of this type are the galvanometers now much used in electrical laboratories. One great advantage possessed by them is that they are not disturbed by the presence of electric currents in neighbouring conductors. By winding the coil on a silver frame the galvanometer can be made very *dead-beat*; that is to say, the galvanometer coil will come to rest very quickly after being disturbed, without executing many oscillations. For many purposes a galvanometer is required which possesses exactly an opposite character, that is to say, as little *dead-beat* as possible. A *ballistic* galvanometer, as such an instrument is termed, is employed for the purpose of measuring, not current, but the time-integral of current. The value of a galvanometer for practical purposes is determined by the degree to which it possesses the following qualities:—(1) The deflection of the coil or needle should be in some constant relation to the current causing it. In mirror instruments it is generally found that, over the limits of scale-length usually employed, the scale deflection is proportional to the current flowing through the instrument. The number by which the scale deflection must be multiplied to obtain the ampere value of the current is called the *galvanometer constant*. (2) The galvanometer should possess a zero-keeping quality; that is to say, when a known current is flowing through it, the galvanometer coil or needle should always take up precisely the same position. (3) For many purposes it is convenient that the value of the galvanometer constant should be capable of being varied by altering the nature of the control. In needle instruments the control generally consists of an external magnet, the proximity of which to the needle determines the magnitude of the control.

A large class of current measuring and detecting instruments depend for their operation on the fact that a mass of ferromagnetic material, say soft iron, if placed in a magnetic field of variable strength, tends to move from places of weak to places of strong magnetic force. If the ferromagnetic material has an elongated shape like a needle, and if it is placed in a uniform field, the direction of the field being inclined to the direction of the longer axis of the needle, then the needle will tend to set its greatest length in the direction of the field. An instrument of this last kind is called a soft-iron needle galvanometer, and it may be made sufficiently sensitive to detect the feeble current through a telephone. A large number of commercial forms of amperemeter are constructed by taking advantage of the same fact. (See MEASURING INSTRUMENTS, ELECTRIC.) Thus if a circular coil of insulated wire of no very great depth is arranged with its plane in a vertical position, and if a small piece of soft iron attached to a pivoted index-needle is so arranged that under the action of gravity the piece of iron occupies a position near the centre of the coil, then when a current is sent through the coil the iron will be displaced to a position nearer the inner surface of the coil. This movement will bring into existence a restoring force due to gravity; hence if the index-needle is made to move over a divided scale, the instrument may be calibrated so as to show directly the value of the current passing through the coil. Another type of current-measuring instrument depends for its action upon the mechanical force discovered by Ampère to exist between conductors which are parallel, or nearly parallel, to each other, and are conveying the same or different electric currents. One of the best-known forms of instrument depending on this principle is the *Electrodynamometer* of Siemens.

Very convenient and accurate instruments based on the

[1] See W. G. Adams, The Bakerian Lecture "On the Forms of Equipotential Curves and Surfaces and Lines of Flow," *Proc. Roy. Soc. London*, 1872; also G. C. Foster and O. J. Lodge, "On the Flow of Electricity in a Uniform Plane-Conducting Circuit," *Phil. Mag.*, May and June 1875.

above principles have been devised by Lord Kelvin, and a large variety of these *ampere balances*, as they are called, suitable for measuring currents from a fraction of an ampere up to many thousands of amperes, have been constructed by that illustrious inventor.

Ampere balances.

The difficulty which has generally presented itself to those who have tried to design instruments on the electrodynamometer principle for use with large currents, has been that of getting the current into and out of the movable conductor, and yet permitting that conductor to remain free to move under very small force. The use of mercury cups is open to many objections on account of the fact that the mercury becomes oxidized, and such instruments are not very convenient for transportation. The great novelty in the ampere balances of Lord Kelvin was a joint or electric coupling, which is at once exceedingly flexible and yet capable of being constructed to carry with safety any desired current. This he achieved by the introduction of a device which is called a metallic ligament. The general principle of its construction is as follows:—Let + A – A

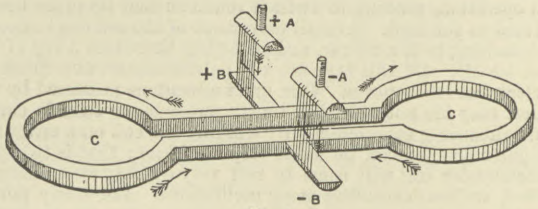


Fig. 4

(Fig. 4) be a pair of semi-cylindrical fixed trunnions which are carried on a supporting frame and held with flat sides downwards. Let + B – B be two smaller trunnions which project out from the sides of the two strips connecting together a pair of rings CC. The rings and the connecting strips constitute the circuit which is to be rendered movable. A current entering by the trunnion + B flows round the two halves of the circuit, as shown by the arrows, and comes out at the trunnion – B. In Fig. 4 the current is shown dividing round the two rings; but in all the balances, except those intended for the largest currents, the current really circulates first round one ring and then round the other. To make the ligament, a very large number of exceedingly fine copper wires laid close together are soldered to the upper surface of the upper trunnion, and also to the end surface of the lower trunnion. The movable circuit CC thus hangs by two ligaments which are formed of very fine copper wires. This mode of suspension enables

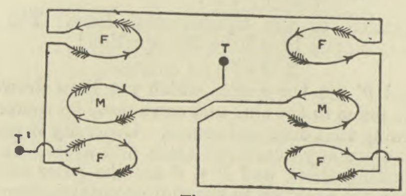


Fig. 5.

the conductor CC to vibrate freely like a balance, but at the same time very large currents can easily be passed through this perfectly flexible joint. Above and below these movable coils, which form as it were the two scale pans of a balance, are fixed other stationary coils, and the connexions of all these six coils (shown in Fig. 5) are such that when a current is passed through the whole of

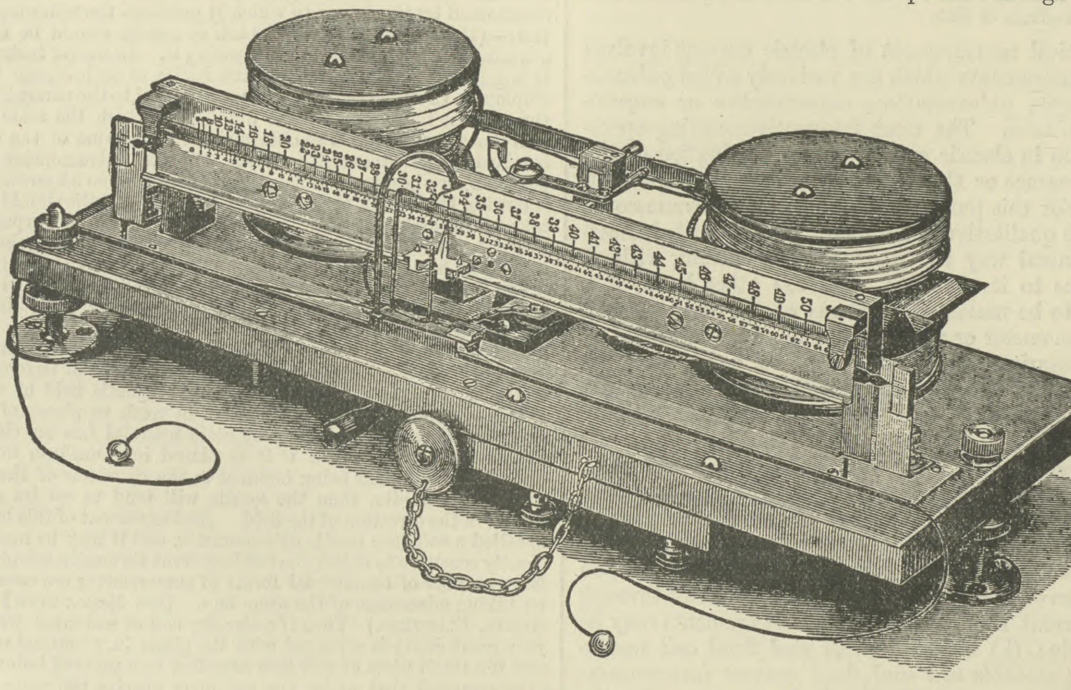


Fig. 6.

the coils in series, forces of attraction and repulsion are brought into existence which tend to force one movable coil upwards and the other movable coil downwards. This tendency is resisted by the weight of a mass of metal, which can be caused to slide along a tray attached to the movable coils. The appearance of the complete instrument is shown by Fig. 6. When a current is passed through the instrument it causes one end of the movable system to tilt downwards, and the other end upwards; the sliding weight is then moved along the tray by means of a silk cord until equilibrium is again established. The value of the current in amperes is then obtained approximately by observing the position of the weight on the scale, or it may be obtained more accurately in the following manner:—The upper edge of the shelf on which the weights slide (see Fig. 7) is graduated into equal divisions, and the weight is provided with a sharp tongue of metal in order that its position on the shelf may be accurately determined. Since the current passing through the balance when equilibrium is obtained with a given weight is proportional to the square root of the couple due to this weight, it follows that the current strength when equilibrium is obtained is

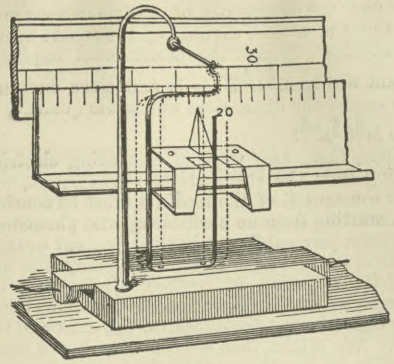


Fig 7.

proportional to the product of the square root of the weight used and the square root of the *displacement* distance of this weight from its zero position. Each instrument is accompanied by a pair of weights and by a square-root table, so that the product of the square root of the number corresponding to the position of the sliding weight, and a certain constant for each weight, gives at once the value of the current in amperes.

These balances are made to cover a certain range of reading, thus:—

The centi-ampere balance ranges from 1 to 100 centi-amperes.
The deci-ampere balance ranges from 1 to 100 deci-amperes.
The ampere balance ranges from 1 to 100 amperes.
The deka-ampere balance ranges from 1 to 100 amperes.
The hecto-ampere balance ranges from 6 to 600 amperes.
The kilo-ampere balance ranges from 100 to 2500 amperes.

They are valuable for the measurement not only of continuous or unvarying, but also of alternating currents. In those intended for alternating currents the main current through the movable coil, whether consisting of one turn or more than one turn, is carried by a wire rope, of which each component strand is insulated by silk covering, to prevent the inductive action from altering the distribution of the current across the transverse section of the conductor. To avoid the creation of induced currents, the coil frames and the base boards are constructed of slate. Kelvin ampere balances are now made in two types—(1) a variable weight type suitable for obtaining the ampere value of any current within their range; and (2) a fixed weight type intended to indicate when a current which can be varied at pleasure has a certain fixed value. An instrument of the latter type of considerable accuracy was designed by Lord Kelvin for the British Board of Trade Electrical Laboratory, and it is there used as the principal standard ampere balance. A fixed weight is placed on one coil and the current is varied gradually until the balance is just in equilibrium. Under these circumstances the current is known to have a fixed value in amperes determined by the weight attached to the instrument. For the measurement of alternating currents, instruments containing soft iron or permanent magnets are not available, and the only forms that can then be employed are those the indications of which do not depend upon the direction of the current, such as the electrodynamometer instruments or ampere balances just described. There are, however, a number of instruments in use for measuring alternating currents in which the heating action of a current is utilized. If a fine wire is traversed by a current either alternating or continuous, heat is generated in it at a rate depending upon the square of the current strength. If the wire is contained in an enclosure which can radiate back to it, the temperature of the wire when it is traversed by a constant current will gradually rise until it reaches a point at which the rate of radiation of heat from the wire is balanced by the rate of generation of heat in it. Under these circumstances the wire expands until it reaches a constant state, and the elongation in its length, being dependent upon its temperature, may be made a measure of the R.M.S. value of the current flowing in the wire. This elongation may be ascertained either by a multiplying arrangement which measures the actual linear elongation, or the two ends of the wire may be fixed, and we may in some way measure the *sag* of the wire as it is heated. Convenient instruments of the latter class have been devised and made by Messrs Hartmann & Braun, and are of considerable use in the laboratory for the measurement of alternating currents. The well-known Cardew voltmeter is an instrument of this type. For the measurement of continuous currents over any range, no instrument is more convenient than that called the Potentiometer.

For further details as to current measurement the reader is referred to the article on MEASURING INSTRUMENTS, ELECTRIC; and for additional information the following treatises may be consulted:—CLERK MAXWELL. *Electricity and Magnetism*, 2 vols. Oxford, 1881.—MASCART and JOUBERT. *Electricity and Magnetism*, translated by E. Atkinson. London, 1883.—J. A. FLEMING. *Handbook for the Electrical Testing Room and Laboratory.* London, 1901—A. GRAY. *Absolute Measurements in Electricity and Magnetism.* London, 1893.—T. H. BLAKESLEY. *Alternating Currents of Electricity.* London, 1889.—F. BEDELL and A. C. CREHORE. *Alternating Currents.* New York, 1893.—R. M. WALMSLEY. *The Electric Current.* London, 1894.—OLIVER HEAVISIDE. *Electromagnetic Theory.* London, 1893.—W. FISHER. *The Potentiometer.* London, 1897.—W. E. AYRTON. *Practical Electricity.* London, 1890.—S. P. THOMPSON. *Polyphase Electric Currents.* 2nd ed. London, 1900. (J. A. F.)

IV. ELECTRIC UNITS.

In order that our acquaintance with any part of Nature may become exact, we must have not merely a qualitative but a quantitative knowledge of facts. Hence the moment that any branch of science emerges from an early stage, attempts are made to measure and evaluate the quantities and effects found to exist. To do this we have to select for each measurable magnitude a *Unit* or standard sample of each quantity, by comparison with which amounts of other like quantities may be numerically defined. There is nothing to prevent us from selecting these standard samples in a perfectly arbitrary and independent manner, and as a matter of fact this is what is generally done in the early stages of every science. The progress of knowledge, however, is greatly assisted if all the measurable quantities are brought into relation with each other by so selecting the units that they are related in the most simple manner, each to the other and to one common set of measurable magnitudes, called the *fundamental quantities.* The progress of this unification of units has been greatly aided by the discovery that forms of physical energy can be converted into one another, and that the conversion is by definite rule and amount. Thus the mechanical energy associated with moving masses can be converted into heat, and the amount of heat required to raise one gramme of water 1° C. in the neighbourhood of 10° C. is equal to forty-two million ergs, the erg being the energy of motion associated with a mass of 2 grammes when moving uniformly without rotation with a velocity of 1 cm. per second. This number is commonly called the mechanical equivalent of heat, but would be more exactly described as the mechanical equivalent of the specific heat of water at 10° C. Again, the fact that the maintenance of an electric current requires energy, and that when produced its energy can be wholly utilized in heating a mass of water, enables us to make a similar statement about the energy required to maintain a current of one ampere through a resistance of one ohm for one second, expressed in its equivalent in the energy of a moving mass. Electric and magnetic units have therefore been selected with the object of establishing simple relations between each of them and the fundamental mechanical units. Electric and magnetic measurements based on such relations are called *Absolute Measurements.* The science of dynamics, as far as that part of it is concerned which deals with the motion and energy of material substances, is based upon certain fundamental definitions concerning the measurable quantities involved. In constructing a system of electric and magnetic units, the first thing to consider is the manner in which we shall connect the system with our dynamical measurements. What, for instance, shall be the unit of electric quantity, and how shall it be determined by simple reference to mechanical units, and, therefore, to units of mass, length, and time? The unit of electric charge may be defined as that charge which if collected on a small conductor repels an equally charged conductor at a unit of distance with the unit of force, and this definition was in fact one of the original starting-points of the Committee of the British Association on Electrical Units. It is well known, however, that the mechanical stress between two electrified bodies depends also upon, and varies inversely as, the Dielectric Constant or Specific Inductive Capacity K of the medium in which they are immersed. Hence unless we take this fact into account, our statement is imperfect; and unless we know the manner in which the mechanical stress is produced and the mechanical details of the operation, we are unable to express the whole of the facts by dynamical statements. The Committee of the British Association evaded this difficulty by omitting all reference to the medium in which the electric operations take place, and thereby they introduced a subsequent difficulty.

If for the moment we neglect all questions of the medium, and regard the mechanical stress between two small electrified conductors merely as a case of action-at-a-distance, then we can obtain the *dimensions* of electrical quantity from the fact discovered by Coulomb, that the mechanical stress between such small bodies varies directly as the product of the electric charge on each, and inversely as the square of their distance (see *Ency. Brit.* vol. vii. p. 241). Hence it follows that if the charges are equal, the dimensions of electrical quantity must be the same as those of a length multiplied by the square root of a force; in other words, they are $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}$. It has been pointed out, however, by Professor A. W. Rücker (*Phil. Mag.*, February 1889), that we have no right to omit in these dimensional expressions all reference to the qualities of the medium, which are determining factors in the production of the forces; and that in the absence of any exact knowledge as to the true dynamical nature of the operations concerned in electrostatic phenomena, we should treat the Dielectric Constant of the medium in which the operations take place as a fundamental quantity of dimensions as yet unknown, thus introducing into the dimensional equations a quantity K not yet resolved into its equivalent in terms of mass, length, and time. If, then, we take into account this dielectric constant, the dimensions of electric quantity are expressible in terms of length, mass, time, and dielectric constant by the symbol $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}K^{\frac{1}{2}}$. If a conductor is charged with a certain quantity of electricity represented by Q which is discharged through another conductor n times per second, this in effect constitutes an electric current which would be represented in magnitude by the product nQ. In other words, the strength of a current is measured by quantity per second passing any section of the circuit. It follows, therefore, that on the above system of electrical measurement the dimensions of electric current must be those of electric quantity per second; in other words, must be represented by the dimensional expression $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}K^{\frac{1}{2}}$. There is, however, another way of approaching the subject. If we consider two linear conductors parallel to one another conveying the same electric current, we know there is an attractive force between them which is proportional to the square of the strength of the current, and inversely proportional to the magnetic permeability μ of the medium in which the conductors are placed. From this point of view the dimensions of electric current must be those of the square root of a force divided by the square root of a magnetic permeability. Hence the dimensional expression for an electric current will be $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}\mu^{-\frac{1}{2}}$, and since electric current is quantity per second the dimensions of electric quantity of measurement will be $M^{\frac{1}{2}}L^{\frac{1}{2}}\mu^{-\frac{1}{2}}$.

We have here, then, two ways of measuring electric quantity; in one, starting from the electrostatic phenomenon, we find that the dielectric constant K of the medium must be considered, while in the other, starting from an electromagnetic phenomenon, we see that the magnetic permeability μ is an important quantity. If we fully understood the structure of the electromagnetic medium, and the mode of its operation in creating electrostatic and electromagnetic effects, we might determine the dynamical nature of its two qualities denominated the dielectric constant and the magnetic permeability. We might then express K and μ in terms of L, M, and T, the units of length, mass, and time, and we should arrive at the same dimensional expressions in both cases; for it is obvious that if the nature of the dynamical machinery involved were thoroughly understood, the dimensions of an electric current or electric quantity would be the same, whatever be the point of view from which we start, or whatever facts we make the basis of our determination of the dimensional expression. As it is, however, being ignorant of the real mechanical nature of the medium, we have two systems of measurement: one called the *electrostatic*, and the other called the *electromagnetic*.

It was formerly the custom to ignore the presence of the quantities K and μ, and to express the dimensions of electric and magnetic quantities on the electrostatic system by assuming that K on the electrostatic system, and μ on the electromagnetic system, was always unity. If, however, we insert the symbols K and μ to stand for the unknown dimensions of the dielectric constant and the magnetic permeability, we can obtain two dimensional expressions for an electric current; and the ratio of the dimensions of electric quantity or electric current on the electrostatic system to the dimensions on the electromagnetic system is that of $LT^{-1}K^{\frac{1}{2}}\mu^{\frac{1}{2}}$; hence $K^{\frac{1}{2}-}\mu^{-\frac{1}{2}}$ must be of the dimensions of a velocity. Accordingly, it appears that although we do not know the dimensions of K and μ independently in terms of length, mass, and time, we do know that their product is of the dimensions of the reciprocal of the square of a velocity.

Turning now to another point, we may consider the dimensions of a magnetic pole strength on the two systems. If two uniformly magnetized filaments of equal strength and great length have their poles brought close to one another, it is known, in accordance with Coulomb's experiments, that the mechanical stress or force between the poles is proportional to the product of their strengths, and varies inversely as the square of the distance between them. It is also known to be inversely proportional to the magnetic permeability of the medium in which the poles are placed. Hence, if the poles are of equal strength, it follows that the dimensions of polar strength on the electromagnetic system of measurement must be $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}\mu^{-\frac{1}{2}}$ where μ stands for the unknown dimensions of magnetic permeability. If a magnetic pole is carried round a current, it can be shown that the mechanical work done in taking the pole once round the conductor, conveying the current against the direction of the magnetic force due to the current, is $4\pi Cm$. Hence the dimensions of the quantity $4\pi Cm$, where C stands for the total current and m for the strength of the magnetic pole, must be those of energy or work, namely, $ML^{2}T^{-2}$. Accordingly, the dimensions of a magnetic pole strength in electrostatic measure must be those of work divided by those of current in electrostatic measure, or $ML^{2}T^{-2} \div M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-2}K^{\frac{1}{2}} = M^{\frac{1}{2}}L^{\frac{1}{2}}K^{-\frac{1}{2}}$. Hence the ratio of a magnetic pole strength in electrostatic measure to that in electromagnetic measure must be $M^{\frac{1}{2}}L^{\frac{1}{2}}K^{-\frac{1}{2}} \div M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}\mu^{\frac{1}{2}} = L^{-1}TK^{-\frac{1}{2}}\mu^{-\frac{1}{2}}$, and this ratio we see to be that of $K^{\frac{1}{2}}\mu^{\frac{1}{2}}$ to the reciprocal of a velocity, or of $K\mu$ to the reciprocal of the square of a velocity.

Again, we may arrive at two dimensional expressions for electromotive force or difference of potential. Electrostatic difference of potential between two places is measured by the mechanical work required to move a small conductor charged with a unit electric charge from one place to the other against the electric force. Hence if V stands for the difference of potential between the two places, and Q for the charge on the small conductor, the product QV must be of the dimensions of the *work* or *energy*, or of the force × length, or of $ML^{2}T^{-2}$. But Q on the electrostatic system of measurement is of the dimensions $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}K^{\frac{1}{2}}$; the potential difference V must be therefore of the dimensions $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}}$. Again, since by Ohm's Law and Joule's Law electromotive force multiplied by a current is equal to the power expended on a circuit, the dimensions of electromotive force, or, what is the same thing, of potential difference, in the electromagnetic system of measurement must be those of power divided by a current. Since mechanical power means *rate of doing work*, the dimensions of power must be ML^2T^{-3}. We have already seen that on the electromagnetic system the dimensions of a current are $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}\mu^{-\frac{1}{2}}$; therefore the dimensions of electromotive force or potential on the electromagnetic system must be $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}\mu^{\frac{1}{2}}$. Here again we find that the ratio of the dimensions on the electrostatic system to the dimensions on the electromagnetic system is $L^{-1}TK^{-\frac{1}{2}}\mu^{-\frac{1}{2}}$.

In the same manner we may recover from fundamental facts and relations the dimensions of every electric and magnetic quantity on the two systems, starting in one case from electrostatic phenomena and in the other case from electromagnetic or magnetic. The electrostatic dimensional expression will always involve K, and the electromagnetic dimensional expression will always involve μ, and in every case the dimensions in terms of K are to those in terms of μ for the same quantity in the ratio of a power of $LT^{-1}K^{\frac{1}{2}}\mu^{\frac{1}{2}}$. This therefore confirms the view that whatever may be the true dimensions in terms of fundamental units of μ and K, their product is the inverse square of a velocity.

The following table gives the dimensions of all the principal electric and magnetic quantities on the electrostatic and electromagnetic systems:—

TABLE XV. *Dimensions of Electric Quantities.*

Quantity.	Symbol.	Dimensions on the Electrostatic System E.S.	Dimensions on the Electromagnetic System E.M.	Ratio of E.S. to E.M.
Magnetic Permeability	(μ)	$L^{-2}T^{2}K^{-1}$	μ	$L^{-2}T^{2}K^{-1}\mu^{-1}$
Magnetic Force or Field	(H)	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-2}K^{\frac{1}{2}}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}\mu^{-\frac{1}{2}}$	$L\,T^{-1}K^{\frac{1}{2}}\mu^{\frac{1}{2}}$
Magnetic Flux Density or Induction	(B)	$L^{-\frac{3}{2}}M^{\frac{1}{2}}K^{-\frac{1}{2}}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}\mu^{\frac{1}{2}}$	$L^{-1}T\,K^{-\frac{1}{2}}\mu^{-\frac{1}{2}}$
Total Magnetic Flux	(Z)	$L^{\frac{1}{2}}M^{\frac{1}{2}}K^{-\frac{1}{2}}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-1}\mu^{\frac{1}{2}}$	$L^{-1}T\,K^{-\frac{1}{2}}\mu^{-\frac{1}{2}}$
Magnetization	(I)	$L^{-\frac{3}{2}}M^{\frac{1}{2}}K^{-\frac{1}{2}}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}\mu^{\frac{1}{2}}$	$L^{-1}T\,K^{-\frac{1}{2}}\mu^{\frac{1}{2}}$
Magnetic Pole Strength	(m)	$L^{\frac{1}{2}}M^{\frac{1}{2}}K^{-\frac{1}{2}}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-1}\mu^{\frac{1}{2}}$	$L^{-1}T\,K^{-\frac{1}{2}}\mu^{-\frac{1}{2}}$
Magnetic Moment	(M)	$L^{\frac{3}{2}}M^{\frac{1}{2}}K^{-\frac{1}{2}}$	$L^{\frac{5}{2}}M^{\frac{1}{2}}T^{-1}\mu^{\frac{1}{2}}$	$L^{-1}T\,K^{-\frac{1}{2}}\mu^{-\frac{1}{2}}$
Magnetic Potential or Magnetomotive Force	(M.M.F.)	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}K^{\frac{1}{2}}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}\mu^{-\frac{1}{2}}$	$L\,T^{-1}K^{\frac{1}{2}}\mu^{\frac{1}{2}}$
Specific Inductive Capacity	(K)	K	$L^{-2}T^{2}\mu^{-1}$	$L^{2}T^{-2}K\,\mu$
Electric Force	(e)	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-2}\mu^{\frac{1}{2}}$	$L^{-1}T\,K^{-\frac{1}{2}}\mu^{-\frac{1}{2}}$
Electric Displacement	(D)	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}K^{\frac{1}{2}}$	$L^{-\frac{3}{2}}M^{\frac{1}{2}}\mu^{-\frac{1}{2}}$	$L\,T^{-1}K^{\frac{1}{2}}\mu^{\frac{1}{2}}$
Electric Quantity	(Q)	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-1}K^{\frac{1}{2}}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}\mu^{-\frac{1}{2}}$	$L\,T^{-1}K^{\frac{1}{2}}\mu^{\frac{1}{2}}$
Electric Current	(A)	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}K^{\frac{1}{2}}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}\mu^{-\frac{1}{2}}$	$L\,T^{-1}K^{\frac{1}{2}}\mu^{\frac{1}{2}}$
Electric Potential / Electromotive Force	(V) / (E.M.F.)	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}\mu^{\frac{1}{2}}$	$L^{-1}T\,K^{-\frac{1}{2}}\mu^{-\frac{1}{2}}$
Electric Resistance	(R)	$L^{-1}T\,K^{-1}$	$L\,T^{-1}\mu$	$L^{-2}T^{2}K^{-1}\mu^{-1}$
Electric Capacity	(C)	$L\,K$	$L^{-1}T^{2}\mu^{-1}$	$L^{2}T^{-2}K\,\mu$
Self Inductance / Mutual Inductance	(L) / (M)	$L^{-1}T^{2}K^{-1}$	$L\,\mu$	$L^{-2}T^{2}K^{-1}\mu^{-1}$

It will be seen that in every case the ratio of the dimensions on the two systems is a power of $LT^{-1}K^{\frac{1}{2}}\mu^{\frac{1}{2}}$, or of a velocity multiplied by the square root of the product K and μ; in other words, it is the product of a velocity multiplied by the geometric mean of K and μ. This quantity $1/\sqrt{K\mu}$ must therefore be of the dimensions of a velocity, and the questions arise, what is the absolute value of this velocity? and how is it to be determined? The answer is, that the value of the velocity in concrete numbers may be obtained by measuring the magnitude of any electric quantity in two ways, one making use only of electrostatic phenomena, and the other only of electromagnetic. To take one instance:—It is easy to show that the electrostatic capacity of a sphere suspended in air or in vacuo at a great distance from other conductors is given by a number equal to its radius in centimetres. Suppose such a sphere to be charged and discharged rapidly with electricity from any source, such as a battery. It would take electricity from the source at a certain rate, and would in fact act like a resistance in permitting the passage through it or by it of a certain quantity of electricity per unit of time. If K is the capacity and n is the number of discharges per second, then nK is a quantity of the dimensions of an electric conductivity, or of the reciprocal of a resistance. If a conductor, of which the electrostatic capacity can be calculated, and which has associated with it a commutator that charges and discharges it n times per second, is arranged in one branch of a Wheatstone's Bridge, it can be treated and measured as if it were a resistance, and its equivalent resistance calculated in terms of the resistance of all the other branches of the bridge. (See *Phil. Mag.*, Sept. 1885, vol. xx. p. 258.)

Accordingly we have two methods of measuring the capacity of a conductor. One, the electrostatic method, depends only on the measurement of a length, which in the case of a sphere in free space is its radius; the other, the electromagnetic method, determines the capacity in terms of the quotient of a time by a resistance. The ratio of the electrostatic to the electromagnetic value of the same capacity is therefore of the dimensions of a velocity multiplied by a resistance in electromagnetic value, or of the dimensions of a velocity squared. This particular experimental measurement has been carried out carefully by many observers, and the result has been always to show that the velocity v which expresses the ratio is very nearly equal to 30 thousand million centimetres per second; v = nearly 3×10^{10}. The value of this important constant can be determined by experiments made to measure electric quantity, potential, resistance, or capacity, both in electrostatic and in electromagnetic measure. For details of the various methods employed, the reader must be referred to standard treatises on Electricity and Magnetism, where full particulars will be found. (See Maxwell, *Treatise on Electricity and Magnetism*, vol. ii. ch. xix., 2nd ed.; also Mascart and Joubert, *Treatise on Electricity and Magnetism*, vol. ii. ch. viii, Eng. trans. by Atkinson.)

The following table gives a list of most of the determinations of v yet made, with references to the original papers.

TABLE XVI. *Table of Observed Values of 'v' in Centimetres per Second.*

Date.	Name.	Reference.	Electric Quantity Measured.	'v' in Centimetres per Second.
1856	Weber and Kohlrausch	*Electrodynamische Maasbestimmungen* and *Pogg. Ann.* xcix., August 10, 1856	Quantity	$3{\cdot}107 \times 10^{10}$
1867 / 1868	Lord Kelvin and W. F. King	*Report of British Assoc.*, 1869, p. 434; and *Reports on Electrical Standards*, F. Jenkin, p. 186	Potential	$2{\cdot}81 \times 10^{10}$
1868	Clerk Maxwell .	*Phil. Trans. Roy. Soc.*, 1868, p. 643	,,	$2{\cdot}84 \times 10^{10}$
1872	Lord Kelvin and Dugald M'Kichan	*Phil. Trans. Roy. Soc.*, 1873, p. 409	,,	$2{\cdot}89 \times 10^{10}$
1878	Ayrton and Perry	*Journ. Soc. Tel. Eng.* vol. viii. p. 126	Capacity	$2{\cdot}94 \times 10^{10}$
1880	Lord Kelvin and Shida	*Phil. Mag.* vol. x. p. 431, 1880	Potential	$2{\cdot}955 \times 10^{10}$
1881	Stoltow . .	*Soc. Franc. de Phys.*, 1881	Capacity	$2{\cdot}99 \times 10^{10}$
1882	F. Exner .	*Wien. Ber.*, 1882	Potential	$2{\cdot}92 \times 10^{10}$
1883	J. J. Thomson .	*Phil. Trans. Roy. Soc.*, 1883, p. 707	Capacity	$2{\cdot}963 \times 10^{10}$
1884	Klemencic .	*Proc. Soc. of Tel. Eng.*, 1887, p. 162	,,	$3{\cdot}019 \times 10^{10}$
1888	Himstedt .	*Electrician*, Mar. 23, 1888, vol. xx. p. 530	,,	$3{\cdot}007 \times 10^{10}$
1888	Lord Kelvin, Ayrton, and Perry	*British Association*, Bath; and *Electrician*, Sept. 28, 1888	Potential	$2{\cdot}92 \times 10^{10}$
1888	Fison . . .	*Electrician*, vol. xxi. p. 215; and *Proc. Phys. Soc. Lond.*, June 9, 1888	Capacity	$2{\cdot}965 \times 10^{10}$
1889	Lord Kelvin .	*Proc. Roy. Inst.*, 1889	Potential	$3{\cdot}004 \times 10^{10}$
1889	Rowland .	*Phil. Mag.*, 1889	Quantity	$2{\cdot}981 \times 10^{10}$
1889	E. B. Rosa .	*Phil. Mag.*, 1889	Capacity	$3{\cdot}000 \times 10^{10}$
1890	J. J. Thomson and Searle	*Phil. Trans.*, 1890	,,	$2{\cdot}995 \times 10^{10}$
1897	M. E. Maltby .	*Wied. Ann.*, 1897	Alternating currents	$3{\cdot}015 \times 10^{10}$

It will be seen that all the most recent values, especially those in which a comparison of capacity has been made, approximate to 3×10^{10} centimetres per second, a value which is closely in accord with the latest and best determinations of the velocity of light.

We have in the next place to consider the question of practical electric units and the determination and construction of practical standards. The Committee of the British Association charged with the duty of arranging a system of absolute and magnetic units settled also on a system of practical units of convenient magnitude, and gave names to them as follows:—

Practical units.

10^9	Absolute Electromagnetic	Units of Resistance	=	1 Ohm
10^8	,, ,,	Units of Electromotive force	=	1 Volt
$\frac{1}{10}$th of an	,, ,,	Unit of Current	=	1 Ampere
$\frac{1}{10}$th of an	,, ,,	Unit of Quantity	=	1 Coulomb
10^{-9}	,, ,,	Units of Capacity	=	1 Farad
10^{-15}	,, ,,	Units of Capacity	=	1 Microfarad

Since the date when the preceding terms were adopted, other multiples of absolute C.G.S. Units have received practical names, thus:—

10^7	Ergs or Absolute C.G.S. Units of Energy	=	1 Joule
10^7	Ergs per second or C.G.S. Units of Power	=	1 Watt
10^9	Absolute Units of Inductance	=	1 Henry
10^8	Absolute Units of Magnetic Flux	=	1 Weber[1]
1	Absolute Unit of Magnetomotive Force	=	1 Gauss[1]

An Electrical Congress was held in Chicago, U.S.A., in August 1893, to consider the subject of International Practical Electrical Units, and the result of a conference between scientific representatives of Great Britain, the United States, France, Germany, Italy, Mexico, Austria, Switzerland, Sweden, and British North America, after deliberation for six days, was a unanimous agreement to recommend the following resolutions as the definition of Practical International Units. The resolutions have since that date been received and adopted by the Governments above mentioned:—

"*Resolved*, That the several Governments represented by the delegates of this International Congress of Electricians be, and they are hereby, recommended to formally adopt as legal units of electrical measure the following:—

"As a unit of resistance, the *International Ohm*, which is based upon the ohm equal to 10^9 units of resistance of the C.G.S. System of electromagnetic units, and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14·4521 grammes in mass, of a constant cross-sectional area and of the length of 106·3 cm.

"As a unit of current, the *International Ampere*, which is one-tenth of the unit of current of the C.G.S. System of electromagnetic units, and which is represented sufficiently well for practical use by the unvarying current which, when passed through a solution of nitrate of silver in water, deposits silver at the rate of 0·001118 of a gramme per second.

"As a unit of electromotive force, the *International Volt*, which is the electromotive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampere, and which is represented sufficiently well for practical use by $\frac{1000}{1434}$ of the electromotive force between the poles or electrodes of the voltaic cell known as Clark's Cell, at a temperature of 15° C., and prepared in the manner described in a certain specification.

"As a unit of quantity, the *International Coulomb*, which is the quantity of electricity transferred by a current of one international ampere in one second.

"As the unit of capacity, the *International Farad*, which is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.

"As a unit of work, the *Joule*, which is equal to 10^7 units of work in the C.G.S. System, and which is represented sufficiently well for practical use by the energy expended in one second by an international ampere in an international ohm.

"As a unit of power, the *Watt*, which is equal to 10^7 units of power in the C.G.S. System, and which is represented sufficiently well for practical use by the work done at the rate of one joule per second.

"As the unit of inductance, the *Henry*, which is the induction in a circuit when an electromotive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampere per second."

It can hardly be said that the present system of practical units is entirely satisfactory in all respects. Great difficulty would of course be experienced in again altering the accepted units, but if at any future time a reformation should be possible, it would be desirable to bear in mind the recommendations made by Mr Oliver Heaviside with regard to their rationalization. The British Association Committee defined the strength of a magnetic pole by reference to the mechanical stress between it and another equal pole: hence the British Association unit magnetic pole is a pole which at a distance of one centimetre attracts or repels another equal pole with a force of one dyne. This, we have seen, is an imperfect definition, because it omits all reference to the permeability of the medium in which the experiment takes place; but it is also unsatisfactory as a starting-point for a system of units for another reason. The important quantity in connexion with polar magnets is not a mechanical stress between the free poles of different magnets, but the magnetic flux emanating from, or associating with, them. From a technical point of view this latter quality is far more important than the mechanical stress between the magnetic poles, because we mostly employ magnets to create induced electromotive force, and the quantity we are then mostly concerned with is the magnetic flux proceeding from the poles. Hence the most natural definition of a unit magnet pole is that pole from which proceeds a total magnetic flux of one unit. The definition of one unit of magnetic flux must then be that flux which, when inserted into or withdrawn from a conducting circuit of one turn having unit area and unit conductivity, creates in it a flow or circulation of one unit of electric quantity. The definition of a unit magnetic pole ought, therefore, to have been approached from the definition of a unit of electric quantity.

Rational units.

On the ordinary or British Association system, if a magnetic filament has a pole strength m,—that is to say, if it has a magnetization I, and a section s, such that Is equals m,—then it can be shown that the total flux emanating from the pole is $4\pi m$. The factor 4π, in consequence of this definition, makes its appearance in many practically important expressions. For instance, in the well-known magnetic equation connecting the vector values of magnetization I, magnetic force H, and magnetic flux density B, where we have the equation

$$B = H + 4\pi I,$$

the appearance of the quantity 4π disguises the real physical meaning of the equation.

The true remedy for this difficulty has been suggested by Heaviside to be the substitution of *rational* for *irrational* formulæ and definitions. He proposes to restate the definition of a unit magnetic pole in such a manner as to remove this constant 4π from the most frequently employed equations. His starting-point is a new definition according to which a unit magnetic pole is said to have a strength of m units if it attracts or repels another equal pole placed at a distance of d centimetres with a force of $\frac{m^2}{4\pi d^2}$ dynes. It follows from this definition that a rational unit magnetic pole is weaker or smaller than the irrational or British Association unit pole in the ratio of $1/\sqrt{4\pi}$ to 1, or ·28205 to 1. The magnetic force due to a rational pole of strength m at a distance of d centimetres being $\frac{m}{4\pi d^2}$ units, if we suppose a magnetic filament having a pole of strength m in rational units to have a smaller sphere of radius r described round its pole, the magnetic force on the surface of this sphere is $m/4\pi r^2$ units, and this is therefore also the numerical value of the flux density. Hence the total magnetic flux through the surface of the sphere is

$$4\pi r^2 \times \frac{m}{4\pi r^2} \text{ units} = m \text{ units};$$

and therefore the number which denotes the total magnetic flux coming out of the pole of strength m in rational units is also m.

[1] Neither the Weber nor the Gauss has received very general adoption, although recommended by the Committee of the British Association on Electrical Units. Many different suggestions have been made as to the meaning to be applied to the word "Gauss." The practical electrical engineer, up to the present, prefers to use *one ampere-turn* as his unit of Magnetomotive Force, and *one line of force* as the unit of Magnetic Flux, equal respectively to $10/4\pi$ times and 1 times the C.G.S. absolute units.

The rational system thus gives us an obvious and natural definition of a unit magnetic pole, namely, that it is a pole through which proceeds the unit of magnetic flux. It follows, therefore, that if the intensity of magnetization of the magnetic filament is I and the section is *s*, the total flux traversing the centre of the magnet is I*s* units; and that if the filament is an endless or poleless iron filament magnetized uniformly by a resultant external magnetic force H, the flux density will be expressed in rational units by the equation $B = I + H$. The physical meaning of this equation is that the flux per square centimetre in the iron is simply obtained by adding together the flux per square centimetre, if the iron is supposed to be removed, and the magnetization of the iron at that place. On the rational system, since the unit pole strength has been decreased in the ratio of I to $1/\sqrt{4\pi}$, or of 3·5441 to 1, when compared with the magnitude of the present irrational unit pole, and since the unit of magnetic flux is the total flux proceeding from a magnetic pole, it follows that Heaviside's unit of magnetic flux is larger than the C.G.S. unit of magnetic flux in the ratio of 3·5441 to 1.

It will be seen, therefore, that the Heaviside rational units are all incommensurable with the practical units. This is a great barrier to their adoption in practice, because it is impossible to discard all the existing resistance coils, ammeters, voltmeters, &c., and equally impossible to recalibrate or readjust them to read in Heaviside Units. Recently, however, a suggestion has been made, in modification of the Heaviside System, which would provide a system of rational practical units not impossible of adoption. It has been pointed out by J. A. Fleming that if in place of the ampere, ohm, watt, joule, farad, and coulomb, we employ the dekampere, dekohm, the dekawatt, the dekajoule, the dekafarad, and the dekacoulomb, we have a system of practical units such that measurements made in these units are equal to measurements made in Heaviside rational units when multiplied by some power of 4π. Moreover, he has shown that this power of 4π, in the case of most units, varies inversely as the power under which μ appears in the complete dimensional expression for the quantity in electromagnetic measurement. Thus a current measured in Heaviside rational units is numerically equal to $(4\pi)^{\frac{1}{2}}$ times the same current measured in dekamperes, and in the electromagnetic dimensional expression for current, namely, $L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}\mu^{-\frac{1}{2}}$, μ appears as $\mu^{-\frac{1}{2}}$. If, then, following the suggestion of Fessenden and Fleming, we consider the permeability of the æther to be numerically 4π instead of unity, the measurement of a current in dekamperes will be a number which is the same as that given by reckoning in Heaviside rational units. In this way a system of *Rational Practical Units* (R.P. Units) might be constructed as follows:—

The R.P.	Unit of	Magnetic Force $= 4\pi$	$\times$	the C.G.S.	Unit.
,,	,,	Magnetic Polarity $= 1/4\pi$	$\times$	,,	,,
,,	,,	Magnetic Flux	$=$	1	,,
,,	,,	Magnetomotive Force	$=$	1	,,
,,	,,	Electric Current	$=$	1	,,
,,	,,	Electric Quantity	$=$	1	,,
,,	,,	Electromotive Force	$=$	10^8	,,
,,	,,	Resistance	$=$	10^8	,,
,,	,,	Inductance	$=$	10^8	,,
,,	,,	Power	$=$	10^8	,,
,,	,,	Work	$=$	10^8	,,
,,	,,	Capacity	$=$	10^{-8}	,,

All except the Unit of Magnetic Force and Magnetic Polarity are commeasurable with the corresponding C.G.S. Units, and in multiples which form a convenient practical system.

Turning to the practical recovery of the International Electric Units, as generally accepted by the Chicago Electrical Conference, the most important matter is the realization of the International Ohm, which is intended as nearly as possible to realize in a concrete form 10^9 C.G.S. electromagnetic units of resistance. The old British Association Unit of electrical resistance (denoted by 1 B.A.U.) was found to be too small when compared with the theoretical ohm in the ratio of ·9866 to 1. In creating better standards, it has been decided to express it in terms of the resistance of a column of mercury of a certain length and weight, the reason being that mercury is a homogeneous liquid metal the density of which is very accurately known, and which is without much difficulty obtained in a state of very great chemical purity by distillation in a vacuum. Hence it is an easily recovered material, and observers in different parts of the world can be tolerably certain of obtaining specimens nearly identical in every respect. This is not the case with other solid metals, in the electric resistivity of which great differences may occur, even in chemically pure specimens (see I. ELECTRIC CONDUCTION). Hence the absolute determination of the ohm really resolves itself into a determination of the specific resistance of mercury or the volume resistivity in absolute C.G.S. units.

The full description of the different methods for determining electric quantities, and especially electric resistance, in absolute measure is given in Maxwell's *Treatise on Electricity and Magnetism*, vol. ii. ch. x; also in Mascart and Joubert's *Treatise on Electricity and Magnetism* (English translation by Atkinson), vol. ii. ch. ix. The relative advantages and disadvantages of the various methods which have been proposed for the determination of resistance in absolute measure are very fully discussed in the *Phil. Mag.*, November 1882, p. 329, by Lord Rayleigh, whose researches on this sub eet have been most extensive and profound. On the subject of Electric Units the reader may with advantage consult the following books and original papers for additional information:—

J. CLERK MAXWELL *Treatise on Electricity and Magnetism*, vol. ii. ch. x., 2nd ed. Oxford, 1881.—MASCART and JOUBERT. *Treatise on Electricity and Magnetism*, translated by E. Atkinson, vol. i. ch. ix. London, 1883.—J. D. EVERETT. *Illustrations of the C.G.S. System of Units.* London, 1891.—MAGNUS MACLEAN. *Physical Units.* London, 1896.—J. A. FLEMING. *Magnets and Electric Currents.* London, 1898.—H. J. CHANEY. *Our Weights and Measures.* London 1897.—F. JENKIN. *Reports on Electrical Standards.* London, 1873.—F. KERNETLER. *Die Unität des Absoluten Maass-Systems.* Budapest, 1899.—*The Report of the Committee on Electrical Units of the British Association for the Advancement of Science*, from 1862 to present date.—G. JOHNSTONE STONEY. "A Survey of that Part of the Range of Nature's Operations which Man is Competent to Study," *Phil. Mag.*, November 1899, vol. xlviii.—W. WILLIAMS. "On the Relation of the Dimensions of Physical Quantities to Directions in Space," *Phil. Mag.*, September 1892; also *Proc. Phys. Soc.*, June 1892.—A. W. RÜCKER. "On the Suppressed Dimensions of Physical Quantities," *Proc. Phys. Soc.* vol. x. p. 37.—W. E. AYRTON and J. V. JONES. ' Determination of the Ohm by a Lorentz Apparatus," *Electrician*, vol. xl. p. 151.—J. V. JONES. "Suggestions towards the Determination of the Ohm by Lorentz Apparatus," *Electrician*, vol. xxv. p. 552; "The Absolute Measurement of Electrical Resistance," *Proc. Roy. Inst.* vol. xiv. part iii. p. 601.—R. A. FESSENDEN. "A Determination of the Nature of the Electric and Magnetic Quantities," *Physical Review*, Jan. 1900.

(J. A. F.)

V. ELECTRIC DISCHARGE THROUGH GASES.

A gas in the normal state can conduct very little electricity unless the strength of the electric field to which it is exposed exceeds a certain value, which depends on the kind of gas and its pressure. It is, however, possible to bring by various means a gas into a state in which it conducts electricity under even the feeblest electric forces. As a study of the properties of gases when in this state throws a great deal of light on the processes by which conduction through gases in general is accomplished, we shall begin by considering the properties of a gas and the laws of electric conduction through it when it is in this conducting state.

§ 1. *Properties of a Gas in the Conducting State.*—Gases may be brought into this conducting state in many ways. Thus they conduct when exposed to Röntgen rays,[1] to the radiation from uranium,[2] thorium,[3] or the radio-active substances polonium, radium, and actinium, discovered by Curie, Curie and Bemont, and Debierne;[4] they become conductors by the passage through them of cathode rays,[5] of Lenard rays,[6] or the radiation emitted by electric sparks (E. Wiedemann's *Entladungstrahlen*).[7] They become conductors when in contact with glowing metal or carbon, and when their temperature is raised beyond a certain point. Gases drawn from the neighbourhood of flames and arcs are also good conductors, as are those which have diffused from a region through which an electric discharge is passing.[8] Air becomes a conductor by passing over phosphorus,[9] and retains the property for some little time after it has left the phosphorus. By whatever means the gas may have been made a conductor, when it has reached this state it possesses characteristic properties. In the first place, it does not lose its conductivity immediately after it is removed from the agency which made it a conductor; its conductivity, however, always diminishes, in some cases very rapidly, after the agent is removed, and finally disappears. Thus a gas exposed to Röntgen rays retains its conductivity for some little time after the rays have ceased to pass through it, and flame gases retain their conductivity for a considerable time after their removal from the flame. If, however, the conducting gas is filtered through a plug of tightly-packed glass wool or through water it loses its conductivity;[10] it also loses its conductivity slowly by being passed through metal tubes, and the finer the bore of the tube the more rapidly does the conductivity disappear. The conductivity also may be at once removed by making the gas traverse a strong electric field, and thus sending a current of electricity through it. The effect of filtering and of passage through metal tubes shows that the conductivity is due to something which is mixed with the gas, and that this something is removed from the gas in the one case by filtration, and in the other by diffusion to the sides of the tube. Again, the experiment with the electric field shows that this something is charged, and moves under the field, while since the gas when in the conducting state often shows as a whole no charge, the charges which move in the field must be both positive and negative. We thus regard the conductivity of the gas as due to the presence of electrified particles, some of these particles having positive charges, others negative. These particles we shall call *ions*, but they must not be assumed to be the same as the ions in the electrolysis of solutions. We shall see that in several cases we can determine the charge and masses of these gaseous ions. The process by which the gas is changed into a conductor we shall call the *ionization* of the gas.

In a gas made a conductor by any of the means we have described, the conductivity does not obey Ohm's law, except for very small electromotive forces. The relation between the current passing between two parallel metal plates immersed in such a gas and the potential difference between the plates is represented by a curve such as that shown in Fig. 8, in which the abscissæ represent the potential difference, and the ordinates the current.[11] We see that when the potential difference is small, the curve is straight; in this stage the conduction obeys Ohm's law, but the current soon begins to increase more slowly than the potential difference, until we reach a stage when there is no appreciable increase in the current however great the increase in the potential difference, provided the increase is not sufficient to make the electric field ionize the gas; when this stage is reached the current increases very rapidly with the strength of the field. There is thus, until the electric field ionizes the gas, a limiting value to the current which can be carried by the gas; this maximum value is often called the *saturation current*. The maximum current which can be obtained between two parallel plates of given area depends upon the amount of ionization between the plates; if the ionization is a volume ionization, the greater the distance between the plates the greater the value of the maximum current, so that if we use potential differences large enough to produce saturation, the thicker the layer of gas between the plates the greater the current —a result which would seem paradoxical on the ordinary resistance view of conduction, as here the resistance of a thick layer appears to be less than that of a thin one.

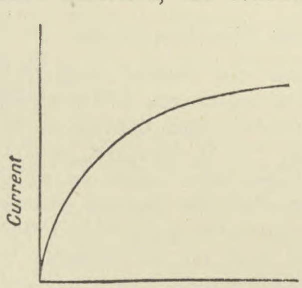


Fig. 8.

The limiting value of the current is very easily explained on the assumption that the conduction is due to ions. For suppose that in the gas between the plates the ionizing agent produces in one second q positive, and q negative ions, if a current c pass between the plates and if e is the charge on an ion, the number of positive ions delivered up at the negative electrode and of negative ions at the positive electrode is in one second c/e. Now when the gas is in a steady state the number of ions taken out of it in a given time cannot be greater than the number of ions produced in the same time; hence c/e cannot be greater than q—that is, the maximum value c is qe. If the ionization takes place uniformly throughout the gas, and if l is the distance between the plates, A the area of the plates, which are supposed to be equal and parallel, and q_0 the number of ions produced in unit volume, then $q=q_0\text{A}l$, so that the maximum value of c is $q_0\text{A}le$, and is thus proportional to the distance between the plates. Excellent examples of this law are afforded by conduction through gas ionized by Röntgen rays.[12] Even if there is no current through the gas to carry off the ions as they are produced, the ions do not increase indefinitely with the time which has elapsed since the gas was exposed to the ionizing agent; their number and the conductivity of the gas very soon acquire a steady value beyond which they do not increase if the rate of ionization remains constant. For the positive and negative ions moving about in the gas sometimes come into collision with each other, and in a certain proportion of these collisions they will remain united, forming a neutral particle, the constituents of which have ceased to be ions. Thus the collisions will cause a certain number of ions to disappear, and the steady state in a gas which is not carrying a current will be reached when the number of ions which disappear in a second from the effect of collisions is equal to the number produced in the same time by the ionizing agent. If q is the number of ions produced in one cubic centimetre of the gas per second by the ionizing agent, and n_1, n_2 the number of positive and negative ions respectively in a cubic centimetre, the number of collisions per second between the positive and negative ions will be proportional to n_1n_2. If we suppose that a certain fraction of the collisions lead to the formation of a neutral particle, then the number of ions which disappear in a second will be equal to αn_1n_2, when α is a quantity which is independent of n_1 and n_2; hence we have

$$\frac{dn_1}{dt}=q-\alpha n_1n_2,$$

$$\frac{dn_2}{dt}=q-\alpha n_1n_2,$$

n_1-n_2 remaining constant, so that if the gas is uncharged to begin with, n_1 always equals n_2. Putting $n_1=n_2$, we get

$$\frac{dn_1}{dt}=q-\alpha n_1^2 \quad . \quad . \quad . \quad . \quad (1).$$

When things have settled into a steady state, $dn_1/dt=0$, and hence by equation (1)

$$n_1=\sqrt{\frac{q}{\alpha}}.$$

Equation (1) may be used to calculate the rate at which the conductivity of the gas decays when the ionizing agent is removed, for putting in that equation $q=0$, we have

$$\frac{dn_1}{dt}=-\alpha n_1^2$$

or,

$$\frac{1}{n_1}-\frac{1}{\text{N}}=\alpha t \quad . \quad . \quad . \quad . \quad (2)$$

or,

$$n_1=\frac{\text{N}}{1+\text{N}\alpha t},$$

where N is the number of ions present when the ionization was stopped, and t the time which has elapsed since the stoppage. This equation has been verified in the case of a gas ionized by the Röntgen rays by Rutherford,[13] and in the case of the gases drawn from flames and arcs by M'Clelland,[14] who measured the quantity of electricity which could be carried by the gas at successive small intervals of time after the ionizing agent had ceased to act. For air, oxygen, carbonic acid, and hydrogen at atmospheric pressure and ionized by Röntgen rays, Townsend[15] found for α the values $3420e$, $3380e$, $3500e$, and $3020e$, where e is the charge on the ion in electrostatic measure; we shall see later that e is about 6×10^{-10}, so that for air, carbonic acid, and oxygen at atmospheric pressure α is about 2×10^{-6}, while for hydrogen it is about 15 per cent. less.

Thus an ion after being formed does not last for ever, nor does it on the other hand disappear instantaneously, but must be regarded as having a certain duration of life, the value of which on the average is seen by equation (2) to be $1/\alpha n$, where n is the number of ions per cubic centimetre of the gas. When the gas between a pair of parallel metal plates is carrying the maximum current, all the ions must reach the plates before they recombine; for this to happen, the velocity of the ions along the lines of electric force must be great enough to make the ion during its life move through a distance equal to the distance between the plates. If V is the velocity of the ion, T its life, and l the distance between the plates, the current will not have its maximum value unless V is greater than l/T; hence the greater the velocity of the ion under a given electromotive force, and the longer its life, the smaller will be the potential difference required to produce the limiting current through the gas. As the ionization produced by an agent like Röntgen rays diminishes as the pressure of the gas diminishes, the life of an ion at low pressure will be longer than at high, since n is smaller; again, the velocity of an ion under a given electromotive force increases as the pressure diminishes (see below). Both these effects tend to diminish the potential difference required to produce the limiting current, so that when the pressure is diminished the potential difference required to produce the maximum current diminishes more rapidly than the pressure. As another illustration of the effect of the life of the ion, let us take the case of a gas where the pressure is kept constant, but the distance between the parallel plates is varied; if we diminish the distance between the plates we increase in the same proportion the potential gradient due to a constant difference of potential. Now the velocity of an ion is proportional to the potential gradient (see below), while when the plates are nearer together the ions have not so far to travel to reach them; taking these effects together, we see that the potential difference required to produce the maximum current between two parallel plates will be proportional to the square of the distance between the plates.

§ 2. *Velocity of the Ions.*—The velocity with which the ions move under given electric forces are quantities of primary importance in the consideration of the passage of electricity through gases. They have been measured by Rutherford [16] and by Zeleny [17] for ions produced by Röntgen rays, by Rutherford [18] for the ions produced by uranium radiation and for the negative ions produced when ultra-violet light is incident on a metal plate; [19] H. A. Wilson [20] has measured the velocity of the ions produced by putting various salts into flames, M'Clelland [21] the velocity of the ions in gases sucked from the neighbourhood of flames and arcs, and Chattock [22] the velocity of the ions produced when electricity escapes from a sharp needle-point into a gas. Several methods have been employed to determine these velocities. The one most frequently employed is to find the electromotive intensity required to force an ion against a stream of gas moving with a known velocity parallel to the lines of electric force. Thus, of two perforated plane electrodes vertically over each other, suppose the lower to be positively, the upper negatively electrified, and suppose that the gas is streaming vertically downwards with the velocity V; then unless the upward velocity of the positive ion is greater than V, no positive electricity will reach the upper plate. If we increase the strength of the field between the plates, and hence the upward velocity of the positive ion, until the positive ions just begin to reach the upper plate, we know that with this strength of field the velocity of the positive ion is equal to V. By this method, which has been used by Rutherford, Zeleny, and H. A. Wilson, the velocity of ions in fields of various strengths has been determined.

The arrangement used by Zeleny is represented in Fig. 9. P and Q are square brass plates. They are bored through their centres, and to the openings the tubes R and S are attached, the space between the plates being covered in so as to form a closed box.

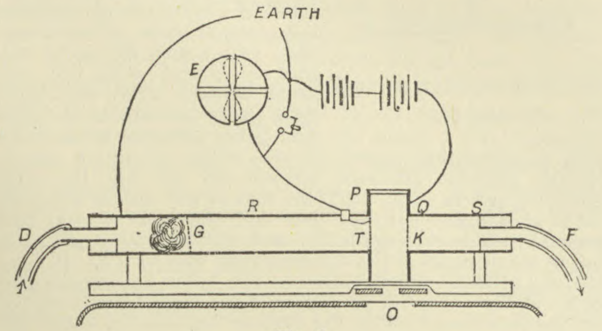


Fig. 9.

K is a piece of wire gauze completely covering the opening in Q; T is an insulated piece of wire gauze nearly but not quite filling the opening in the plate P, and connected with one pair of quadrants of an electrometer E. A plug of glass wool G filters out the dust from a stream of gas which enters the vessel by the tube D and leaves it by F; this plug also makes the velocity of the flow of the gas uniform across the section of the tube. The Röntgen rays to ionize the gas were produced by a bulb at O, the bulb and coil being in a lead-covered box, with an aluminium window through which the rays passed. Q is connected with one pole of a battery of cells, P and the other pole of the battery are put to earth. The changes in the potential of T are due to ions giving up their charges to it. With a given velocity of air-blast the potential of T was found not to change unless the difference of potential between P and Q exceeded a critical value. The field corresponding to this critical value thus made the ions move with the known velocity of the blast.

Another method which has been employed by Rutherford and M'Clelland is based on the action of an electric field in destroying the conductivity of gas streaming through it. Suppose that BAB, DCD (Fig. 10) are a system of parallel plates boxed in so that a stream of gas, after flowing between BB, passes between DD without any loss of gas in the interval. Suppose the plates DD are insulated, and connected with one pair of quadrants of an electrometer, by charging up C to a sufficiently high potential we can drive all the positive ions which enter the system DCD against the plates D; this will cause a deflexion of the electrometer, which in one second will be proportional to the number of positive ions which have entered the system in that time. If we charge A up to a high potential, B being put to earth, we shall find that the deflexion of the electrometer connected with DD is less than it was when A and B were at the same potential, because some of the positive ions in their passage through BAB are driven against the plates B. If u is the velocity along the lines of force in the uniform electric field between A and B, and t the time it takes for the gas to pass through BAB, then all the positive ions within a distance ut of the plates B will be driven up against these plates, and thus if the positive ions are equally distributed through the gas, the number of positive ions which emerge from the system when the electric field is on will bear to the number which emerge when the field is off the ratio of $1 - ut/l$ to unity, where l is the distance between A and B. This ratio is equal to the ratio of the deflexions in one second of the electrometer attached to D, hence the observations of this instrument give $1 - ut/l$. If we know the velocity of the gas and the length of the plates A and B, we can determine t, and since l can be easily measured, we can find u, the velocity of the positive ion in a field of given strength. By charging A and C negatively instead of positively we can arrive at the velocity of the negative ion. In practice it is more convenient to use cylindrical tubes with coaxial wires instead of the systems of parallel plates, though in this case the calculation of the velocity of the ions from the observations is a little more complicated, inasmuch as the electric field is not uniform between the tubes

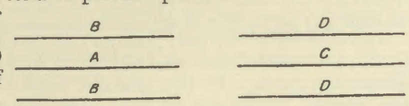


Fig. 10.

A method which gives very accurate results, though it is only applicable in certain cases, is the one used by Rutherford[23] to measure the velocity of the negative ions produced close to a metal plate by the incidence on the plate of ultra-violet light. The principle of the method is as follows:—AB (Fig. 11) is an insulated horizontal plate of well-polished zinc, which can be moved vertically up and down by means of a screw; it is connected with one pair of quadrants of an electrometer, the other pair of quadrants being put to earth. CD is a base-plate with a hole EF in it; this hole is covered with fine wire gauze, through which ultra-violet light passes and falls on the plate AB. The plate CD is connected with an alternating current dynamo, which produces a simply-periodic potential difference between AB and CD, the other pole being put to earth. Suppose that at any instant the plate CD is at a higher potential than AB, then the negative ions from AB will move towards CD, and will continue to do so as long as the potential of CD is higher than that of AB. If, however, the potential difference changes sign before the negative ions reach CD, these ions will go back to AB. Thus AB will not lose any negative charge unless the distance between the plates AB and CD is less than the distance traversed by the negative ion during the time the potential of CD is higher than that of AB. By altering the distance between the plates until CD just begins to lose a negative charge, we find the velocity of the negative ion under unit electromotive intensity. For suppose the difference of potential between AB and CD is equal to $a \sin pt$, then if d is the distance between the plates, the electric intensity is equal to $a \sin pt/d$; if we suppose the velocity of the ion is proportional to the electric intensity, and if u is the velocity for unit electric intensity, the velocity of the negative ion will be $ua \sin pt/d$. Hence if x represent the distance of the ion from AB

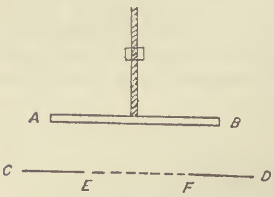


Fig. 11.

$$\frac{dx}{dt}=\frac{ua}{d}\sin pt,$$

$$x=\frac{ua}{pd}(1-\cos pt), \text{ if } x=0 \text{ when } t=0.$$

Thus the greatest distance the ion can get from the plate is equal to $2au/pd$, and if the distance between the plates is gradually reduced to this value the plate AB will begin to lose a negative charge; hence when this happens

$$d=\frac{2au}{pd}, \text{ or } u=\frac{pd^2}{2a},$$

an equation by means of which we can find u.

The velocity of the ions produced by the discharge of electricity from a fine point has been determined by Chattock by an entirely different method. In this case the electric field is so strong and the velocity of the ion so great that the preceding methods are not applicable. Suppose P represents a vertical needle discharging electricity into air, consider the force acting on the ions included between two horizontal planes A, B. If ρ is the density of the electrification, and Z the vertical component of the electric intensity, F the resultant force on the ions between A and B is vertical and equal to

$$\iiint Z\rho dxdydz.$$

Let us suppose that the velocity of the ion is proportional to the electric intensity, so that if w is the vertical velocity of the ions, which are supposed all to be of one sign, $w=RZ$.

Substituting this value of Z, the vertical force on the ions between A and B is equal to

$$\frac{1}{R}\iiint w\rho dxdydz.$$

But $\iint w\rho dxdy=\iota$, where ι is the current streaming from the point. This current, which can be easily measured by putting a galvanometer in series with the discharging point, is independent of z, the vertical distance of a plane between A and B below the charging point. Hence we have

$$F=\frac{\iota}{R}\int dz$$

$$=\frac{\iota}{R}\cdot z.$$

This force must be counterbalanced by the difference of gaseous pressures over the planes A and B; hence if p_B and p_A denote respectively the pressures over B and A, we have

$$p_B-p_A=\frac{\iota}{R}z.$$

Hence by the measurement of these pressures we can determine R, and hence the velocity with which an ion moves under a given electric intensity.

There are other methods of determining the velocities of the ions, but as these depend on the theory of the conduction of electricity through a gas containing charged ions, we shall consider them in our discussion of that theory.

§ 3. *Results of Measurements.*—The results of experiments made by the preceding methods on the velocity of ions produced by Röntgen rays, by uranium rays, by the incidence of ultra-violet light on metals, and by the discharge of electricity from points, show that, whether the ions are produced in one or other of these ways, their velocities in a given gas are as nearly equal, considering the great difficulties of these experiments, as we could expect, on the supposition that the ions are identical. We may therefore conclude that the ions produced by these agents depend only on the gas, and not on the agent. It has been proved by direct experiment that in the case of the first three agents the velocity of an ion is proportional to the electric intensity acting upon it. In the case of the ions produced by ultra-violet light Rutherford (*loc. cit.*) has shown that, at any rate down to pressures as low as 34 mm. of mercury, the velocity of the ion under a given electric intensity is inversely proportional to the pressure. He has also shown that the velocity of the ion remains unaltered however the metal on which the light falls is changed, provided that the gas in which the metals are immersed remains the same. Zeleny made the very interesting discovery that the velocity of the negative ions was always greater than that of the positive in the case of ions produced by Röntgen rays. Rutherford showed that this was true for the ions produced by uranium radiation, and Chattock (*loc. cit.*) that it held also for those produced by the discharge of electricity from points. Townsend,[24] by measuring the rates of diffusion of ions, has shown that the ratio of the velocity of the negative ion to that of the positive is considerably greater in a dry gas than in a wet one. The presence of moisture produces a very appreciable diminution in the velocity of the negative, while its effect on the positive ion is comparatively small, and generally in the opposite direction; *i.e.*, the positive ions seem to move a trifle faster in a damp gas than they do in a dry one. Rutherford's results for the velocity of the ions in different gases produced by different agents are given in the following table. The velocities given are those due to a potential gradient of 1 volt per centimetre.

Gas.	Mean Velocity of Positive and Negative Ions in Röntgen Ray Conduction.	Velocity of Negative Ions in Ultra-Violet Light Conduction.
Air	1·6 cm./sec.	1·4 cm./sec.
Hydrogen	5·2 ,,	3·9 ,,
Carbonic acid	1·07 ,,	·78 ,,

Rutherford also compared the velocities of the ions produced by uranium radiation with those produced by Röntgen rays, and found them equal within the limits of error of the experiments. For the ions produced by the escape of electrification from a point Chattock (*loc. cit.*) found 1·38 cm./sec. as the velocity of the positive ion, and 1·8 cm./sec. as that of the negative. For the ratio of the velocity of the negative ion to that of the positive Zeleny found the following values. The gases were not specially dried.

Gas.	Velocity of Negative Ion divided by Velocity of Positive Ion.	Gas.	Velocity of Negative Ion divided by Velocity of Positive Ion.
Air	1·24	Carbonic acid	1·
Oxygen	1·24	Ammonia	1·045
Nitrogen	1·23	Acetylene	·985
Hydrogen	1·14	Nitrogen monoxide	1·105
Coal gas	1·15		

The effect of moisture on the ratio of the velocities of the ions is shown by the results given by Townsend in the following table. The quantity K determined by Townsend is not the velocity of the ion, but the coefficient of diffusion of the ion through the gas. K is, however, proportional to that velocity.

Coefficients of Diffusion of Ions produced by Röntgen Rays in Dry Gases.

Gas.	K for + ion.	K for − ion.	Mean Values of K.	Ratio of Values of K.
Air . . .	·028	·043	·0347	1·54
Oxygen . .	·025	·0396	·0323	1·58
Carbonic Acid .	·023	·026	·0245	1·13
Hydrogen .	·123	·190	·156	1·54
Coefficients of Diffusion in Moist Gases.				
Air . . .	·032	·035	·0335	1·09
Oxygen . .	·0288	·0358	·0323	1·24
Carbonic Acid .	·0245	·0255	·025	1·04
Hydrogen .	·128	·142	·135	1·11

We can derive some information as to the constitution of the ions by calculating the velocity with which a molecule of the gas would move in the electric field if it carried the same charge as the ion. From the theory of the diffusion of gases, as developed by Maxwell (see DIFFUSION, *Ency. Brit.* vol. vii.), we know that if the particles of a gas A are surrounded by a gas B, then, if the partial pressure of A is small, the velocity u with which its particles will move when acted upon by a force Xe is given by the equation

$$u=\frac{Xe}{(p_1/N_1)}D,$$

where D represents the coefficient of inter-diffusion of A into B, and N_1 the number of particles of A per cubic centimetre when the pressure due to A is p_1. Let us calculate by this equation the velocity with which a molecule of hydrogen would move through hydrogen if it carried the charge carried by an ion, which we shall prove shortly to be equal to the charge carried by an atom of hydrogen in the electrolysis of solutions. Since p_1/N_1 is independent of the pressure, it is equal to π/N, where π is the atmospheric pressure and N the number of molecules in a cubic centimetre of gas at atmospheric pressure. Now $Ne=1{\cdot}22\times10^{10}$, if e is measured in electrostatic units; $\pi=10^6$, and D in this case is the coefficient of diffusion of hydrogen into itself, and is equal to 1·7. Substituting these values we find

$$u=1{\cdot}97\times10^4X.$$

If the potential gradient is 1 volt per centimetre, $X=1/300$. Substituting this value for X, we find $u=66$ cm./sec., for the velocity of a hydrogen molecule. We have seen that the velocity of the ion in hydrogen is only about 5 cm./sec., so that the ion moves more slowly than it would if it were a single molecule. The most obvious inference would seem to be that the ion is bigger than the molecule, and is in fact an aggregation of molecules, the charged ion acting as a nucleus around which molecules collect like dust round a charged body. This view is supported by the effect produced by moisture in diminishing the velocity of the negative ion, for, as C. T. R. Wilson[25] has shown, moisture tends to collect round the ions, and condenses more easily on the negative than on the positive ion. In connexion with the velocities of ions in the gases drawn from flames, we shall find other instances which suggest that condensation takes place round the ions. An increase in the size of the system is not, however, the only way by which the velocity might fall below that calculated for the hydrogen molecule, for we must remember that the hydrogen molecule, whose coefficient of diffusion is 1·7, is not charged, while the ion is. The forces exerted by the ion on the other molecules of hydrogen are not the same as those which would be exerted by a molecule of hydrogen, and as the coefficient of diffusion depends on the forces between the molecules, the coefficient of diffusion of a charged molecule into hydrogen might be very different from that of an uncharged one.

§ 4. *Velocity of Ions in Gases from Flames and Arcs.*—The velocities of the ions in gases drawn from Bunsen flames and arcs are very much smaller than those of the ions previously considered. They were found by M'Clelland[26] to depend upon the distance the gases had travelled from the flame. Thus with a Bunsen flame the velocity of the ion at a distance of 5·5 cm. from the flame, where the temperature was 230° C., with a potential gradient of 1 volt per cm., was ·23 cm./sec.; at a distance of 10 cm. from the flame, where the temperature was 160° C., it was ·21 cm./sec.; while at a distance of 14·5 cm. from the flame, where the temperature was 105° C., it was only ·04 cm./sec. If the temperature of the gas at a distance from the flame was raised by external means the velocity of the ions increased. Similar results were obtained with a CO flame. These results suggest a rapid condensation on the ions as they get into cooler regions. With these ions, as with those previously considered, the velocity of the negative ion is always greater than that of the positive, the difference amounting to about 15 per cent. M'Clelland also found that, with the ions from flames, arcs, and the neighbourhood of incandescent wires, the velocity diminishes as the temperature of the flame, arc, or wire increases, the other circumstances remaining the same. The velocities of the ions produced by putting salts into flames have been measured by H. A. Wilson.[27] The salts used were Na_2CO_3, K_2CO_3, Li_2CO_3, Cs_2CO_3, Rb_2CO_3, KCl, NaCl, KF, KI, KBr. They were sprayed by a Gouy sprayer into a flame whose temperature was estimated at about 2000° C. It was found that in all cases the velocity of the positive ion under a potential gradient of 1 volt per centimetre was about 62 cm./sec., while the velocity of the negative ion under the same potential gradient was about 1030 cm./sec. The velocity of the negative ions is thus independent of the nature of the salt from which they are derived. The velocities of these ions are much greater than those of the ions produced by Röntgen rays, and very much greater than those in the comparatively cold gases sucked from flames. The ratio of the velocity of the negative ion to that of the positive is also very much greater. Experiments were also made by Wilson on the velocities of the ions when the salts were volatilized by a stream of hot air at a temperature of about 1000° C. The salts tried were Na_2CO_3, NaOH, NaCl, K_2CO_3, KOH, KCl, KBr, KI, KF, LiCl, Li_2CO_3, RbCl, Rb_2CO_3, CsCl, Cs_2CO_3, $CaCl_2$, $BaCl_2$, $SrCl_2$, $Ba(NO_3)_2$. The velocities of the ions under a potential gradient of 1 volt per centimetre are: for (1) negative ions of all the salts, 26 cm./sec.; for (2) positive ions of salts Li, Na, K, Rb, and Cs, 7·2 cm./sec.; and for (3) positive ions of salts of Ba, Sr, and Ca, 3·8 cm./sec. These numbers, on account of the difficulties of the experiment, are only to be considered as approximately true. The velocities in the hot air are very much smaller than those in the flame. They show, however, the same peculiarities, the velocities of all the negative ions being the same, as well as those of the positive ions from the alkali metals. It will be noticed that the fall in temperature from 2000° C. in the flame to 1000° C. in the hot air has had a much greater effect on the velocity of the negative ion than on that of the positive. The reduction in the velocity which follows the fall in temperature is analogous to that observed by M'Clelland in the case of the gases drawn from flames.

§ 5. *Determination of the Electric Charge carried by an Ion.*—The charge on the ions was first measured by the present writer,[28] using a method founded on C. T. R. Wilson's[29] discovery that when Röntgen rays are passed through dust-free air a cloud is produced by an expansion of the gas, which is too small to produce cloudy condensation when the gas is not exposed to these rays. When the gas is exposed to the rays the ions produced by them seem to act as nuclei around which the water condenses. It has been shown (J. J. Thomson, *Applications of Dynamics to Physics and Chemistry*, p. 164) that for a charged sphere of less than a certain radius the effect of the charge in promoting condensation more than counterbalances the effect of surface tension in preventing it. Thus a charged ion will produce a very small drop of water, which may act as a nucleus for larger drops. That the drops constituting the cloud are formed round the ions is proved by the fact that the cloud is not formed when the gas is exposed to a strong electric field while the rays are passing through it, the electric field removing the ions from the gas as fast as they are formed. The experiment also shows that the drops are only formed round the ions. Suppose now we wish to count the number of ions in a cubic centimetre of air, we cool the air by sudden expansion until the supersaturation produced by the cooling is sufficient to cause a cloud to be formed round the ions. The problem of finding the number of ions per cubic centimetre of the gas is thus reduced to finding the number of drops per cubic centimetre in the cloud. Knowing the amount of the expansion, we can calculate the amount of water deposited per cubic centimetre of the cloud. The water is deposited as drops, and if the drops are of equal size the number per cubic centimetre will be equal to the volume of the water deposited per cubic centimetre divided by the volume of one of the drops. Hence we can calculate the number of the drops if we know their size, and this can be determined by measuring v, the velocity with which they fell under gravity through the air. From the theory of the motion of a sphere through a viscous fluid,

$$v=\frac{2}{9}\frac{ga^2}{\mu},$$

where a is the radius of the drop, g the value of gravity, and μ the coefficient of viscosity of the gas through which the drop falls. From this equation we can determine a, and hence deduce n, the number of ions per cubic centimetre. If we place two parallel metal plates in the gas, and establish between them a known potential difference, we shall get a current of electricity through the gas which we can measure by means of an electrometer. If e is the charge on an ion, and u the mean velocity of the positive and negative ions in the electric field between the plates, the current across a square centimetre is neu; hence, by the electrical measurements we determine the product neu. We know n by the experiments on the clouds, and u by the determinations which have been made of the velocities of the ions. We can therefore deduce the value of e, the charge on the ion. For the details of the experiment see papers by J. J. Thomson, *Phil. Mag.* xlvi. p. 528; xlviii. p. 547. The result of measurements made by this method is that the charge on the ion is the same whether the ionization is produced by Röntgen rays or by the incidence of ultra-violet light on a metal plate. It is also the same whether the gas ionized is hydrogen, air, or CO_2, and thus is presumably independent of the nature of the gas. The value of the ionic charge in electrostatic units is about $6\cdot5\times10^{-10}$ c.g.s. units.

The ratio of the ionic charge to the charge carried by an atom of hydrogen in the electrolysis of solutions has been determined by Townsend by a method depending upon the measurement of the rate of diffusion of the ions into the surrounding gas (*Phil. Trans.* cxciii. p. 129). If we have a quantity of positive and negative ions in a gas contained in a vessel with metal walls, their number will diminish in two ways: (1) some of the positive and negative ions will unite and form a neutral system, and (2) the ions will diffuse to the walls of the vessel, and coming in contact with the metal, cease to behave like ions, so that the metal sides can be regarded as absorbing all the ions which come in contact with it. The number absorbed in a given time depends upon the coefficient of diffusion of the ions through the gas in the vessel, and if we arrange the experiment so that the first cause of the decrease in the number of ions produces effects small compared with those produced by the second, a measurement of the rate at which the ions disappear will give the coefficient of diffusion of the gas. The theory of the connexion between these quantities may be illustrated by the consideration of a very simple case.

Suppose that initially the distribution of ions between two parallel metal plates is uniform, and that the ions are left to diminish by diffusion to the plates. Then if D is the coefficient of diffusion of the ions into the gas, we have by the theory of gaseous diffusion (see DIFFUSION, *Ency. Brit.* 9th edition), if n is the number of ions per cubic centimetre of the gas,

$$\frac{dn}{dt}=\mathrm{D}\left(\frac{d^2n}{dx^2}+\frac{d^2n}{dy^2}+\frac{d^2n}{dz^2}\right).$$

Let us take the axis of x normal to the metal plate; then if the distribution of ions was initially uniform, n will be independent of y and z, and the equation becomes

$$\frac{dn}{dt}=\mathrm{D}\frac{d^2n}{dx^2}.$$

If a is the distance between the plates, the boundary conditions are that $n=0$ when $x=0$, or when $x=a$ for all values of t, and that when $t=0$ n is constant for all values of x between 0 and a, and equal to n_0. The solution of the differential equations with these boundary conditions is

$$n=\frac{4n_0}{\pi}\sum_{n=1}^{n=\infty}\frac{e^{-\frac{(2n-1)^2\pi^2\mathrm{D}t}{a^2}}}{2n-1}\sin(2n-1)\frac{\pi x}{a}.$$

If N is the number of ions between the plates at the time t, N_0 the number when $t=0$,

$$\frac{\mathrm{N}}{\mathrm{N}_0}=\frac{\int_0^a ndx}{n_0a}=\frac{8}{\pi^2}\sum_{n=1}^{n=\infty}\frac{e^{-\frac{(2n-1)^2\pi^2\mathrm{D}t}{a^2}}}{(2n-1)^2}\quad . \quad . \quad . \quad (1).$$

Now N/N_0 can easily be determined, as it is equal to the ratio of the quantities of electricity which can be sent across the plates by a strong electromotive force at the time t and at the time $t=0$. These quantities can readily be measured by an electrometer. Knowing N/N_0, we can then, by means of equation (1), calculate D. In practice it was found more convenient to use cylindrical tubes instead of parallel plates, and though the calculation of the connexion between N/N_0 and D is in this case a little more troublesome, the principles involved are the same. We have seen (see § 3) that if u is the velocity of the ion under an electric intensity X, e the charge on the ion,

$$u=\frac{\mathrm{X}e}{(p_1/\mathrm{N}_1)}\mathrm{D},$$

where N_1 is the number of ions per cubic centimetre of the gas required to produce a partial pressure of the ions equal to p_1, but

$$\frac{p_1}{\mathrm{N}_1}=\frac{\pi}{\mathrm{N}},$$

where N is the number of molecules in a cubic centimetre of any gas at the atmospheric pressure, π. Putting $\pi=10^6$, $\mathrm{X}=1/300$ (this corresponds to a potential gradient of 1 volt per centimetre), u_1 the velocity of the ion under this potential gradient, we have

$$u_1=\frac{1}{300\times10^6}\mathrm{N}e\,.\,\mathrm{D},$$

or

$$\mathrm{N}e=3\times10^{10}\frac{u_1}{\mathrm{D}}.$$

Now u_1 is known from the experiments on the velocity of the ions, and D is known by Townsend's experiments. In this way Townsend found that if e_A, e_O, e_C, e_H, denote the charges on the ions produced by Röntgen rays in air, oxygen, carbonic acid, and hydrogen respectively, we have $\mathrm{N}e_A=1\cdot35\times10^{10}$; $\mathrm{N}e_O=1\cdot25\times10^{10}$; $\mathrm{N}e_C=1\cdot30\times10^{10}$; $\mathrm{N}e_H=1\cdot15\times10^{10}$; while if E is the charge carried by the atom of hydrogen in the electrolysis of solutions, we know $\mathrm{NE}=1\cdot22\times10^{10}$.

It follows from these results that the charges on the ions produced by Röntgen rays in the gases named are all equal to each other and to the electrolytic charge on the hydrogen atom. Thus these results confirm that obtained by the method of clouds, viz., that the charge on the ion is independent of the nature of the gas from which it is produced. If we substitute for E the value obtained by the cloud method, viz., $6\cdot5\times10^{-10}$, we obtain for N the value $1\cdot9\times10^{19}$. This value, obtained by direct experiment, thus agrees very closely with the value $2\cdot1\times10^{19}$ obtained by Maxwell for the number of particles in a cubic centimetre of air by the application of the kinetic theory of gases. Townsend has applied his method to the calculation of the charges on the ions produced by the incidence of ultra-violet light on metals, by radio-active substances, and by the discharge of electricity from points, as well as those produced by Röntgen rays, and has found that in all these cases the charges are the same. Thus the charge on the ion seems to be independent of the agent by which it is produced as well as of the gas from which it originates.

§ 6. *Calculation of the Mass of the Ions at Low Pressures.*—Although at ordinary pressures the ion seems to have a very complex structure and to be the aggregate of many molecules, yet we have evidence that at very low pressures the structure of the ion, and especially of the negative one, becomes very much simpler. This evidence is afforded by determination of the mass of the atom. We can measure the ratio of the mass of an ion to the charge on the ion by observing the deflexion produced by a given magnetic force on a moving ion. If an ion carrying a charge e is moving with a velocity v, at a point where the magnetic force is H, a mechanical force acts on the ion, whose direction is at right angles both to the direction of motion of the ion and to the magnetic force, and whose magnitude is $ev\mathrm{H}\sin\theta$, where θ is the angle between v and H. Suppose then that we have an ion moving through a gas whose pressure is so low that the free path of the ion is long compared with the distance through which it moves whilst we are experimenting upon it; in this case the motion of the ion will be free, and will not be affected by the presence of the gas.

Let the mass of the ion be m, its charge e, and let it move in a field where the electric and magnetic forces are both uniform, the electric force X being parallel to the axis of x, and the magnetic force Z parallel to the axis of z, then if x, y, are the co-ordinates of the ion at the time t, the equations of motion of the ion are—

$$m\frac{d^2x}{dt^2}=\mathrm{X}e-\mathrm{H}e\frac{dy}{dt},$$

$$m\frac{d^2y}{dt^2}=\mathrm{H}e\frac{dx}{dt}.$$

The solution of these equations, if x, y, dx/dt, dy/dt all vanish when $t=0$, is

$$x=\frac{\mathrm{X}m}{e\mathrm{H}^2}\left\{1-\cos\left(\frac{e}{m}\mathrm{H}t\right)\right\}$$

$$y=\frac{\mathrm{X}m}{e\mathrm{H}^2}\left\{\frac{e}{m}\mathrm{H}t-\sin\left(\frac{e}{m}\mathrm{H}t\right)\right\}.$$

These equations show that the path of the ion is a cycloid, the generating circle of which has a diameter equal to $2\mathrm{X}m/e\mathrm{H}^2$, and rolls on the line $x=0$.

Suppose now that we have a number of ions starting from the plane $x=0$, and moving towards the plane $x=a$. The particles starting from $x=0$ describe cycloids, and the greatest distance they can get from the plane is equal to the diameter of the generating circle of the cycloid, *i.e.*, to $2\mathrm{X}m/e\mathrm{H}^2$. (After reaching this distance they begin to approach the plane.) Hence if a is less than the diameter of the generating circle, all the particles starting from $x=0$ will reach the plane $x=a$, if this is unlimited in extent; while if a is greater than the diameter of the generating circle none of the particles which start from $x=0$ will reach the plane $x=a$. Thus, if $x=0$ is a plane illuminated by ultra-violet light, and consequently the seat of a supply of negative ions, and $x=a$ a plane connected with an electrometer, then if a definite electric intensity is established between the planes, *i.e.*, if X be fixed, so that the rate of emission of negative ions from the illuminated plate is given, and if a is less than $2\mathrm{X}m/e\mathrm{H}^2$, all the ions which start from $x=0$ will reach $x=a$. That is, the rate at which this plane receives an electric charge will be the same whether there is a magnetic field between the plate or not, but if a is greater than $2\mathrm{X}m/e\mathrm{H}^2$, then no particle which starts from the plate $x=0$ will reach the plate $x=a$, and this plate will receive no charge. Thus the supply of electricity to the plate has been entirely stopped by the magnetic field. Thus, on this theory, if the distance between the plates is less than a certain value, the magnetic force should produce no effect on the rate at which the electrometer plate receives a charge, while if the distance is greater than this value the magnetic force would completely stop the supply of electricity to the plate. The actual phenomena are not so abrupt as this theory indicates. We find that when the plates are very near together the magnetic force produces a very slight effect, and this an *increase* in the rate of charging of the plate. On increasing the distance we come to a stage where the magnetic force produces a great diminution in the rate of charging. It does not, however, stop it abruptly, there being a considerable range of distance, in which the magnetic force diminishes but does not destroy the current. At still greater distances the current to the plate under the magnetic force is quite inappreciable compared with that when there is no magnetic force. We should get this gradual instead of abrupt decay of the current if the particles, instead of all starting from the actual surface of the plate $x=0$, started from a layer of finite thickness t; in that case the first particles stopped would be those which started from the surface of the plate. This would be when $a=2\mathrm{X}m/e\mathrm{H}^2$, but particles would continue to reach the plate until $a=t+2\mathrm{X}m/e\mathrm{H}^2$. Thus if we measure the value of a when the magnetic force first begins to affect the leak to the electrometer we determine $2\mathrm{X}m/e\mathrm{H}^2$, and as we can easily measure X and H, we can deduce the value of m/e.

By this method the writer determined the value of m/e for the negative ions produced when ultra-violet light falls on a metal plate, as well as for the negative ions produced by an incandescent carbon filament in an atmosphere of hydrogen (*Phil. Mag.* xlviii. p. 547). For the ions produced by ultra-violet light the value e/m was found to be $7{\cdot}3\times10^6$, and for those produced by the incandescent carbon filament, $8{\cdot}7\times10^6$ (e is measured in electro-magnetic units). The difference between these values is not greater than the error of experiment. When we consider the properties of the cathode rays we shall see that for the negatively electrified particles which constitute those rays the value of e/m is the same as that just found, and is independent of the nature of the gas from which the rays originate; in fact, in all cases in which the value of e/m has been determined for gases at low pressures, the result has been to show that it is a constant quantity independent both of the nature of the gas from which the ions are produced and of that of the agent used to produce them. Townsend's experiments (*loc. cit.*) show that the value of e, the charge on the ion, is equal to the charge carried by an atom of hydrogen in the electrolysis of solutions. But if M is the mass of an atom of hydrogen, e/M is equal to 10^4, and M is equal to about $1000m$. Thus the mass of the negative ion is exceedingly small compared with that of the mass of the atom of hydrogen, the smallest mass recognized in chemistry. The production of negative ions thus involves the splitting up of the atom, as from a collection of ions something is detached whose mass is less than that of a single atom. It is important to notice in connexion with this subject that an entirely different line of argument, based on what is known as the Zeeman effect (see MAGNETO-OPTICS), leads to the recognition of negatively electrified particles, for which e/m is of the same order as that just deduced from the consideration of purely electrical phenomena.

When we determine e/m for the positive ions we find an entirely different set of laws from those which hold for the negative ions. The value of e/m for the positive ions is not constant, nor has it the exceedingly large value which is characteristic of the negative ions. The writer has determined the value of e/m for the positive ions produced near an incandescent platinum wire in an atmosphere of oxygen or carbonic acid gas at a very low pressure, using the method already described for the determination of the corresponding quantity for the negative ions, *i.e.*, by measuring the distance between two parallel plates when a magnetic field begins to affect the current passing between them. To get any result with positive ions, it is necessary to use exceedingly strong magnetic fields, for while a magnetic force of about 150 was found a convenient one for the experiment with the negative ions, it had no appreciable effect on the positive ions, and for these it was necessary to use a magnetic force of about 8000. Using this magnetic force, the value of e/m for the positive ions in oxygen was found to be about $10^4/40$, while for carbonic acid gas it was slightly less. If the charge on the positive ion had been carried by a molecule of oxygen, the value of e/m would have been $10^4/32$, so that the carrier of the positive charge is probably a molecule of oxygen. Experiments, which we shall have to consider later in connexion with another part of the subject, made by W. Wien[30] and Ewers[31] on the value of e/m for the positively charged particles in what are called the *Kanal-strahlen*, are entirely consistent with the view that the mass of the carrier of the positive charge in this case is that of a molecule of some substance present in the vessel in which the ions are produced and varying as these substances are changed. Thus the carriers of negative electricity at a low pressure have a constant mass very small compared with that of the atom of any known substance, while the carriers of positive electricity have a variable mass which is comparable with that of the molecule of the chemical elements.

§ 7. *Distribution of Potential between two Parallel Plates in a Conducting Gas.*—Zeleny[32] and Child[33] have shown that when a current of electricity is passing between two parallel plates immersed in a gas exposed to Röntgen rays, the electric intensity in the space between the plates is not constant, but is greater in the immediate neighbourhood of the plates than it is in the rest of the gas, where it has a nearly constant value. The general character of the distribution of electric potential between the plates is shown in Fig. 12, where the ordinates represent the potential. We can readily see why the electric intensity should be greater near the plates than in the rest of the gas, for from the layer of gas next the positive plate the positive ions will be driven out, so that there will be an excess of negative ions in this layer. Similarly, in the layer of gas next the negative plate there will be an excess of positive ions, and this free electrification will increase the slope of potential in the neighbourhood of the plates. The distribution of electric intensity between the plates can be deduced by the following considerations :—

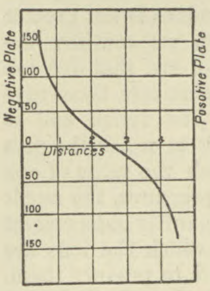


Fig. 12.

Let the two plates be at right angles to the axis of x; then we may suppose that between the plates the electric intensity X is everywhere parallel to the axis of x. The velocities of both the positive and negative ions are assumed to be proportional to X. Let R_1X, R_2X represent these velocities respectively ; let n_1, n_2 be respectively the number of positive and negative ions per unit volume at a point fixed by the co-ordinate x; let q be the number of positive or negative ions produced in unit time per unit volume at this point ; and let the number of ions which recombine in unit volume in unit time be an_1n_2 ; then if e is the charge on the ion, the volume density of the electrification is $(n_1 - n_2)e$, hence

$$\frac{dX}{dx} = 4\pi(n_1 - n_2)e \quad . \quad . \quad . \quad . \quad (1).$$

If I is the current through unit area of the gas and if we neglect any diffusion except that caused by the electric field,

$$n_1eR_1X + n_2eR_2X = I \quad . \quad . \quad . \quad . \quad (2).$$

From equations (1) and (2) we have

$$n_1e = \frac{1}{R_1 + R_2}\left(\frac{I}{X} + \frac{R_2}{4\pi}\frac{dX}{dx}\right) \quad . \quad . \quad . \quad (3),$$

$$n_2e = \frac{1}{R_1 + R_2}\left(\frac{I}{X} - \frac{R_1}{4\pi}\frac{dX}{dx}\right) \quad . \quad . \quad . \quad (4),$$

and from these equations we can, if we know the distribution of electric intensity between the plates, calculate the number of positive and negative ions.

In a steady state the number of positive and negative ions in unit volume at a given place remains constant, hence

$$\frac{d}{dx}(Rn_1X) = q - an_1n_2 \quad . \quad . \quad . \quad . \quad (5)$$

$$-\frac{d}{dx}(R_2n_2X) = q - an_1n_2 \quad . \quad . \quad . \quad . \quad (6).$$

If R_1 and R_2 are constant, we have from (1), (5), and (6)

$$\frac{d^2X^2}{dx^2} = 8\pi e(q - an_1n_2)\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \quad . \quad . \quad . \quad (7),$$

an equation which is very useful, because it enables us, if we know the distribution of X^2, to find whether at any point in the gas the ionization is greater or less than the recombination of the ions. We see that $q - an_1n_2$, which is the excess of ionization over recombination, is proportional to d^2X^2/dx^2. Thus when the ionization exceeds the recombination, *i.e.*, when $q - an_1n_2$ is positive, the curve for X^2 is convex to the axis of x, while when the recombination exceeds the ionization the curve for X^2 will be concave to the axis of x. Thus, for example, Fig. 13 represents the

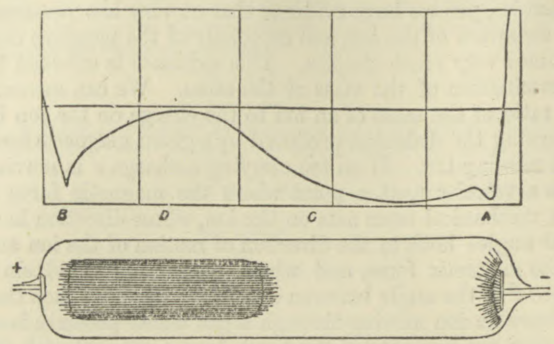


Fig. 13.

curve for X^2 observed by Graham (*Wied. Ann.* lxiv. p. 49) in a tube through which a steady current is passing. Interpreting it by equation (7), we infer that ionization was much in excess of recombination at A and B, slightly so along C, while along D the recombination exceeded the ionization. Substituting in equation (7) the values of n_1 n_2 given in (3), we get

$$\frac{d^2X^2}{dx^2} = 8\pi e\left[q - \frac{a}{e^2X^2(R_1 + R_2)^2}\left(I + \frac{R_2}{8\pi}\frac{dX^2}{dx}\right)\left(I - \frac{R_1}{8\pi}\frac{dX^2}{dx}\right)\right]\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \quad (8).$$

This equation can be solved (see Thomson, *Phil. Mag.* xlvii. p. 253), when q is constant and $R_1 = R_2$. From the solution it appears that if X_1 be the value of x close to one of the plates, and X_0 the value midway between them,

$$\frac{X_1}{X_0} = \frac{1}{\beta^{2-2/\beta}}$$

where $\beta = \frac{8\pi ek_1}{a}$.

Since $e = 6{\cdot}5 \times 10^{-10}$, $a = 2 \times 10^{-6}$, and R_1 for air at atmospheric pressure $= 450$, β is about 3·8 for air at atmospheric pressure and it becomes much greater at lower pressures.

Thus X_1/X_0 is always greater than unity, and the value of the ratio increases from unity to infinity as β increases from zero to infinity. As β does not involve either q or I, the ratio of X_1 to X_0 is independent of the strength of the current and of the intensity of the ionization.

No general solution of equation (8) has been found when R_1 is not equal to R_2, but we can get an approximation to the solution when q is constant. The equations (1), (2), (3), (4) are satisfied by the values—

$$n_1 = n_2 = (q/a)^{\frac{1}{2}},$$

$$R_1n_1Xe = \frac{R_1}{R_1 + R_2}I,$$

$$R_2n_2Xe = \frac{R_2}{R_1 + R_2}I,$$

$$X = \left(\frac{a}{q}\right)^{\frac{1}{2}}\frac{I}{e(R_1 + R_2)}.$$

These solutions cannot, however, hold right up to the surface of the plates, for across each unit of area, at a point P, $R_1I/(R_1 + R_2)e$ positive ions pass in unit time, and these must all come from the region between P and the positive plate. If λ is the distance of P from this plate, this region cannot furnish more than $q\lambda$ positive ions, and only this number if there are no recombinations. Hence the solution cannot hold when $q\lambda$ is less than $R_1I/(R_1 + R_2)e$, or where λ is less than $R_1I/(R_1 + R_2)qe$.

Similarly the solution cannot hold nearer to the negative plate than the distance $R_2I/(R_1 + R_2)qe$.

We can arrive at the same value of λ in another way. The force cannot by equation (7) be constant unless as many ions recombine as are produced by the ionizing agent. Now the ions travel a certain distance before they recombine, this distance being the product of the velocity of the ion and the duration of its life. Now the life of the positive ion is $1/\alpha n_2$, and its velocity is R_1X; hence the distance an ion will travel before it recombines is equal to average $R_1X/\alpha n_2$.

If we suppose X and n_2 to have the values they have in the region where X is constant, we find, substituting the values for X and n_2, that this distance is equal to $\frac{R_1}{R_1+R_2}\frac{I}{qe}$, the value we found before for the thickness of the layer within which X was variable; hence in this region we may assume that there is no recombination going on. We shall suppose that the electric intensity is uniform, except in a layer of thickness $R_1I/(R_1+R_2)qe$ next the positive electrode, and in one of thickness $R_2I/(R_1+R_2)qe$ next the negative electrode, and that within these layers there is no recombination of the ions. On these suppositions, it can readily be proved that if X_1, X_2, X are respectively the values of the electric intensity next the positive electrode, next the negative electrode, and between the layers.

$$X_1 = X\{1+\beta_1\}^{\frac{1}{2}},$$
$$X_2 = X(1+\beta_2)^{\frac{1}{2}},$$

where $\beta_1 = \frac{4\pi e}{\alpha}\frac{R_1}{R_2}(R_1+R_2)$, $\beta_2 = \frac{4\pi e}{\alpha}\frac{R_2}{R_1}(R_1+R_2)$.

Thus X_1 and X_2 are always greater than X, and if the velocity of the negative ion is greater than that of the positive, β_2 is greater than β_1; hence the electric intensity at the negative electrode is greater than that of the positive, and the thickness of the layer of inconstant X is greater at the negative than at the positive electrode. The curve representing the distribution of electric intensity between the plates when R_2/R_1 is large is shown in Fig. 14.

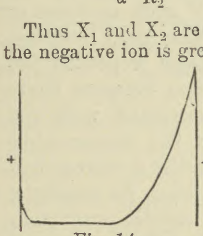


Fig. 14.

When β_1 and β_2 are large, as they are for hydrogen up to the atmospheric pressure and for air at somewhat lower pressures, the potential difference on crossing the layers next the positive and negative electrodes may easily be shown to be respectively

$$\tfrac{1}{2}(1+\beta_1)^{\frac{1}{2}}\frac{\alpha^{\frac{1}{2}}}{q^{\frac{3}{2}}}\frac{I^2}{e^2}\frac{R_1}{(R_1+R_2)^2},$$
$$\tfrac{1}{2}(1+\beta_2)^{\frac{1}{2}}\frac{\alpha^{\frac{1}{2}}}{q^{\frac{3}{2}}}\frac{I^2}{e^2}\frac{R_2}{(R_1+R_2)^2}.$$

Thus if R_2 is greater than R_1 the fall of potential at the negative electrode is greater than that at the positive; both are proportional to the square of the current. If V is the potential difference between the plates, and l the distance between them, it follows from these expressions that

$$V = \left(\frac{\alpha}{q}\right)^{\frac{1}{2}}\frac{I}{e(R_1+R_2)}\left\{\tfrac{1}{2}(1+\beta_1)^{\frac{1}{2}}\frac{R_1}{R_1+R_2}\frac{I}{qe} + \tfrac{1}{2}(1+\beta_2)^{\frac{1}{2}}\frac{R_2}{R_1+R_2}\frac{I}{qe} - \frac{I}{qe} + l\right\}$$

This relation between the current and potential difference between the plates is of the form

$$V = AI + BI^2.$$

If I is small, so that we may neglect I^2,

$$V = \left(\frac{\alpha}{q}\right)^{\frac{1}{2}}\frac{Il}{e(R_1+R_2)}.$$

This solution has been applied by Rutherford (*Phil. Mag.* xliv. p. 422) to find (R_1+R_2). Since $(q/\alpha)^{\frac{1}{2}}$ is the number of positive and negative ions per unit volume, if we stop the ionizing agent at the instant it is cut off, $l(q/\alpha)^{\frac{1}{2}}e$ is the quantity of positive electricity between the plates. By applying a very large potential difference between the plates we can drive this positive electricity to one of the plates before it has time to recombine with the negative ions. Hence Q, the positive charge received by the plate, is equal to $l(q/\alpha)^{\frac{1}{2}}e$, and

$$V = Il^2/Q(R_1+R_2);$$

and as we can measure V, I, and Q, we can determine (R_1+R_2). The measurements of the velocities of the ions by this method agree well with those made by the direct methods already described.

The solution given above only holds as long as the layers of variable force next the positive and negative plates do not meet. As the current increases the layers expand, until, when the saturating current is reached, they touch. After this there is no space between the plates where the electric intensity is uniform. The electric intensity at a place at a distance x from the positive plate is given by the equation

$$X^2 = 8\pi qe\left\{\frac{x^2}{2}\left(\frac{1}{R_1}+\frac{1}{R_2}\right) - \frac{Ix}{R_2}\right\} + X_1^2,$$

where X_1 is the electric intensity at the positive plate. We see again that, if the velocity of the negative ion is greater than that of the positive, the electric intensity is greater at the negative electrode than it is at the positive.

§ 8. *Path of a Moving Ion in a Magnetic Field.*—For the explanation of some of the effects of a magnet on the electric discharge we require to know the path of an ion in a magnetic field. We have already investigated one case of this problem (see § 6); there are, however, two other important cases which it is necessary to consider.

The first case is that of a charged ion moving in a uniform field of magnetic force, and free from the action of any electric force, the pressure of the gas being so low that it does not retard the motion of the particle. Then if v is the velocity of the particle, m its mass, and e its charge, H the magnetic force and δ the angle between v and H, the mechanical force acting on the particle is at right angles both to v and H, and equal to evH sin θ. Since the force on the particle is at right angles to its direction of motion, the velocity of the particle will be constant, and since the force is at right angles to the magnetic force, the components of the velocity parallel to the magnetic force will be constant, *i.e.*, $v\cos\theta$ is constant, so that as v is constant, θ is also constant. If ρ is the radius of curvature of the path of the particle $mv^2/\rho = Hev\sin\theta$, so that as v and θ are constant ρ is constant. Thus the path of the particle is a curve whose tangent makes a constant angle θ with the direction of the magnetic force, and whose radius of curvature is $mv/He\sin\theta$. The path of the particle is therefore a helix wound on a circular cylinder whose axis is parallel to the magnetic force, and whose radius is $\rho\sin\theta$ or $mv\sin\theta/He$.

The other case we shall consider is when the pressure of the gas through which the particle moves is considerable, so that the viscosity of the gas makes the velocity of the particle proportional to the force acting upon it. In this case there must be an electric field acting on the particles, otherwise the viscosity of the gas will reduce them to rest. Let X, Y, Z be the x, y, z components of the electric intensity, α, β, γ those of the magnetic force, and u, v, w the components of the velocity of the particle. The components of the force on the particle are

$$Xe + e(\beta w - \gamma v),\quad Ye + e(\gamma u - \alpha w),\quad Ze + e(\alpha v - \beta u).$$

If the velocity of the particle is R/e times the force acting on it, we have

$$u = R(X + \beta w - \gamma v),$$
$$v = R(Y + \gamma u - \alpha w),$$
$$w = R(Z + \alpha v - \beta u).$$

Solving these equations, we have

$$u = \frac{RX + R^2(\gamma Y - \beta Z) + R^3\alpha(\alpha X + \beta Y + \gamma Z)}{1 + R^2(\alpha^2 + \beta^2 + \gamma^2)},$$
$$v = \frac{RY + R^2(\alpha Z - \gamma X) + R^3\beta(\alpha X + \beta Y + \gamma Z)}{1 + R^2(\alpha^2 + \beta^2 + \gamma^2)},$$
$$w = \frac{RZ + R^2(\beta X - \alpha V) + R^3\gamma(\alpha X + \beta Y + \gamma Z)}{1 + R^2(\alpha^2 + \beta^2 + \gamma^2)}.$$

We see at once from these equations that when R times the magnetic force is small compared with unity, u, v, w are proportional to X, Y, Z; that is, the particle follows a line of electric force. But on the other hand, when R times the magnetic force is large, u, v, w are proportional to α, β, γ; that is, the path of the particle is a line of magnetic force. In the general case, if H is the magnetic, F the electric force, and θ the angle between them, the velocity has a component along the electric force proportional to RF, another component along the magnetic force proportional to $R^3H^2F\cos\theta$, and a third component at right angles to both the electric and magnetic forces, and proportional to $R^2HF\sin\theta$. In this case the path is along the lines of neither electric nor magnetic force, but is a spiral. The quicker the particle moves under a given force the more likely it is to follow the lines of magnetic force. Thus the negative particles are more likely to do this than the positive. If the particle moves with a velocity of n cm./sec. under a potential gradient of 1 volt per centimetre through the gas when at a pressure of one atmosphere, then at the pressure of $1/m$ atmosphere R is equal to $nm10^{-8}$. Thus from what we know of the velocities of the ions it is only at very low pressures that RH can be large for practicable values of H.

§ 9. *Difference of Potential between Metals immersed in a Conducting Gas.*—If plates of different metals immersed in a conducting gas are connected with the quadrants of an electrometer, they will show the same potential difference as if they had been immersed in an electrolyte. This has been proved when the conductivity is due to gases from flames by Maclean and Goto,[34] when due to ultra-violet light by Stoletow,[35] Righi,[36] Hallwachs,[37] Arrhenius,[38] when due to Röntgen rays by Erskine Murray,[39] and when due to rays from uranium by Lord Kelvin.[40]

We shall now leave the consideration of conducting gases in general and proceed to discuss the phenomena accompanying the discharge of electricity through them in special cases.

§ 10. *Conduction through Gases when in a Normal State.*—Even in its normal state a gas possesses a small amount of conductivity, which, however, is so small that it is only quite recently that the existence of a leak from a charged body through the air and independent of dust in the air has been unmistakably proved. The experiments of Matteucci, Warburg, Boys, Linss, Elster and Geitel, and C. T. R. Wilson[41] have proved that there is a very slight leak from a charged body through the surrounding gas, that this leak takes place in the dark as well as in daylight, in caves as well as above ground, and that the rate of leak is approximately proportional to the pressure of the gas. Matteucci could detect no difference between the rate of leak through hydrogen and that through air or carbonic acid. Warburg, however, found, on the other hand, that the rate of leak through hydrogen was only about one-half of that through the other two gases.

§ 11. *Conduction of Electricity through Hot Gases, &c.*—Gases become conductors when raised to a temperature at which metals become luminous. Thus Becquerel[42] found that air at a white heat would allow electricity to pass through it, even though the potential difference was only a few volts. This result was confirmed by Blondlot,[43] who observed that air at a bright red heat allowed a current to pass through it under a potential difference of $\frac{1}{1000}$ of a volt. The writer[44] observed that gases which are dissociated by heat, such as iodine, chlorine, bromine, and their compounds, conduct much better at the same temperature than gases such as air, hydrogen, nitrogen, which are not dissociated. The vapours of many metals are good conductors, mercury, however, being an exception. It is probable that a large part of the conductivity is produced at the surface of contact of the gas with the glowing electrodes or other solids which may be immersed in it, as H. A. Wilson[45] has shown that when salts are put into a flame there is great ionization where the salt-bearing flame comes into contact with glowing metals, and comparatively little anywhere else. We shall see later on that there is always a production of ions at the surface of a glowing metal. The view that the greater part of the ions are produced next the surface of the glowing electrodes explains a curious phenomenon observed by the writer, who found that when a current of electricity was passing between two glowing electrodes in a hot gas the interposition of a cold piece of thin metal stopped the current as completely as the interposition of a non-conductor, but that as soon as the metal began to glow the current was re-established. If the ions came from the glowing electrodes, then the negative ion, which travels to the positive electrode, started from the negative electrode; thus an interposed piece of metal, so long as no ions are produced at its surface, will stop the negative ions from reaching the positive electrode and the positive ions from reaching the negative electrode. The current will, however, begin again as soon as the plate begins to glow, for then ions are produced at the plate, furnishing a supply of positive ions for the negative electrode and of negative ions for the positive. The same view will explain the fact discovered by Blondlot (*loc. cit*), and also by Pringsheim,[46] that for the conduction of electricity through hot gases under small potential differences the current increases faster than the potential difference. If the ions are produced at the surface of the electrodes, the number torn from the electrode and sent into the gas will depend upon the potential difference. But the velocity with which these ions move is proportional to the potential difference, and as the current is proportional to the product of the number of ions into the velocity of an ion, it will increase more rapidly than the potential difference. Pringsheim has succeeded in observing a polarization analogous to electrolytic polarization in the conduction through hot gases.

The gases coming from flames are conductors of electricity, and retain this property for some time after leaving the flame. In one case observed by Giese[47] the conductivity lasted for fifteen minutes after the gases had left the flame. The conductivity of flame gases is more persistent than that of gases which have been exposed to Röntgen rays, and can survive bubbling through a considerable column of conducting liquid,[48] such as water or mercury, without total destruction. The gas, however, loses its conductivity when forced through a porous pot of unglazed earthenware. This difference between flame gases and other conducting gases is connected with the very slow speed with which the ions in the former move in the electric field (see § 4). This implies a correspondingly slow rate of diffusion, so that in going, for example, through a long metal tube a very much smaller proportion of the ions will diffuse to the walls of the tube than would be the case with the more rapidly moving ions from a gas exposed to Röntgen rays. We owe a large portion of our knowledge of the laws of conduction through flames to Giese, whose researches on flames led him to the view, which he was the first to suggest, that electricity is carried through them by oppositely charged particles. Thus Giese showed that the conductivity can be removed from the gas by making the gas traverse an electric field, and that the current in the great majority of cases does not increase so rapidly as the potential difference. Certain exceptions which he found to this rule can be explained in the same way as the analogous cases in the conduction through hot gases. A more extensive investigation of the relation between current and potential difference for flame gases has been made by M'Clelland,[49] who finds that the relation between current and potential difference is represented by a curve like Fig. 8. The current through the flame exhibits polar properties, for if the electrodes are of different sizes the current is much greater when the larger electrode is negative than when it is positive. We can easily see that this result is a direct consequence of the greater part of the ionization taking place next the glowing electrode, and of the velocity of the negative ion greatly exceeding that of the positive, for in consequence of this difference in velocity the current will be chiefly carried by the negative ions, and if the ionization takes place at the surface of the glowing electrodes, there will be a much larger quantity of negative ions available for carrying the current when the larger electrode is negative than when it is positive. The same considerations will explain why if the electrodes are of equal size, but placed in parts of the flame where the temperatures are different, the current will be greater when the hotter electrode is negative than when it is positive. If the electrodes are connected with a galvanometer without any battery there is a small current from the colder to the hotter electrode through the flame, for the negative ions diffuse faster than the positive, so that there will be an excess of positive ions at the electrodes. This excess will be greater at the hotter electrode than at the colder, because there are more ions formed at the hotter electrode, which will therefore be continually receiving a charge of positive electricity. Arrhenius[50] has shown that when solutions of salts of the alkali metals are thrown into a flame by a spray-producer, the conductivity of the flame is greatly increased, and that the conductivity of salt vapours in flames is closely analogous to the conductivity of an aqueous solution of the salt, being proportional to the square root of the concentration of the salt vapour in the flame. He concluded that the salt vapour is partly ionized at the high temperature of the flame. H. A. Wilson (*loc. cit.*) has shown, however, that the greater part of the ionization takes place, not in the general body of the flame, but at the surface of the glowing electrodes. He gives several independent proofs of this; perhaps the simplest is one where the salt was introduced as a bead between two glowing electrodes immersed in the flame. If the bead was placed between the electrodes, so that the salt vapour did not come into contact with the glowing metal, the current was not increased at all; if it came into contact with the negative electrode the current was very greatly increased; while if it only came in contact with the positive electrode the current was but slightly increased. The difference between the effects at the positive and negative electrodes is due to the velocity of the negative ion being much greater than that of the positive. Hittorf[51] long ago showed that the current is greater when the bead of salt is placed near the negative electrode than when it is placed near the positive. The distribution of potential between two electrodes immersed in a flame sprayed with salt solution is not by any means uniform, as is obvious from the curves in Fig. 15, which are taken

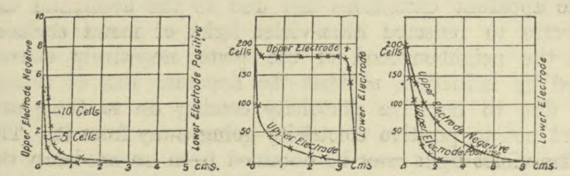


Fig. 15.

from the paper by H. A. Wilson (*loc. cit.*). The electrodes were horizontal strips of metallic gauze. The first curve represents the distribution of potential when both the electrodes are red-hot; near each electrode there is a rapid fall of potential, which is greatest at the negative one, while between the electrodes there is an approximately uniform small potential gradient. The general distribution of potential is analogous to that observed in electric discharge through gases at low pressures. In the second curve the electrodes are so far apart that the upper one is appreciably colder than the lower, and in the third the tendency of the fall of potential to be greatest at the negative electrode is very well marked. The current sent by a given potential difference through a flame depends upon the material of which the electrodes are made. Thus Petinelli[52] found that, *ceteris paribus*, the current between two carbon electrodes was about 500 times that between two iron electrodes. If one electrode was carbon and the other iron, the current when the carbon was negative and the iron positive was more than a hundred times greater than when the electrodes were reversed. A charged body placed near a flame will lose its charge even although it is placed below or to one side of the flame, so as to be out of the way of the flame gas. The electric field due to the charged body drags out of the flame the ions of opposite sign to the charge on the body. These ions move up to the body and gradually discharge it.

§ 12. *Ionization produced by Glowing Metals.*—It will thus be seen that in conduction through flames ionization in the neighbourhood of glowing metals plays a large part. The electrical properties of glowing metals have been studied with great care by Elster and Geitel,[53] to whom we owe most of our knowledge of this subject. They found that when a platinum wire is heated to luminosity in air, the air in the neighbourhood of the wire is charged with positive electricity, while the wire itself receives a negative charge. The close coincidence between the appearance of luminosity in the wire and positive electrification in the air is very remarkable. So far as we know, we do not get one without the other. At first the amount of positive electrification in the air is small, but this very rapidly increases as the temperature increases. Though at a dull red heat only positive electrification appears in the air round the wire, yet as the temperature increases some negative electricity begins to come off, until at a white heat there are as many negative as positive ions in the gas round the wire. When the pressure of the gas is very low there are always more negative than positive ions round the wire when it is white hot. This is in accordance with the experiments of Guthrie,[54] who was the first to make observations on the electrical effects near glowing bodies. He found that if a heated iron sphere was connected with the earth and held near a charged body, then when it was white hot the body soon lost its charge, whether this was positive or negative; but when it became colder the body was discharged when negatively, but not when positively, electrified. Elster and Geitel tried the effect of heating the wire in various gases, such as air, hydrogen, oxygen, carbonic acid, water vapour, and vapours of sulphur, phosphorus, and mercury. In the last they got no sign of electrification; in hydrogen at a red heat the electrification in the gas was negative; and in all the other gases and vapours the electrification at a red heat was positive. When carbon filaments were heated the electrification in the gas was always negative; these filaments, however, give off so much gas that the conditions of the experiment are somewhat indefinite. Branly[55] observed that the effects at a dull red heat depended on the nature of the glowing body; thus, when this was a lamp shade covered with oxides of lead or bismuth a positively electrified body in the neighbourhood was discharged, whilst a negatively electrified one was not. This is a reversal of the effect observed with surfaces of clean metal. Stanton[56] found that a hot surface of clean copper discharges a positively electrified conductor in its neighbourhood, but ceases to do so as soon as the copper gets coated with a layer of oxide. When, however, the hot oxidized copper and a positively electrified body are placed in an atmosphere of hydrogen, the electrified body loses its charge as long as the oxide is being reduced, but ceases to do so as soon as the reduction is complete. M'Clelland has found that by sending a strong blast against a red-hot wire both positive and negative ions are blown off, though there are more positive than negative ones. It would thus appear that by the incandescence of the metal the gas was ionized, and both positive and negative ions produced, but that then at a red heat more of one kind of ion than of the opposite went to the wire. In this case chemical forces probably exert a very large effect. For example, if we have oxidation going on we should expect the electropositive metal to combine with a negative ion and have an excess of positive ions in the surrounding gas, while if reduction is going on we should expect the oxide to combine with a positive ion, and so leave an excess of negative ions in the gas. This accords with the observations. The different rates at which the positive and negative ions diffuse would also have an influence on the sign of the charge in the gas, as in consequence of the more rapid diffusion of the negative ions more negative than positive ions would come in contact with the metal, and this would tend to make the charge in the gas positive. M'Clelland[57] has found that the velocity of the ions coming from the neighbourhood of the wire depends upon the temperature of the wire; the higher this temperature the smaller the velocity. When a wire is heated occluded gas is driven out, and this has an effect upon the electrical phenomena. The writer observed that the behaviour of a wire in a high vacuum did not become regular until it had been raised to a white heat repeatedly at intervals for more than a week, the irregularities being probably due to occluded gases, which are only got out with great difficulty. Elster and Geitel[58] showed that in gases at very low pressures the discharge of a positively electrified conductor near an incandescent wire in hydrogen, where the gas in the neighbourhood of the wire is negatively electrified, is retarded by a magnetic field when the lines of magnetic force are transverse to those of electric force. When the incandescent wire is in oxygen, where the electrification in the gas is positive, they found a very much smaller effect, and in the opposite direction. The writer has found, however, that in very intense magnetic fields the discharge of a negatively electrified body is retarded according to the same laws as that of a positively electrified body in hydrogen in much weaker fields. The theory of this effect, given in § 6, shows that the greater sensitiveness of the discharge in hydrogen to the magnetic force is due to the smallness of the mass of the negative ion at low pressures, as compared with that of the positive ion.

§ 13. *Conducting Gas produced by Arcs.*—The effect of an arc on the gas in its neighbourhood is very similar to that of an incandescent wire. Thus in the neighbourhood of the arc, in air or oxygen, there is positive electrification, while near the arc, between platinum terminals in hydrogen, there is, at atmospheric pressure, a slight negative electrification.[59] The gases sucked from the neighbourhood of the arc retain their conductivity for some time, and, like those from flames, can be bubbled through conducting liquids, or passed through several layers of wire gauze, without losing it. The conduction through these gases, which has been studied by M'Clelland,[60] and Merritt and Stewart,[61] exhibits the ordinary characteristics of discharge through ionized gas. M'Clelland has measured the velocity of the ions in an electric field, and finds it to be of the same order as for ions from flames. The velocity of the negative ion is greater than that of the positive, and the brighter the arc the slower the velocity. The electrification in the neighbourhood of the arc depends upon the nature of the terminals. Thus if an arc be sent through hydrogen, between well-oxidized copper terminals, the oxide gets reduced, and while reduction is going on there is negative electrification in the hydrogen near the arc; when, however, the oxide has been reduced and the terminals are bright, there is positive electrification near the arc. This shows the influence exerted by chemical effects on the sign of the electrification. The considerations advanced to explain the analogous effects with incandescent metals will apply to this case.

Conducting gas seems to be produced not only by the arc discharge, but also to a greater or less degree by every form of electric discharge. Thus Hittorf[62] showed that a few galvanic cells can send a current through a gas which is conveying a discharge at right angles to the current. Schuster[63] made an experiment which showed this effect in a very clear way. A large discharge-tube containing air at a low pressure was divided into two compartments by a metal plate with openings round the perimeter, these openings allowing the gas in one compartment to flow into the other, while the metal screened off one compartment from any electrical action occurring in the other. When a vigorous discharge passed through one compartment a potential difference of about one-quarter of a volt was sufficient to send a current through the gas in the other compartment. Again, if a blast of air be blown across the terminals of an electrical machine in action upon the disc of an electroscope, charged with either positive or negative electricity, the electroscope is rapidly discharged.[64] A charged body placed near a place where sparks are passing, whether from an induction coil or an electrical machine, will soon lose its charge.

§ 14. *Conductivity produced by Ultra-Violet Light.*—The discovery by Hertz,[65] in 1887, that the incidence of ultra-violet light on a spark gap facilitates the passage of a spark, led to a series of investigations by Hallwachs,[66] Hoor,[67] Righi,[68] and Stoletow[69] on the effect of ultra-violet light on electrified bodies. These researches have shown that a freshly cleaned metal surface, charged with negative electricity, rapidly loses its charge, however small, when exposed to ultra-violet light, and that if the surface is insulated and without charge initially, it acquires a positive charge under the influence of the light. The magnitude of this positive charge may be very much increased by directing a blast of air on the plate. This, as Zeleny[70] has shown, has the effect of blowing from the neighbourhood of the plate negatively electrified gas, which has similar properties to the charged gas obtained by the separation of ions from a gas exposed to Röntgen rays or uranium radiation. If the metal plate is positively electrified, there is no loss of electrification caused by ultra-violet light. This has been questioned, but a very careful examination of the question by Elster and Geitel[71] has shown that the apparent exceptions are due to the accidental exposure to reflected ultra-violet light of metal surfaces in the neighbourhood of the plate negatively electrified by induction, so that the apparent loss of charge is due to negative electricity coming up to the plate, and not to positive electricity going away from it. The ultra-violet light may be obtained from an arc-lamp, the effectiveness of which is increased if one of the terminals is made of zinc or aluminium, the light from these substances being very rich in ultra-violet rays; it may also be got very conveniently by sparking with an induction coil between zinc or cadmium terminals. Sunlight is not rich in ultra-violet light, and does not produce anything like so great an effect as the arc light. Elster and Geitel,[72] who have investigated with great success the effects of light on electrified bodies, have shown that the more electro-positive metals lose negative charges when exposed to ordinary light, and do not need the presence of the ultra-violet rays. Thus they found that amalgams of sodium or potassium enclosed in a glass vessel lose a negative charge when exposed to daylight, though the glass stops the small amount of ultra-violet light left in sunlight after its passage through the atmosphere. If sodium or potassium be employed, or, what is more convenient, the mercury-like liquid obtained by mixing sodium and potassium in the proportion of their combining weights, they found that negative electricity was discharged by an ordinary petroleum lamp. If the still more electro-positive metal rubidium is used, the discharge can be produced by the light from a glass rod just heated to redness; but there is no discharge till the glass is luminous. Elster and Geitel arrange the metals in the following order for the facility with which negative electrification is discharged by light:—rubidium, potassium, alloy of sodium and potassium, sodium, lithium, magnesium, thallium, zinc. With copper, platinum, lead, iron, cadmium, carbon, and mercury the effects with ordinary light are too small to be appreciable. The order is the same as that in Volta's electro-chemical series. With ultra-violet light the different metals show much smaller differences in their power of discharging negative electricity than they do with ordinary light. Elster and Geitel found that the ratio of the photo-electric effects of two metals exposed to approximately monochromatic light depended upon the wave-length of the light, different metals showing a maximum sensitiveness in different parts of the spectrum. This is shown by the following table for the alkaline metals. The numbers in the table are the rates of emission of negative electricity under similar circumstances. The rate of emission under the light from a petroleum lamp was taken as unity:—

	Blue.	Yellow.	Orange.	Red.
Rb . . .	·16	·64	·33	·039
Na . . .	·37	·36	·14	·009
K . . .	·57	·07	·04	·002

The table shows that the absorption of light by the metal has great influence on the photo-electric effect, for while K is more sensitive in blue light than Na, the strong absorption of yellow light by Na makes it more than five times more sensitive to this light than K. Stoletow, at an early period, called attention to the connexion between strong absorption and photo-electric effects. He showed that water, which does not absorb to any great extent either the ultra-violet or visible rays, does not show any photo-electric effect, while strongly coloured solutions, and especially solutions of fluorescent substances such as methyl green or violet, do so to a very considerable extent; indeed, a solution of methyl green is more sensitive than zinc. Hallwachs[73] has proved that in liquids showing photo-electric effects there is always strong absorption; we may, however, have absorption without these effects. Phosphorescent substances, such as sulphide of calcium, show this effect, as also do various specimens of fluor-spar. As phosphorescence and fluorescence are probably accompanied by a very intense absorption by the surface layers, the evidence is strong that to get the photo-electric effects we must have strong absorption of some kind of light, either visible or ultra-violet.

The connexion between the potential gradient and the rate of escape of negative electricity from the plate has been investigated by Stoletow,[74] Righi,[75] and Elster and Geitel.[76] The method adopted by Stoletow was as follows:—Light from an arc-lamp A, Fig. 16, passed through a hole in a metal screen; it then fell on the metal plates C, connected up with a battery and galvanometer. The plate nearest the light was perforated, and the light passed through the perforations on to the sensitive plate connected with the negative pole of the battery. The current passing round the circuit was measured by a galvanometer. The results of Stoletow's investigations are shown in the curves of Fig. 17, where the ordinates represent the current, the abscissæ the potential difference between the plates, and the numbers on the curves the distance between the plates in millimetres. X is a small unknown distance. The conduction does not obey Ohm's law, the current not increasing so fast as the potential difference. There seem, however, indications of a stage when the current increases more rapidly than the potential difference, probably due to a greater number of ions being pulled away by the greater potential gradient. For large

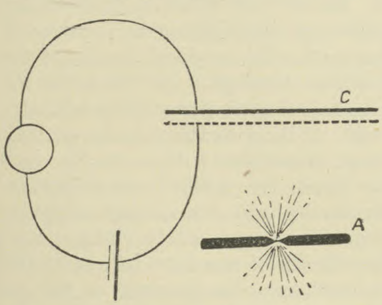


Fig. 16.

potential differences the curves seem to approximate to straight lines inclined to the axis along which potential differences are measured. In the corresponding curves for conduction through a gas exposed to Röntgen rays or uranium radiation the curves ultimately become straight lines parallel to this axis. Stoletow has shown, however, that at low pressures the curves for ultra-violet light become parallel to the axis, so that the current gets "saturated," just as it does in other cases of discharge through conducting gases. At atmospheric pressures Stoletow has shown that the current for a given gas depends only on the potential gradient, so that it is not altered if the potential difference and the distance between the plates are increased in the same proportion. The nature of the gas between the plates has a considerable effect upon the current through the gas. Elster and Geitel[77] measured the current when the illuminated plate was immersed in air, carbonic acid, oxygen, and hydrogen, and found that it was much greater through carbonic acid than through any of the other gases. Stoletow[78] and Righi[79] have investigated the effect of the pressure of the gas on the current passing through it, and find that the current increases as the pressure diminishes, until a certain pressure is reached, below which further diminution causes a diminution in the current, though the change in the current is small compared with the change in the pressure. The stage at which the change of current with pressure is most rapid is at a pressure a little greater than that at which the current is a maximum. The amount of change in the current with the pressure may be illustrated by the following measurements given by Stoletow. The potential difference was equal to that of 65 Clark's cells, and the distance between the plates was 3·71 mm.; p stands for the pressure in millimetres of mercury, and c for the corresponding current.

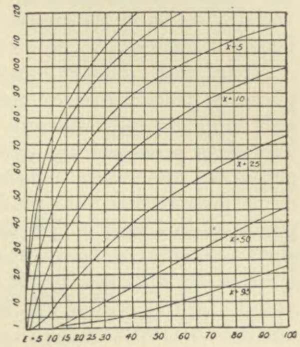


Fig. 17.

p=754, 152, 21, 8·8, 3·3, 2·48, 1·01, ·64, ·52, ·275, ·105, ·014, ·0047, ·0031

c=8·46, 13·6, 26·4, 32·2, 48·9, 74·7, 106·8, 108·2, 102·4, 82·6, 65·8 53·8, 50·7, 49·5

If p_m is the pressure at which the current is a maximum, Stoletow has shown that p_m is proportional to the potential gradient; he has also shown that at very low pressures the current is not, as it is at atmospheric pressures, fixed by the potential gradient, but that with the same potential gradient the current increases with the distance between the plates. This seems to indicate that at these low pressures the ionization is not confined to the surface of the plate, but extends throughout a layer of finite thickness, so that when the plates are brought nearer together than the thickness of this layer the supply of ions is curtailed and the current consequently reduced. Stoletow found that at exceedingly low pressures the current was independent of the pressure. This would seem to indicate that in these cases the current was carried either by mercury vapour from the pump or more probably by corpuscles from the metal surface at these very low pressures the current is very easily saturated and thus becomes independent both of the electric field and of the pressure. The fact that Rutherford found the velocity of the ions at higher pressures to be the same whatever metal was used, indicates that at higher pressure little, if any, of the current is carried by molecules torn from the metal plate. Stoletow (*loc. cit.*) made a series of experiments to see if the discharge from a negatively electrified plate lasted an appreciable time after the light was cut off. He was not able to obtain any evidence that the cessation of the leak was not contemporaneous with the cessation of the light, and was able to show that there was no leak after the light had been cut off for $\frac{1}{1000}$ of a second.

Elster and Geitel[80] found that the orientation of the plane of polarization of the incident light had considerable influence upon the amount of the photo-electric effect. The effect produced by light polarized in a plane at right angles to the plane of incidence is at oblique incidence much greater than that produced by light polarized in the plane of incidence. To show this effect the reflecting surface ought to be very smooth; a suitable surface is most easily obtained by using the liquid alloy of sodium and potassium, which has the further advantage of being sensitive to ordinary light. In light polarized in a plane at right angles to that of incidence, the periodic electric intensity which, on the electro-magnetic theory of light, exists in the incident light-wave has a component at right angles to the reflecting surface, and produces a periodic effect on the electrification of the surface. When the light is polarized in the plane of incidence the electric intensity is parallel to the reflecting surface, and does not produce a periodic variation in the electrification over this surface. The periodic electric intensity at right angles to the surface seems to facilitate the escape of negative electricity from the surface. Another circumstance which may be connected with the effect produced by the position of the plane of polarization, is the fact discovered by Quincke,[81] that light polarized at right angles to the plane of incidence penetrates more deeply into metal than light polarized in that plane. At normal incidence the electric intensity in the incident light has no component at right angles to the reflecting surface, whatever the plane of polarization. Elster and Geitel have shown that when the surfaces are smooth there is little photo-electric effect at normal incidence.

The question whether ultra-violet light produces any ionization when it passes through a gas without falling on a metallic surface has been investigated by Buisson[82] in the case of air, and by Henry[83] for the vapours of iodine and methyl iodide, two gases which are very much ionized when Röntgen rays pass through them; neither of these observers could detect any trace of ionization. Quite recently, however, Lenard[84] has shown that ionization is produced in certain cases by the passage through a gas of ultra-violet light; the kind of light which produces this effect is, however, absorbed so rapidly by the gas that the ionization can only be observed within a few centimetres of the source of light which in Lenard's case was a spark between aluminium terminals. C. T. R. Wilson[85] has shown that when ultra-violet light passes through dust-free damp air it produces cloudy condensation along its path; he could, however, detect no sign of electrification on the drops, so that this is not evidence of ionization. Elster and Geitel[86] found that at very low pressures the rate of escape of negative electrification is very much diminished by a magnetic force parallel to the reflecting surface. We have already considered the theory of this effect in § 6. Lenard and Wolff[87] found that a steam jet in the neighbourhood of a negatively electrified surface illuminated by ultra-violet light showed by its change of colour that the steam in it had been condensed. They attributed this condensation to metallic dust coming from the electrified surface, the metallic dust, in accordance with Aitken's[88] experiments, producing condensation by forming nuclei around which the water-drops collect. The indications of a steam jet are, however, very ambiguous, as condensation is produced not only by dust, but also by chemical action and by the presence of ions. We have already seen reasons for thinking that little, if any, of the current from the negatively electrified surface is carried by metallic particles.

The phenomena connected with the discharge of negative electricity by ultra-violet light admit of explanation by the theory that the incidence of ultra-violet light on a metal causes a discharge of negatively electrified corpuscles from the metal; when the metal is surrounded by a gas at a very low pressure we have seen that the existence of this stream of corpuscles from the metal can be detected by direct experiment. Those rapidly-moving corpuscles coming from the metal will ionize the gas through which they pass; but if the gas is at a pressure comparable with the atmospheric pressure, they will only be able to penetrate a short distance into the gas; the metal will thus be surrounded by a thin layer of ionized gas. If the metal is positively electrified the electrostatic attraction will prevent the escape of the negatively electrified corpuscles, so that in this case there will not be any layer of ionized gas round the metal. When this ionized layer exists, and is acted on by an electric field, the positive ions in the layer will move in towards the metal plate, while the negative ones will move away from it. These positive and negative ions, however, tend to recombine and form a neutral molecule, so that the only ions which are available for carrying a current of electricity through the gas are those which are torn from the ionized layer before they have time to recombine. Thus the stronger the field the greater the number of negative ions liberated from the layer, and therefore the greater the current. As the strength of the electric field is increased, the strength of the current will increase until all the negative ions are torn from the layer before they have time to combine with the positive ions; when this occurs the current will be saturated, and will not increase with the electric field, until the latter gets so strong that it imparts so great a velocity to the ions already in the field that they are able to produce fresh ions. Let us now consider what on this theory would be the effect of diminishing the pressure of the gas surrounding the metal. The corpuscles coming from the metal will travel farther through a gas the lower the pressure, while the number of ions per cubic centimetre produced by the passage of the ions through the gas will diminish as the pressure diminishes: thus, as the ions are a greater distance apart, the rate of recombination will be slower, as each ion has to move through a greater distance before meeting with an oppositely charged ion; in addition to this the velocity of the ions in an electric field of given strength increases as the pressure of the gas diminishes. Thus the negative ions will be more easily torn from the ionized layer when the pressure is low than when it is high, and thus the current will increase when the pressure of the gas is diminished. This increase will go on until the layer through which the ionization extends fills the space between the electrodes between which the current is passing; when this stage is reached any further diminution in the pressure will diminish the number of ions produced between the electrodes, and hence the number available for carrying the current. The saturation value of the current will therefore diminish; thus there will be a certain pressure, at which, with a given electric field, the current through the gas is a maximum. When the pressure of the gas is exceedingly low, the corpuscles coming from the metal will make very few collisions before reaching the other electrode. Thus there will be very little ionization between the electrodes, and there will be very little recombination, as there are so few positive ions for the negative ones to combine with. Thus the current will be very easily saturated, and will become independent both of the electric field and of the pressure, becoming equal to that carried by the negative corpuscles discharged from the surface of the metal by the action of the ultra-violet light. Thus this theory gives a simple explanation of the most conspicuous photo-electric effect. When the pressure of the gas is low and the potential gradient large the negative ions will be moving through the gas with very great velocities; for, as we have seen, the velocity varies inversely as the pressure, and at atmospheric pressure in air the velocity is about 1·5 cm./sec. for a potential gradient of 1 volt per centimetre. Now, in the case of the cathode and Lenard rays (see § 19) we have also negatively electrified particles moving with great velocities, and we know that in these cases the gas is ionized by the passage through it of the particles. We should expect then at low pressure, in the case of the discharge by ultra-violet rays, to get a secondary volume ionization due to the motion of the negative ions. The fact that the saturation current through a thick layer of gas is greater than that through a thin layer, indicates that there is some such volume ionization.

§ 15. *Conductivity in Gases produced by Röntgen Rays.*—Röntgen rays passing through a gas turn it into a conductor, and the gas retains its conductivity for some little time after the rays have ceased. The gas through which the rays have passed shows all the characteristics mentioned in § 1; the conductivity is discharged when the gas is sucked through a plug of cotton-wool or bubbled through water, or subjected to a strong current of electricity. If the gas is sent through a metal tube or allowed to stand in a metal vessel it acquires a positive charge, because the negative ions, diffusing more rapidly than the positive, reach the walls in greater numbers, and so leave an excess of positive ions in the gas. The ease with which the negative ions give up their charges to the metal seems to depend to some extent on the nature of the metal, for Rutherford [89] found that the excess of positive ions was greater when the Röntgenized gas had passed through zinc tubes than when it had passed through copper. If the tubes through which the Röntgenized gas is blown are made of insulating material the ions cling to the walls of the tube for a considerable time, and a blast of air sent through them will dislodge ions hours after the Röntgenized air has passed. Minchin [90] has shown that metal plates previously uncharged get, when exposed to Röntgen rays, charges of electricity, positive in some cases, negative in others. The potentials to which these metals are raised by the charges are not large, being, except in the case of sodium or sodium amalgam, much less than 1 volt. The effects are due to the Röntgenized gas acting, as far as the contact difference of potentials of metals immersed in them go, like a bath of an electrolyte (see § 9), so that two different metals connected with the quadrants of an electrometer will show the same potential difference as they would if immersed in an electrolyte.

We can measure q, the number of ions produced per second by the rays in a cubic centimetre of the gas, by measuring I, the saturation current through the gas, for (see § 7) $I = qle$, where l is the distance between the parallel plates which act as electrodes, and e is the charge on the ion. If we use this method to determine the ionization of the gas by the rays we must be careful, for a reason which will be explained later, not to let the rays strike against the electrodes. From experiments made by Perrin,[91] Rutherford,[92] and the writer,[93] the results of which are given in the following table, it will be seen that the amount of ionization of gas at the same pressure varies very much with the nature of the gas. It is least for hydrogen and greatest for mercury vapour, but is not proportional to the density of the gas, for the ionization is much greater for HCl than it is for CO_2.

Value of q (Air = 1).

Gas.	Rutherford.	Perrin.	J. J. Thomson.
H_2	·5	·026	·33
N_2	·9	...	·89
O_2	1·2	...	1·1
CO_2	1·2	1·34	1·4
CO			
NO	...	...	1·08
N_2O	...	1·3	1·47
C_2N_2	...	...	1·05
C_2H_2	...	...	1
H_2S	6	...	6
SO_2	4	6	6·4
HCl	11	8?	8·9
Cl_2	18	...	17·4
NH_3	...	·1?	1?
Coal Gas	·8		

[For helium Strutt (*Phil. Mag.*, March 1900) found the value ·44]. The values of q for the vapours of mercury and iodine are greater than any of those given in the preceding table, but the difficulties in the way of getting accurate numerical values are very great. The numbers given above show that, with the exception of CN, the coefficients of ionization of the gases obey, approximately at any rate, the addition law, *i.e.*, if 2[A], 2[B] represent the coefficients of ionization for the elementary gases A_2, B_2 respectively, the ionization of the compound gas, A_pB_q will be equal to $p[A]+p[B]$. It is only when the current is saturated that it is proportional to the coefficient of ionization. With very small potential differences the current through hydrogen is greater than that through air, though the coefficient of ionization is very much less. We have by § 7—

$$\iota = e(R_1 + R_2)\sqrt{\frac{q}{a}}$$

if the current is small; hence this current is proportional to $R_1 + R_2$, the mean velocity of the ions under a given electric intensity. Now, the velocity of the ions in hydrogen is about three times that in air, and this greater velocity is more than sufficient to counterbalance the effect of the smaller ionization. The very large ionization of mercury vapour is interesting, as this is a monatomic gas; the process of ionization must, therefore, involve much finer subdivision than the splitting of a molecule into atoms. The number of ions produced by the rays is very small compared with the number of molecules, the proportion between the two depending, of course, upon the intensity of the radiation. It may, however, give some idea of the order of this quantity to state that in some experiments made by the writer, using the rays from a bulb of the kind ordinarily used for taking Röntgen photographs, the proportion of the number of ions to the number of the molecules of the gas was as 1 to 10^{12}. Perrin (*loc. cit.*) has shown that the number of ions produced in a cubic centimetre of a gas is proportional to the pressure of the gas, and independent of the temperature. This statement is equivalent to saying that the number of ions produced from a given number of molecules of the gas is independent of the pressure and directly proportional to the absolute temperature of the gas.

§ 16. *Absorption of Rays by the Gas.*—The rays gradually get absorbed by the gas. The intensity of a parallel beam of rays after travelling through a distance d in the gas may be represented by $\epsilon^{-\lambda d}$, the intensity when the beam entered the gas being taken as unity. λ may be called the co-efficient of absorption of the gas; it depends upon the kind of rays travelling through the gas, being small for rays emitted from a very highly exhausted bulb —Röntgen's "hard rays"—and larger for the rays emitted by a bulb at a higher pressure. As we have no way of specifying the kind of ray we are using, the determinations of λ are indefinite. We can, however, by using the same bulb in the same condition, compare the values of λ for different gases for the same kind of radiation. Rutherford found that while the intensity of the radiation after passing through 10 cm. of air, oxygen, or coal gas was only diminished by about 1 per cent., it was diminished by about 4 per cent. after passing through 10 cm. of sulphuretted hydrogen, by 20 per cent after passing through 20 cm. of chlorine, by 50 per cent. after passing through 7 cm. of mercury vapour at atmospheric pressure, and by 60 per cent. after passing through 13 cm. of the vapour of methyl iodide. The order of the absorbing power of the gases was the same as that of the amount of ionization, and in many cases the coefficient λ seemed to be roughly proportional to the ionization. If more accurate determinations of λ should confirm this result, which seems to be true for uranium radiation, and if the energy absorbed is spent in ionizing the gas, then since the amount of energy absorbed is proportional to the number of ions formed, whatever the gas from which the ions are derived, it follows that the work required to produce a given number of ions is the same for all gases.

§ 17. *Ionization near a Metal Plate exposed to Röntgen Rays.*—Perrin (*loc. cit.*) found that the ionization close to a metal plate struck by Röntgen rays was greater than in the gas at some distance from the rays. This may be shown by the following experiment due to Perrin :—

AA^1 (Fig. 18) is a condenser with a guard ring. A beam of Röntgen rays, indicated by the arrows, passes between its plates without touching them, and enters a second condenser BB^1 at right angles to the plates, through a window KL covered with thin aluminium. The distance between the plates of the condenser BB^1 is equal to $\alpha\beta$. The plates B and $\alpha\beta$ are connected with the needle of an electrometer, and put to earth, and the plates B^1 and A^1 are connected with the terminals of a battery containing a large number of cells, the middle of this battery being put to earth. Thus B^1 and A^1 are at equal and opposite potentials. The connexion between the needle and the earth is then broken, and the rays sent through the condensers. If there is no secondary effect due to the impact of the rays on the metal, since rays of the same intensity pass through the same volume of gas in the two condensers, the ionization between the plates of the condenser ought to be the same, and so under strong electric fields the charge received by B would be equal and opposite to that received by $\alpha\beta$. Hence the needle of the electrometer would remain uncharged. It is found, however, that the needle does receive a charge if the metal plates of the condenser BB^1 are dry, the amount of the charge depending upon the material of which the plates are made. The sign of the charge is such as to show there is more ionization in BB^1 than in AA^1. If the plates are wet with water, alcohol, or petroleum, the needle of the electrometer remains uncharged. There is thus an increased ionization produced when Röntgen rays strike directly against metal. The interposition of a film of water between the metals and the rays seems to destroy, or at any rate greatly reduce, this effect, which was called by Perrin the metal effect.

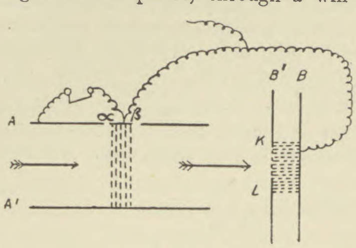


Fig. 18.

The method of studying this effect adopted by Langevin and Townsend [94] was to measure the saturation currents between two parallel metal plates. A considerable portion of one of these plates was made of aluminium, and its inner surface wetted, so as to get rid of the metal effect. The Röntgen rays, passing through this plate at right angles, fell on the other. Apart from the metal effect, the total amount of ionization between the plates is proportional to the distance between them; hence increasing this distance from d to $d+x$ should increase the amount of ionization and therefore the saturation current by an amount independent of d. It was found, however, that the amount by which the saturation current is increased for a given value of x is much greater when d is small than when it is large, and although it attains a constant value when the plates are a considerable distance apart, it does not do so before, in a gas at atmospheric pressure, d amounts to several millimetres. Thus the abnormal ionization extends from the surface through a layer of gas several millimetres thick. By making a series of determinations of the saturation current for a consecutive series of values of d, we can determine the amount of ionization in the various layers of the gas. In this way Townsend has shown that the ionization in a layer near the surface of the metal is sometimes more than twenty times that in a layer of equal thickness some distance away from the metal. The effect depends greatly on the particular metal of which the plate is made. If it is a heavy one, the ionization near the metal is very great, but the thickness of the layer through which the ionization is abnormal is comparatively small; but if the metal is a light one, the ionization near the surface is not so great, though the thickness of the layer through which the influence of the metal is felt is much greater. The results of Townsend's experiments are represented in Fig. 19, where the ordinates represent the total ionization due to the secondary rays within a distance from the surface represented by the abscissæ. Curves are given when the reflecting surfaces are copper, zinc, and aluminium. The line P represents the ionization due to the direct rays. Perrin seemed to think that the metal effect might be due to the greater ease with which a gas is ionized when brought near to a conductor; we had an example of this in the case of conduction through flames. The thickness of the layer through which the ionization is anomalous seems to imply that some other cause must be at work. It would seem most probable that this ionization is the result of the secondary radiation which is produced when Röntgen rays pass through matter. Röntgen [95] showed that when the rays pass through air, the air gives off secondary radiations having all the properties of Röntgen rays, but of less penetrating power. Sagnac [96] showed that metals on which Röntgen rays fall give out secondary rays; these are not the primary rays irregularly reflected, but are different in character, not being nearly so penetrating. The lighter the metal struck by the primary rays, the more penetrating are the secondary rays, although when the metal is light the rays are not so numerous as when it is heavy. He showed that when the secondary rays strike against a metal, tertiary rays are given out which are still less penetrating than the secondary. As these secondary and tertiary rays ionize a gas when they pass through, it is clear that until we are so far away from the metal that they are absorbed by the gas before reaching us, the ionization in the gas is greater than that due to the primary rays. The secondary rays observed by Sagnac could traverse several centimetres of air before being absorbed. The fact that the greater part of the metal effect takes place within a few millimetres of the surface of the metal shows that the rays producing this ionization are absorbed by a few millimetres of air; they are probably tertiary rays produced by the passage through the surface layers of the metal of secondary rays starting from a little behind them.

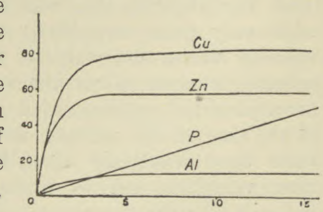


Fig. 19.

§ 18. *Conduction produced by the Radiation from Uranium, Thorium, &c.*—Becquerel [97] showed that a gas surrounding a piece of uranium or one of its salts becomes a conductor of electricity, and Schmidt [98] found that the same is true of thorium. Subsequently M. and Mme. Curie [99] found that this property was possessed to a very much greater extent by two new substances, radium and polonium, which they obtained from pitch-blende. Polonium appears to emit a kind of radiation very similar to the Röntgen rays, inasmuch as, besides rendering gases conductive, it produces phosphorescent effects on a potassium platinocyanide screen, and affects a photographic plate even when protected by a screen opaque to ordinary light. Like the Röntgen radiation, it can be neither refracted nor polarized;

it is not, however, nearly so penetrating as the ordinary primary Röntgen radiation, resembling, in this respect, the secondary Röntgen radiation. Radium emits radiation of at least two types—one, easily absorbed, resembles Röntgen, the other, more penetrating, resembles cathode rays, being deflected by a magnet, and carrying a charge of negative electricity. The properties of gas rendered conducting by uranium or thorium radiation have been investigated by Becquerel (*loc. cit.*), Rutherford,[100] Owens,[101] De Smolan and Beattie.[102] These properties are the same as when the gas is made a conductor by Röntgen radiation; the velocities of the ions are the same, as are also the laws connecting the current and the potential difference. The uranium radiation being much more quickly absorbed than Röntgen radiation, the phenomena due to the former are liable to be complicated by absorption effects. Rutherford has shown that uranium salts emit at least two kinds of radiation—one is absorbed in a few millimetres of air at atmospheric pressure, while the other can traverse many centimetres before being extinguished. The ionization in thin layers of air close to the surface of the uranium is chiefly due to the more easily absorbed radiation, and as this is wholly absorbed by a few millimetres of the gas, we can by altering the gas over the uranium compare the total amount of ionization in different gases when all this radiation is absorbed. Rutherford found that this was the same for air, hydrogen, oxygen, carbonic acid, coal gas, hydrochloric acid, and ammonia, and that though in hydrogen the ionization close to the uranium was not so great as in a heavier gas, yet the greater thickness of the layer through which it extended just compensated for the deficiency in intensity. If we could be sure that all the energy of the rays is spent in ionizing the gas, and none in raising the temperature, this would indicate that the work required to produce a definite number of ions is independent of the gas from which they are produced, a result suggested also by the experiments on conduction due to Röntgen radiation. Rutherford's experiments on compounds of thorium indicate that, besides emitting radiation, these emit something which is itself radio-active. The activity of this emanation gradually disappears, but lasts long enough to be appreciable for some minutes after it has left the thorium. It is not destroyed by being passed through plugs of cotton-wool or being bubbled through water or sulphuric acid, processes which, as we have seen, would be fatal to the existence of ions. The emanation can pass through very thin plates of metal and through several sheets of paper. It is blown about by the slightest draught, even when acted upon by a strong electric field—in fact, an electric field seems to have no effect upon it, a fact which suggests that it is not permanently charged with electricity. This deduction is confirmed by the circumstance that on blowing a quantity of it into an inductor no evidence of any charge can be detected. Rutherford has also shown that if the air between two plates is made conducting by thorium radiation, and a current of electricity sent between them, the metal against which the positive ions discharged becomes radio-active, and retains, though with gradually diminishing intensity, this power long after the current has ceased. The radiation it emits is not identical in character with that emitted by the thorium, there being great differences in the proportion of the two radiations stopped by an aluminium plate of given thickness. A plate rendered radio-active in this way can be washed with water, caustic potash, or nitric acid without losing its activity, which is, however, considerably diminished by warm sulphuric acid. M. and Mme. Curie (*Comptes Rendus*, Nov. 1899) have shown that substances exposed to the radiation from radium become themselves radio-active for a time; the radiation from polonium produces a similar effect, but to a much smaller extent. Debierne (*Comptes Rendus*, July 1900) has shown that the radiation from actinium produces very intense induced radio-activity.

Elster and Geitel[103] have shown that the current through a gas at a very low pressure made a conductor by the radiation from radium is much diminished by a strong magnetic field, when the lines of magnetic force are at right angles to the current.

§ 19. *Conductivity due to Passage of Cathode and Lenard Rays through a Gas.*—The passage through a gas of the small particles carrying negative charges which constitute cathode and Lenard rays makes it a conductor in which both positive and negative ions are present. This has been proved for cathode rays by the writer,[104] and by Lenard[105] for the rays which bear his name. The conduction through gas ionized in this way follows the same laws as in the cases hitherto considered, the current increasing less rapidly than the potential difference, and reaching a saturation value at which it remains constant even though the potential difference is greatly increased. The number of ions produced by the passage of these negative charges through a gas is many times the number of these charged particles. The amount of ionization produced by Lenard rays in different gases has been investigated by M'Lennan,[106] who found that, for all the gases he tried (air, oxygen, nitrogen, carbonic acid, hydrogen, and nitrous oxide), the amount of ionization produced in one second by Lenard rays of given intensity in 1 cubic centimetre was proportional to the density of the gas, and independent of its chemical composition. Thus the ionization in 1 cc. of oxygen at 47 mm. pressure is the same as in 1 cc. of hydrogen at 16×47 mm. pressure. Lenard[107] has shown that the absorption of his rays depends only on the density and not on the chemical composition, so that in this case, as in the case of uranium and probably of Röntgen radiation, equal absorption gives equal ionization, whatever the nature of the gas.

§ 20. *Spark Discharge through Gases.*—Hitherto we have only considered cases when conductivity was conferred on the gas by agents independent of the electric field used to drive the current through it, and for the conducting gases hitherto considered the weakest electric field was sufficient to cause some current to flow through the gas. We shall now proceed to consider cases where the conductivity of the gas is due to the electric field itself. Here there is neither appreciable conductivity nor current unless the electric field is strong. Let us suppose that we have two parallel plates of metal placed close together, and that one plate is connected through a large resistance to one pole of a large battery of cells, while the other plate is connected with the other pole; no appreciable current will pass round this circuit unless the electromotive force of the battery exceeds a definite value, but when it does exceed this value a current will pass, accompanied by luminosity between the plates, the potential difference between which will be found to be little if at all affected by the number of cells in the circuit. This potential difference, which is frequently called the statical spark potential, we will call the spark potential difference; its value depends on the distance between the plates, and on the nature and pressure of the gas in which they are immersed. It must not be supposed, however, that whenever it is applied to the plates we always get a spark to pass. If it is only maintained for a short time, it may be that no spark passes; indeed, it is possible under certain circumstances to apply to the plates a much greater potential difference without getting a spark. Faraday[108] long ago showed that it takes a greater potential difference to start the first spark than is required to keep up the sparks, and that the effect of one spark in facilitating the passage of a second does not die away until the gas has rested for several minutes. The writer[109] found that if the gas between the electrodes was dried with extreme care, it was possible to get the gas to stand without discharge a potential difference between the electrodes three or four times as great as that which was sufficient to produce a discharge in less perfectly dried gas; the gas, however, seemed to be in an unstable state as far as its electrical behaviour was concerned, for when once a spark had been forced through it, the potential difference between the plates at once fell to the value it had before the gas was dried, and the gas was not again able to withstand a potential difference any greater than this without discharge until it had had a rest for several minutes. The very great potential difference withstood in this case without discharge seems to suggest that if we had a perfectly pure dry gas it might be able to withstand almost any potential difference without discharge. It would, however, be in an unstable state, and might be compared to a supersaturated solution, into which a foreign body has to be introduced to start the crystallization, though the process, when once started, goes on until the solution ceases to be supersaturated; another analogy would be gas supersaturated with aqueous vapour, where for condensation to take place we require the presence of nuclei round which the drops may collect. Various influences may prevent the gas getting into the unstable electric state, such as the presence of moisture, the fall of ultra-violet light on the cathode or of Röntgen rays on the spark gap, the presence of gases from flames, sparks, or arcs—in short, the presence of any ion seems fatal to the continuance of this unstable state. The influence of several of these agents has been investigated by Warburg,[110] whose method consisted in measuring the interval which elapses between the application of a potential difference greater than the spark potential difference and the passage of the spark. This *lag* of the spark, as we may call it, is a very important quantity in the phenomena attending the passage of the spark, for if it is great, and the spark terminals are connected with an induction coil or some other source of electricity furnishing a potential difference which changes quickly, the terminals may support for the short time during which it lasts a potential difference which would cause a spark to pass if the lag were much shorter. Thus an agent may make sparks pass when the potentials of the terminals are inconstant by diminishing the time of lag, even though it has no effect on the steady potential difference required to produce a spark. A notable illustration of this is afforded by the action of ultra-violet light on sparks passing between the terminals of an induction coil. Hertz[111] showed that when the spark gap was exposed to such light, sparks passed much more easily than when the light was screened off; then E. Wiedemann and Ebert[112] showed that it was only when the cathode was exposed to the light that any effect was produced (it is only in this case that any ions are sent into the spark gap); finally, Warburg (*loc. cit.*) showed that the effect of the ultra-violet light was to diminish very greatly the lag, without producing much effect on the statical spark potential. Swyngedauw[113] also showed that ultra-violet light had a much greater effect on the sparking potential when this was rapidly changing than it had on the statical spark potential.

The effect of ultra-violet light on the lag is strikingly shown by the following table taken from Warburg's paper. The fractions in the columns have for their numerator the number of times a spark passed when the potential difference at the top of the column was applied to the electrodes for a time ·0012 seconds: the denominator of the fraction is the number of times the potential difference was applied; thus the fraction $\frac{0}{10}$ indicates that the spark never passed, the fraction $\frac{10}{10}$ that it always did so. Hydrogen at a pressure of 11 millimetres of mercury was employed. The statical spark potential was 960 volts in daylight, 1260 in the light from an arc lamp which had passed through glass, and 1080 in the direct light from the lamps:—

Potential Difference in Volts.	960.	1440.	1500.	1920.	2040.	2940.	3000.	3960.	5040.	8940.
In the dark .	...	...	...	...	...	...	$\frac{0}{10}$	$\frac{1}{10}$	$\frac{1}{10}$	$\frac{8}{10}$
In daylight .	...	...	$\frac{1}{10}$	...	$\frac{3}{10}$	$\frac{8}{10}$				
In the arc light through glass	...	$\frac{0}{10}$	...	$\frac{10}{10}$						
In the arc light	$\frac{0}{10}$	$\frac{10}{10}$								

It will be seen from this table that we may apply in the dark for ·0012 sec. a potential difference nine times that required to produce a spark with a steady potential difference without always producing a spark, and also that daylight has a distinct effect in diminishing the lag of the spark. It was also shown by Warburg that the chief effect of a small quantity of water vapour was to make the lag very much less than for a perfectly dry gas.

The significance of this lag seems first to have been pointed out by Jaumann,[114] who showed that it was much diminished if very rapid changes took place in the potential of the electrodes. During the lag some process is going on by which the gas between the electrodes is being changed from an insulator into a conductor. Experiments were made by Jaumann and Warburg[115] to see whether this process was accompanied by a dark discharge of electricity through the gas—no luminous effects can be observed in the darkest room,—but they could get no indication by means of electroscopes of the existence of such a discharge, though Warburg obtained some indirect evidence which led him to the conclusion that such a discharge takes place. This evidence is based upon the action of a magnet upon the discharge of electricity through a gas at low pressure. If the magnetic force is transverse to the current of electricity through the gas, the discharge is hindered by the magnetic field, owing to the deflexion of the conducting gas. Now Warburg found that not only was the luminous discharge at low pressures hampered by the magnetic field, but that the lag was much increased by the magnetic field. He concluded from this that during the lag there is a current of electricity through the gas too feeble to affect an electroscope, and without luminosity. Walter[116] and Boys,[117] by taking photographs of sparks on rapidly-moving plates, have shown that the bright spark is preceded by faintly luminous brush discharges. It seems to the writer probable that the process by which the gas is changed from an insulator to a conductor is analogous to the ionization of a gas by cathode or Lenard rays. In these cases the rapid motion of an ion through the gas ionizes the gas surrounding the moving ion. Suppose then that in some way or another we had some ions in the gas between the electrodes, these would be acted on by the electric field and set in motion, and if they had sufficient energy given them during their life by the electric field for each to give rise to more than one ion, the number of ions would go on increasing, the gas become a conductor, and a spark would pass. If, however, the energy given by the electric field to the ion were not sufficient to enable each ion to provide more than one successor, the number would not grow, and the gas would remain an insulator. Thus for the electric field to turn a gas into a conductor would on this view require a field of sufficient intensity to give the requisite energy to an ion already in the field. This is in accordance with the phenomena. It is also necessary that some ions (a very small number would suffice) should be present to start the spark, and the very great values to which the potential difference may attain under certain conditions without any discharge passing seem to lend support to this view.

§ 21. *Connexion between Length of Spark and Potential Difference.*—The relation between the spark potential and the length of the spark has been investigated by Baille,[118] Paschen,[119] and Liebig.[120] Their researches have shown that when the electrodes are planes, or spheres whose radii are large compared with the length of the spark, the relation between the potential difference V and the length of spark l, when l for gases at atmospheric pressure is greater than 2 millimetres, can be expressed by the linear relation $V = \alpha + \beta l$. For air at atmospheric pressure $\alpha = 4{\cdot}997$, $\beta = 99{\cdot}593$, in electrostatic measure. Thus the curve representing the relation between spark length and potential difference is a straight line which does not pass through the origin. For sparks at atmospheric pressures whose length is less than 2 millimetres the curve ceases to be a straight line, and for slightly shorter sparks becomes concave to the axis along which the spark length is measured. There is some evidence that for still shorter sparks the curve has a point of inflexion, so that the potential required to produce very short sparks increases as the length of the spark diminishes. An illustration of this is that sparks passing between a plane and a slightly curved surface, when these are very near together, do not pass between the points which are nearest together, but prefer a longer route. There is a certain minimum potential required for the production of a spark, and no spark can pass if the potential falls below this value. This minimum is independent of the pressure of the gas; for air it is 341 volts, for hydrogen 302 volts, for nitrogen 251 volts, and for helium 261 volts.[121] The fact that the potential difference required to produce a spark can be represented by an equation of the form $V = \alpha + \beta l$ shows that the electric intensity between the plates V/l is greater for short sparks than it is for long. Baille found that to spark across a layer of air ·0015 cm. thick required an electric intensity about nine times that required to spark across a layer 1 cm. thick. The fact that a greater electric intensity is required to spark across a thin layer of gas than a thick one was discovered by Lord Kelvin[122] in 1860.

Baille,[123] Paschen,[124] and Freyberg[125] have made some very interesting experiments on the potential difference required to spark between two equal spheres of small enough radius to make the variations in electric intensity in different parts of the field considerable. These experiments show that for a given length of spark passing between two equal spheres, one charged and insulated and the other put to earth, the potential difference varies with the diameter of the sphere. Starting from plane electrodes, the potential difference at first increases with the curvature, and attains a maximum when the spheres have a certain diameter, depending upon the spark length and increasing with it. When the spheres are smaller than this, the potential difference falls off quickly, so that a much smaller difference of potential is required to produce a spark between very small spheres than between parallel planes. When the spark passes between pointed electrodes the potential difference is still smaller. Schuster[126] has calculated from Baille and Paschen's experiments the maximum electric intensity in the field when the spark is passing, and has shown that, keeping the spark length constant, the maximum intensity increases as the diameter of the spheres diminishes. Thus with a spark length of 1 cm. the maximum electric intensity between plane electrodes was 106, and between spheres 1 cm. in diameter 733. If the diameter of the electrodes is kept constant and the length of the spark increased, Schuster found that, starting with very short sparks, an increase in the length of the spark at first diminished the maximum electric intensity in the field, but that this attained a minimum, after which any further increase in the spark length increased the maximum electric intensity. The smaller the spheres the shorter the spark corresponding to the minimum electric intensity. When the sparks pass between spherical electrodes of different diameter, Faraday[127] and, later, De la Rue and Müller[128] found different values for the spark potential according as the smaller electrode was positive or negative. According to Wesendonck,[129] this difference only occurs when a brush discharge accompanies the spark; when nothing but a spark passes between the balls he finds that the potential difference remains the same when the signs of the electrodes are reversed. Photographs of long sparks, such as those in Fig. 20, show distinct

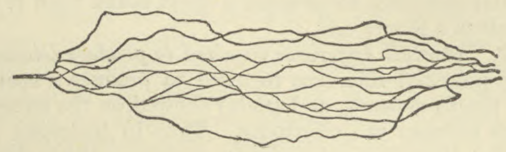


Fig. 20.

differences between the appearances at the positive and negative electrodes; thus there is a straight piece of considerable length at the positive electrode which is wanting at the negative, and when the spark branches as in Fig. 20, the branches point to the negative electrode. Experiments made by Righi,[130] Peace,[131] and others show that the material of which the electrodes are made has little if any effect on the potential difference required to produce a spark. It is just possible that this result might be modified if a large quantity of electricity were allowed to pass with each spark.

§ 22. *Connexion between Spark Potential and Pressure of Gas.*—As the pressure of the gas diminishes, the potential difference required to produce a spark of given length also diminishes, until the pressure reaches a critical value, which depends mainly upon the length of the spark and the nature of the gas. At this pressure, the potential difference being a minimum, any further diminution in the pressure leads to its increase. The critical pressure is higher the shorter the spark. The following values for the critical pressures corresponding to different spark lengths are due to Peace.[132]

Spark Length.	Critical Pressure.	Spark Length.	Critical Pressure.
·001 cm.	250 mm.	·01016 cm.	55 mm.
·0025 cm.	150 mm.	·02032 cm.	35 mm.
·00508 cm.	110 mm.		

The connexion between spark potential and pressures at pressures much greater than the critical pressure has been investigated by Baille,[133] Macfarlane,[134] and Paschen,[135] who have found that this relation can be represented by a very slightly curved portion of a hyperbola. Paschen showed that as long as the product of the density of the gas and the spark length is constant, the sparking potential is also constant over a wide range of pressure for the same gas. His results can be approximately represented by an equation of the form $V = a + b\frac{l}{\lambda}$, where V is the potential difference, l the spark length, λ the mean free path of a molecule of the gas, and a and b constants. The relation between the spark potential and the pressure, for pressures in the neighbourhood of the

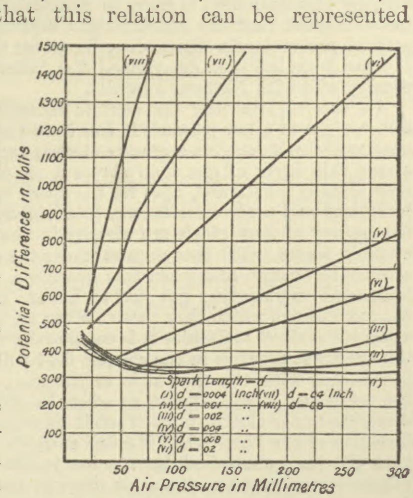


Fig. 21.

critical pressure, has been investigated by Peace (*loc. cit.*); the results of some of his experiments are shown by the curves in Fig. 21, where the ordinates represent the potential and the abscissæ the pressure. The small changes in the potential over a considerable range of pressure in the case of the shorter sparks is very well marked; the curves corresponding to different spark lengths cut one another, indicating that at low pressures it requires a greater potential difference to produce a short spark than it does to produce a longer one.

§ 23. *Potential Difference required to produce Discharge.*—The potential difference required to produce a spark of given length depends, as Faraday showed, on the nature of the gas between the electrodes. Thus in hydrogen it is much less than in air at the same pressure. Measurements have been made by Faraday,[136] Baille,[137] Liebig,[138] Paschen,[139] Wolf,[140] Röntgen,[141] and Natterer.[142] The following table gives the ratio of the potential difference required to produce sparks in hydrogen and carbonic acid to that required to produce a spark of the same length in air, the pressure in all cases being 750 mm.

Spark Length in Centimetres.	Hydrogen.			Carbonic Acid.		
	Baille.	Liebig.	Paschen.	Baille.	Liebig.	Paschen.
·1 . .	·49	·873	·639	1·67	1·20	1·05
·2 . .	·49	·787	·578	1·24	1·16	·988
·3 . .	·50	·753	·560	·94	1·07	·962
·4 . .	·50	·704	·553	·76	1·03	·930
·5 . .	·50	·670	·548	...	·994	·910
·6 . .	...	·656	·555	...	·974	·910

Wolf found that the electric intensity required to produce a spark 1 mm. in length between electrodes 5 cm. in radius, when the pressure was x atmospheres, was—for hydrogen, $65{\cdot}09\,x+62$; for oxygen, $96{\cdot}0\,x+44$; for air, $107\,x+39$; for nitrogen, $120{\cdot}8x+50$; for carbonic acid, $102{\cdot}2\,x+72$. Röntgen came to the conclusion that the potential difference required to produce a spark of given length from a pointed electrode in different gases is inversely proportional to the mean free path of the molecules of the gas. Ebert[143] found that if a vessel containing two electrodes was pumped until the pressure was reached when the discharge went with the minimum potential difference, then the pressures for different gases were such as to make the free path of the molecules of the different gases the same at the critical pressure. Natterer, as the result of a series of experiments on the lengths of spark given by a small induction coil, came to the conclusion that for gases with the same number of atoms in the molecule the spark length diminished as the molecular weight of the gas increased. The measurements made by this method are hardly definite enough to enable us to say whether this statement is more in accordance with the facts than the statement that the spark length diminishes as the mean free path of the molecule diminishes, for as far as the mean free path of these gases has been determined the latter view seems to accord equally well with Natterer's results.

We can explain why the electric intensity required to spark across a gas at a low pressure is less than that required at a high one, and why it requires a greater electric intensity to spark across a very thin layer of gas than across a thick one, if we take the view already mentioned, that for the spark to pass, the gas has to be ionized and made a conductor, this ionization being effected by the agency of ions which are already in the gas before the spark actually passes. The ions acquire under the electric field a certain amount of energy, and when this exceeds a certain value the ions ionize the surrounding gas just as Lenard or cathode rays ionize the gas through which they pass. When an ion is moving through a gas with whose molecules it is continually coming into collision, the energy it acquires in the electric field will not go on increasing indefinitely with the time it is in the gas; for in consequence of the collisions it will almost as often be moving in the opposite direction to the electric force (when it loses energy) as it does in the direction of the force (when it gains energy). It follows, therefore, that the energy acquired by the ion in the electric field will be approximately equal to the work done by the field on the ion as it moves through the average distance it traverses before its direction of motion is reversed. This distance will be proportional to λ, the mean free path of the ion; let it equal $c\lambda$. Then if F is the electric intensity and e the charge on the ion, the energy acquired by the ion is $Fec\lambda$. If the ion is to ionize the gas and so allow the spark to pass, this energy must exceed a certain value q, hence the limiting value of F for a spark is given by the equation $Fec\lambda=q$, or $F\lambda$ is constant. Thus F is inversely proportional to λ, or directly proportional to the pressure of the gas, so that a smaller electric intensity is required to spark at a low pressure than at a high one. Next suppose that d, the distance between the electrodes, is less than $c\lambda$, then the greatest distance the ion can move in the direction of the force is d, so that to get ionization $Fed=q$; hence F will be greater than before. This is on the supposition that the chances in favour of the moving ion ionizing the surrounding gas are as great as they were in the other case; it would seem, however, that, if this ionization is due to collisions between the ions and the gas, the chances are not so great, because the ion is delivered up against an electrode before it has completed its collisions. This would tend still further to increase F, the intensity required to produce a spark.

The spark itself at atmospheric pressures is not in general affected by the magnetic field, but the kind of aureole or glory of luminous gas with which it is surrounded spreads out in strong magnetic fields into a wide band. Precht[144] has observed that if the discharge passes between a point as the positive electrode and the rounded end of a wire as the negative electrode, it can be charged from a brush to a spark discharge by a strong magnetic field even at atmospheric pressures. Schuster and Hemsalech[145] have made some very interesting researches on the constitutions of sparks following rapidly one after another, such as are produced by the oscillatory discharge of a Leyden jar. These were photographed on a rapidly moving film mounted on the rim of a wheel making about thirty rotations per second; the motion of the film was at right angles to the direction of the spark, so that the line traced on the film by any luminous matter moving with finite velocity along the spark length would be inclined to the direction of the spark, and the inclination would, if the velocity of the film were known, determine the velocity of the luminous matter. By sending the light of the spark through a spectroscope before reaching the film, the velocity corresponding to any line in the spectrum could be determined. The conclusion arrived at by the authors was that the first spark passed through air, but that if the sparks followed each other very quickly, and the spark was not too long, the succeeding ones passed through metal vaporized by the heat produced by the first spark. The measurement of the velocity of diffusion of the metallic vapours in the flame gave some very interesting results, since different lines of one and the same metal indicated different velocities. Thus in bismuth some of the lines indicated a velocity of diffusion of 1420 metre/sec., others a velocity of about 300 metre/sec., and others a still smaller velocity.

§ 24. *Discharge from a Point.*—A very interesting case of electric discharge is that between a sharply pointed electrode, such as a needle, and a metal surface of considerable area. At atmospheric pressures the luminosity is confined to the immediate neighbourhood of the point. If the sign of the potential of the point does not change, the discharge is carried by ions of one sign—that of the charge on the pointed electrode. The velocity of these ions under a given potential gradient has been measured by Chattock,[146] and found to agree with that of the ions produced by Röntgen or uranium radiation, while Townsend[147] has shown that the charge on these ions is the same as that on the ions streaming from the point. If the pointed electrode be placed at right angles to a metal plane serving as the other electrode, the discharge takes place when, for a given distance of the point from the plane, the potential difference between the electrodes exceeds a definite value depending upon the pressure and nature of the gas through which the discharge passes; its value also depends upon whether, beginning with a small potential difference, we gradually increase it until discharge commences, or, beginning with a large potential difference, we decrease it until the discharge stops. The value found by the latter method is less than that by the former. According to Chattock's measurements the potential difference V for discharge between the point and the plate is given by the linear relation $V=a+bl$, where l is the distance of the point from the plate and a and b are constants. From v. Obermayer's[148] experiments, in which the distance l was greater than in Chattock's, it would seem that the potential for larger distances does not increase quite so rapidly with l as is indicated by Chattock's relation. The potential required to produce this discharge is much less than that required to produce a spark of length l between parallel plates; thus from Chattock's experiments to produce the point discharge when $l=\cdot5$ cm. in air at atmospheric pressure requires a potential difference of about 3800 volts when the pointed electrode is positive, while to produce a spark at the same distance between plane electrodes would require a potential difference of about 15,000 volts. Chattock showed that with the same pointed electrode the value of the electric intensity at the point was the same whatever the distance of the point from the plane. The value of the electric intensity depended upon the sharpness of the point. When the end of the pointed electrode is a hemisphere of radius a, Chattock showed that for the same gas at the same pressure the electric intensity f when discharge takes place is roughly proportioned to $a^{-\cdot 8}$. The value of the electric intensity at the pointed electrode is much greater than its value at a plane electrode for long sparks; but we must remember that at a distance from a pointed electrode equal to a small multiple of the radius of curvature of its extremity the electric intensity falls very far below that required to produce discharge in a uniform field, so that the discharge from a pointed electrode ought to be compared with a spark whose length is comparable with the radius of curvature of the point. For such short sparks the electric intensity is very high. The electric intensity required to produce the discharge from a gas diminishes as the pressure of the gas diminishes, but not nearly so rapidly as the electric intensity for long sparks. Here again the discharge from a point is comparable with short sparks, which, as we have seen, are much less sensitive to pressure changes than longer ones. The minimum potential at which the electricity streams from the point does not depend upon the material of which the point is made; it varies, however, considerably with the nature of the gas. The following are the results of some experiments on this point. Those in the first two columns are due to Röntgen,[149] those in the third and fourth to Precht [150]:—

Gas.	Discharge Potential. Point +.		Pressure 760.	
	Pressure 205.	Pressure 110.	Point +.	Point −
	Volts.	Volts.	Volts.	Volts.
H_2	1296	1174	2125	1550
O_2	2402	1975	2800	2350
CO	2634	2100		
CH_4	2777	2317		
NO	3183	2543		
CO_2	3287	2655	3475	2100
N_2	...	...	2600	2000
Air	...	...	2750	2050

We see from this table that in the case of the discharge from a positively electrified point the greater the molecular weight of the gas the greater the potential required for discharge. Röntgen concluded from his experiments that the discharging potential from a positive point in different gases at the same pressure varies inversely as the mean free path of the molecules of the gas. In the same gas, however, at different pressures the discharging potential does not vary so quickly with the pressure as does the mean free path. In Precht's experiments, in which different gases were used, the variations in the discharging potential are not so great as the variations in the mean free path of the gases.

The current of electrified air flowing from the point when the electricity is escaping—the well-known "electrical wind"—is accompanied by a reaction on the point which tends to drive it backwards. This reaction has been measured by Arrhenius,[151] who finds that when positive electricity is escaping from a point in air the reaction on the point for a given current varies inversely as the pressure of the gas, and for different gases (air, hydrogen, and carbonic acid) inversely as the square root of the molecular weight of the gas. The reaction when negative electricity is escaping is much less. The proportion between the reactions for positive and negative currents depends on the pressure of the gas. Thus for equal positive and negative currents in air at a pressure of 70 cm. the reaction for a positive point was 1·9 times that of a negative one, at 40 cm. pressure 2·6 times, at 20 cm. pressure 3·2 times, at 10·3 cm. pressure 7 times, and at 5·1 cm. pressure 15 times the reaction for the negative point. An investigation similar to that in § 2 shows that the reaction should be proportional to the quotient of the current by the velocity acquired by an ion under unit potential gradient. Now this velocity is inversely proportional to the pressure, so that the reaction should on this view be directly proportional to the pressure. This agrees with Arrhenius' results when the point is positive. Again, the velocities of an ion in hydrogen, air, and carbonic acid at the same pressure are approximately inversely proportional to the square roots of their molecular weights, so that the reaction should be directly proportional to this quantity. This also agrees with Arrhenius' results for the discharge from a positive point. The velocity of the negative ion is greater than that of a positive one under the same potential gradient, so that the reaction for the negative point should be less than that for a positive one, but the excess of the positive reaction over the negative is much greater than that of the velocity of the negative ion over the velocity of the positive. There is, however, reason to believe that a considerable condensation takes place around the negative ion as a nucleus after it is formed, so that the velocity of the negative ion under a given potential gradient will be greater immediately after the ion is formed than when it has existed for some time. The measurements which have been made of the velocities of the ions relate to those which have been some time in existence, but a large part of the reaction will be due to the newly-formed ions moving with a greater velocity, and thus giving a smaller reaction than that calculated from the observed velocity.

With a given potential difference between the point and the neighbouring conductor the current issuing from the point is greater when the point is negative than when it is positive, except in oxygen, when it is less. Warburg[152] has shown that the addition of a small quantity of oxygen to nitrogen produces a great diminution in the current from a negative point, but has very little effect on the discharge from a positive point. Thus the removal of a trace of oxygen made a leak from a negative point 50 times what it was before. Experiments with hydrogen and helium showed that impurities had a great effect in these gases on the current when the point was negative, and but little when it was positive. This suggests that the impurities, by condensing round the negative ions as nuclei, seriously diminish their velocity. If a point is charged up to a high and rapidly alternating potential, such as can be produced by the electric oscillations started when a Leyden jar is discharged, then in hydrogen, nitrogen, ammonia, and carbonic acid gas a conductor placed in the neighbourhood of the point gets a negative charge, while in air and oxygen it gets a positive one.[153] There are two considerations which are of importance in connexion with this effect. The first is the velocity of the ions in the electric field, and the second the ease with which the ions can give up their charges to the metal point. The greater velocity of the negative ions would, if the potential were rapidly alternating, cause an excess of negative ions to be left in the surrounding gas. This is the case in hydrogen. If, however, the metal had a much greater tendency to unite with negative than with positive ions, such as we should expect to be the case in oxygen, this would act in the opposite direction, and tend to leave an excess of positive ions in the gas. In oxygen and air the second effect seems to overpower the first. Precht (*loc. cit.*) has observed the changes which take place in the pointed electrodes after the discharge has been running for some time. He finds that the metal is torn from the positive point, which sometimes gets hollowed out into a kind of crater, but that there is no change in a negative point.

§ 25. *The Arc Discharge.*—The discharges we have hitherto considered have been characterized by large potential differences and small currents. In the arc discharge we get very large currents with comparatively small potential differences. We may get the arc discharge by taking a battery of cells large enough to give a potential difference of 60 to 80 volts, and connecting the cells with two carbon terminals, which are put in contact, so that a current of electricity flows round the circuit. If the terminals, while the current is on, are drawn apart, a bright discharge, which may carry a current of many amperes, passes from one to the other. This arc discharge, as it is called, is characterized by intense heat and by the brilliant luminosity of the terminals. This makes it a powerful source of light. The temperature of the positive terminal is much higher than that of the negative. According to Violle,[154] the temperature of the tip of the former is about 3500° C., and that of the latter 2700° C. The temperature of the arc itself he found to be higher than that of either of its terminals. As the arc passes, the positive terminal gets hollowed out into a crater-like shape, but the negative terminal remains pointed. Both terminals lose weight.

The appearance of the terminals is shown in Fig. 22, given by Mrs Ayrton;[155] *a*, *b* represent the terminals when the arc is quiet, and *c* when it is accompanied by a hissing sound. The intrinsic

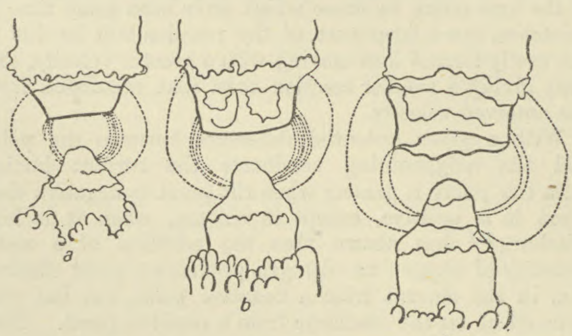


Fig. 22.

brightness of the positive crater does not increase with an increase in the current; an increased current produces an increase in the area of the luminous crater, but the amount of light given out by each unit of area of luminous surface is unaltered. This indicates that the temperature of the crater is constant; it is probably that at which carbon volatilizes. W. E. Wilson[156] has shown that at pressures of several atmospheres the intrinsic brightness of the crater is considerably diminished.

The connexion between V, the potential difference between the terminals, and l, the length of the arc, is somewhat analogous to that which holds for the spark discharge. Fröhlich[157] gives for this connexion the relation $V=m+nl$, where m and n are constants. Mrs Ayrton finds that both m and n depend upon the current passing between the terminals, and gives as the relation between V and l, $V=\alpha+\frac{\beta}{I}+\left(\gamma+\frac{\delta}{I}\right)l$, where α, β, γ, δ are constants and I the current. The relation between current and potential difference was made the subject of a series of experiments by Ayrton,[158] some of whose results are represented in Fig. 23. For a quiet arc an increase in current is accompanied by a fall in potential difference, while for the hissing arc the potential difference is independent of the current. The quantities m and n which occur in Fröhlich's equation have been determined by several experimenters. For carbon electrodes in air at atmospheric pressure m is about 39 volts, varying somewhat with the size and purity of the carbons; it is diminished by soaking the terminals in salt solution. The value of n given by different observers varies considerably, ranging from ·76 to 2 volts when l is measured in millimetres; it depends upon the current, diminishing as the current increases. When metallic terminals are used instead of carbons, the value of m depends upon the nature of the metal, m in general being larger the higher the temperature at which the metal volatilizes. Thus

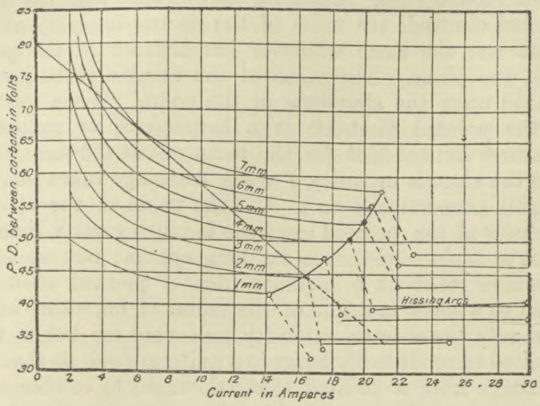


Fig. 23.

v. Lang[159] found the following values for m in air at atmospheric pressure:—C=35; Pt=27·4; Fe=25; Ni=26·18; Cu=23·86; Ag=15·23; Zn=19·86; Cd=10·28. Lecher[160] gives Pt=28, Fe=20, Ag=8, while Arons[161] found for Hg the value 12·8; in this case the fall of potential along the arc itself was abnormally small. In comparing these values it is important to remember that Lecher (*loc. cit.*) has shown that with Fe or Pt terminals the arc discharge is intermittent. Arons has shown that this is also the case with Hg terminals, but no intermittence has been detected with terminals of C, Ag, or Cu. The preceding measurements refer to mean potentials, and no conclusions as to the actual potential differences at any time can be drawn when the discharge is discontinuous, unless we know the law of discontinuity. The ease with which an arc is sustained depends greatly on the nature of the electrodes; when they are brass, zinc, cadmium, or magnesium it is exceedingly difficult to get the arc.

The potential difference between the terminals is affected by the pressure of the gas. The most extensive series of experiments on this point is that made by Duncan, Rowland, and Tod,[163] whose results are represented in Fig. 24. We see from these curves that for very short arcs the potential difference increases continuously with the pressure, but for longer ones there is a critical pressure at which the potential difference is a minimum, and that this critical pressure seems to increase with the length of arc. The nature of the gas also affects the potential difference. The magnitude of this effect may be gathered from the following values given by Arons[164] for the potential difference required to produce an arc 1·5 mm. long, carrying a current of 4·5 ampères, between terminals of different metals in air and pure nitrogen.

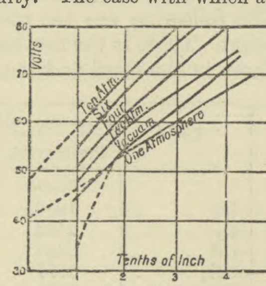


Fig. 24.

Terminal.	Air.	Nitrogen.	Terminal.	Air.	Nitrogen.
Ag . .	21	?	Pt . .	36	30
Zn . .	23	21	Al . .	39	27
Cd . .	25	21	Pb . .	...	18
Cu . .	27	30	Mg . .	..	22
Fe . .	29	20			

Thus, with the discharge for an arc of given length and current, the nature of the terminals is the most important factor in determining the potential difference. The effects produced by the pressure and nature of the surrounding gas, although quite appreciable, are not of so much importance, while in the spark discharge the nature of the terminals is of no importance, everything depending upon the nature and pressure of the gas.

The potential gradient in the arc is very far from being uniform. With carbon terminals Luggin[165] found that, with a current of 15 amperes, there was a fall of potential of 33·7 close to the anode, and one of 8·7 close to the cathode, so that the curve representing the distribution of potential between the terminals would be somewhat like that shown in Fig. 25. We have seen that a somewhat analogous distribution of potential holds in the case of conduction through flames (see § 11), though in that case the greatest drop of potential is in general at the cathode and not at the anode. The difference between the changes of potential at the anode and cathode are not so large with Fe and Cu terminals as with carbon ones; with mercury terminals, Arons[166] found the anode fall to be 7·4 volts, the cathode fall 5·4 volts.

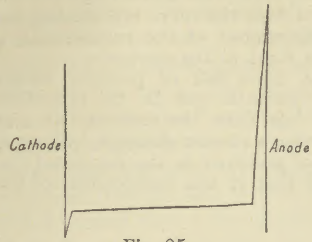


Fig. 25.

If we take the view that the conduction in the arc is effected by means of charged ions, the experiments on conduction through flames would lead us to believe that the larger part of the current would be carried by the negative ions. In a flame at a temperature of about 2000° C. the velocity of the negative ion is about 17 times that of the positive, while at a temperature of 1000° C. it is only about four times that of the positive. If the ratio of the velocity of the negative goes on increasing with the temperature, we should expect that at the high temperature of the arc it would reach a very large value, so that the ability of the negative ions to carry the current would be very much greater than that of the positive. If the current is carried by the negative ions we can see why the electric field close to the positive electrode must be very strong, for in consequence of the volatilization of the electrodes there is a wind of metallic vapour issuing from the electrodes. The experiments of Schuster and Hemsalech on the spark discharge indicate that the velocity of this wind would be several hundred metres per second. Thus in order to bring the negative ions up to the positive electrode it is necessary to have an electric field strong enough to drive them against this very rapid wind. Fleming[167] has given reasons for thinking that the discharge in the arc proceeds from the negative to the positive terminal. Placing in the arc a carbon electrode whose temperature was much lower than that of either terminal, he found that when this was connected with the negative electrode of the arc through a galvanometer and a battery of a few cells, a current could be sent by the cells through the circuit in the direction of the current through the arc, but not in the opposite one. He advances the view that the particles of metal torn from the cathode are the carriers of the current; it seems to the writer more probable that the main portion of the current is carried by the negative ions of very small mass, which we meet with in so many cases of the discharge of electricity through gases. There is in the arc a transport of matter from one terminal to the other; thus, if one terminal is made of copper and the other of iron, after the arc has passed for some time, copper will be found on the iron terminal and iron on the copper one. Experiments have been made by Groves,[168] Matteucci,[169] and Herwig[170] to see whether there is any connexion between the quantity of metal so transferred and the amount of the same metal that would have been deposited in the ordinary electrolysis of solutions by the same current, but no definite relations have been established. The vaporization of the terminals and the subsequent condensation of the metallic vapours would make this relation, if it existed, very difficult to detect. It is, however, worthy of notice that the amount of metal lost by the terminals is in many cases much less than the product of the quantity of electricity which has passed through the arc and the electro-chemical equivalent of the metal, showing that the bulk of the electricity must be carried by something different from positively charged atoms of the metal.

The fact that the potential difference required to produce a spark of length l is of the form $m+nl$ shows that no electricity can be carried across an arc, however short, without the expenditure of a finite amount of work. The nature of the physical process which this work has to do has not been settled. According to the theory of S. P. Thompson,[171] this work is that required to vaporize the terminals, but though this is doubtless a part of the work the current has to do, it cannot be the whole, as a calculation of the work required to vaporize the amount of mercury that would carry one unit of electricity shows that it corresponds to a potential difference of less than a volt, while the actual potential difference is about 12 volts. On the view that the discharge in the arc is carried by ions, part at least of the work must be spent in producing the ions, part in getting the small ions from the negative terminals. That chemical processes play an important part is shown by the fact, discovered by Mrs Ayrton, that access of oxygen to the positive crater lowers the potential difference by about 10 volts, and also by the difference between the potential differences in air and pure nitrogen.

Hissing Arcs.—When the current is increased beyond a certain value the discharge becomes noisy, and is accompanied by a hissing sound, while the potential difference between the electrodes falls considerably, and no longer varies with the current (see Fig. 23). The hissing of the arc has been studied by Mrs Ayrton, who has shown that it is caused by the crater extending beyond the tip of the terminal, and being no longer completely protected by the carbon vapour from oxidation by the air. She has proved that if the arc passes in a closed vessel no hissing takes place on an increase in the current after the oxygen has been burnt up, but that it at once recurs when fresh oxygen is blown into the vessel. Trotter[172] has shown that the arc is in rapid rotation in the unstable stage through which it passes just before hissing.

Magnetic Deflexion of the Arc.—The arc is deflected by a magnetic in much the same way as a flexible current between its terminals. As the arc lengthens when deflected by a magnet the potential difference between the terminals is increased by the magnetic field, and by using very strong magnetic fields it can be blown out.

A very interesting example of the arc discharge is when by means of transformers we produce a great difference of potential between the terminals, and transmit a considerable current. The discharge rises from the electrodes in two columns, sometimes some feet long, which unite at the top, where striations are often seen. These columns flicker slowly about and are very easily blown out, a slight puff of air being sufficient to extinguish them. The air-blast apparently breaks the belt of ionized gas along which the current passes, and the current is stopped just as a current through a wire would be stopped if the wire were cut. This arc differs from the arc hitherto considered in that it passes through the air, and not through the metallic vapours from the terminals.

§ 26. *Discharge through Gases at Low Pressures.*—As the pressure of a gas through which a spark is passing is gradually reduced, the luminous discharge broadens out, and pronounced differences begin to appear between the brightness and colour of various parts of the discharge, until at a pressure of about ·5 mm. of mercury the discharge presents an appearance similar to that shown in Fig. 26.

A velvety glow spreads, often in irregular patches, over the surface of the negative electrode k, and a body placed in the glow casts a shadow on the electrode.[173] Next to this there is a comparatively dark region, called the first dark space, or Crookes dark space; its length depends on the pressure of the gas, increasing as the pressure diminishes. Schuster has shown that an increase in the current produces a slight increase in the thickness of the dark space, the luminous boundary of which is approximately the locus of the extremities of normals of constant length drawn from the negative electrode. According to Hittorf,[174] this dark space disappears when the negative electrode is raised to a temperature at which it is incandescent. Adjoining it is a luminous column called the negative glow, the length of which is very variable, even when the pressure is constant. It is independent of the position of the positive electrode, its development is checked when the space round the negative electrode is too much restricted by the walls of the tube, and its size increases with the current. Thus if the cathode is a straight wire, it may, with a very small current, only just cover the tip of the wire, but as the current is increased it will cover more and more of the wire until it reaches the glass through which the wire passes. Next after the negative glow comes a second comparatively non-luminous space, ph (Fig. 26), called by some writers the "second negative dark space," and by others the "Faraday dark space"; it is of very variable length, and is sometimes entirely absent. Next after this we have a luminous column reaching right up to the positive electrode, called the positive column. When the pressure is within certain limits its luminosity often exhibits remarkable periodic alterations in intensity, such as those shown in Fig. 26; these are called *striations*. The bright parts of the striations are slightly concave to the positive electrode, and the distance between them increases as the pressure of the gas diminishes. If the discharge takes place in a tube which is wider at some places than others, they are nearer together in the narrow parts than they are in the wide. They are much influenced by the strength of the current, disappearing when it is increased beyond a certain value, and they are especially noticeable when the gas contains traces of the vapour of some organic compounds, *e.g.*, ether. The positive column behaves very differently from the negative glow and the Crookes dark space, for while the latter do not depend on the position of the positive electrode, and are not increased when the length of the tube is increased, the positive column takes the shortest route from the positive to the negative electrode, and by the use of sufficiently long tubes can be made of almost any length. The writer has had tubes with positive columns 50 feet long. The colours of the various parts of the discharge are very different, depending

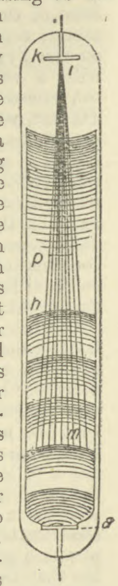


Fig. 26.

on the nature of the gas; thus, in nitrogen the positive column is somewhat the colour of chamois leather, while the negative glow is bluish. There are also very interesting differences in the spectra[175] of different parts of the discharge. Besides the difference in luminosity and colour there are also great variations in other quantities, such as the electric force at various points in the discharge and the mean temperature of the gas.

The distribution of electric force was measured by Hittorf,[176] and recently by Graham,[177] A. Herz,[178] Skinner,[179] and H. A. Wilson.[180] Fig. 27 is a curve given by Wilson, showing the distribution in a tube filled with hydrogen at a pressure of 2·25 mm. of mercury, and carrying a current of ·568 milli-amperes; the luminous parts of the discharge are indicated by the dotted lines. The electric

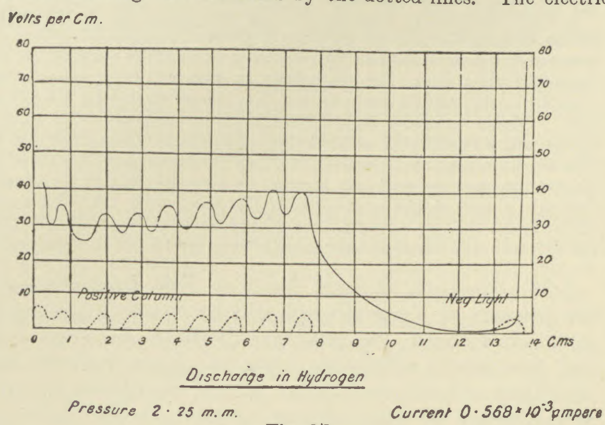


Fig. 27.

force is a minimum just outside the Crookes dark space, and increases with great rapidity inside that space. In the Faraday dark space the potential gradient indicates an excess of negative electrification. In the positive column there is a periodic variation in the potential gradient corresponding to the striation, while in front of the anode the electric force is again a minimum, and increases rapidly right up against the anode. In § 7 we saw that on the hypothesis that the discharge is carried by ions moving with a velocity proportional to the force acting upon them, the excess of ionization over recombination is proportional to d^2X/dx^2, when X is the electric force; hence the ionization will exceed the recombination when the curve for X^2 is convex to the axis of x, and be less than the recombination when the curve is concave to the axis of x. Applying this to the curve in Fig. 27, we see that there is strong ionization near each of the electrodes, and that the ionization exceeds the recombination in the Faraday dark space, while in the luminous parts of the discharge the recombination exceeds the ionization. In the striated discharge we see from Fig. 13 that recombination is greater than ionization in the bright parts, and less in the dark parts.

Cathode Fall of Potential.—The electric field in the neighbourhood of the electrodes, and especially of the cathode, has been made the subject of many researches. Hittorf showed that the potential difference between the cathode and a point in the negative glow was independent of the current, unless the current was so large that the negative glow covered the whole of the cathode. When that stage was reached an increase in the current increased the fall of potential. Warburg[181] showed that this fall of potential was independent of the pressure of the gas, and that if the terminals were made of aluminium or magnesium the fall of potential was considerably less than when they were made of other metals, all of which gave approximately the same potential fall. He showed too that the potential fall was very much influenced by impurities in the gas. Thus the potential fall in nitrogen containing traces of moisture and oxygen was 260 volts, but after the gas was carefully dried the potential rose to 343, while on the removal of the oxygen it fell again to 243 volts. Measurements of the cathode fall of potential have been made by Capstick[182] and Strutt,[183] whose results are shown in the following table. The cathode fall of potential seems to agree very nearly with the minimum potential difference required to produce a spark :—

Gas.	Cathode Fall with Pt Electrodes.			Minimum Potential Difference required to produce a Spark (Strutt).
	Warburg.	Capstick.	Strutt.	
Air . .	340–350 volts.	..	..	341
H_2 . .	About 300 volts.	298	..	302–303
O_2 . .	..	369		
N_2 . .	230 if free from O.	232	..	251
Hg. vapour	340			
Helium .	..	..	226	261–326
H_2O . .	..	469		

Schuster found that the potential difference V in the dark space at a distance x from the cathode was represented by the formula $V = V_0(1 - \epsilon^{Rx})$. Graham (*loc. cit.*) found that this formula did not hold right up to the cathode, but that the curve representing the electric intensity in the neighbourhood of the cathode had a minimum value immediately in front of the electrode.

Anode Fall of Potential.—A finite fall of potential occurs between the anode and the luminous gas in its immediate neighbourhood; this is much less than the cathode fall, and it seems to take place within even a shorter distance. Skinner, who investigated the anode fall of potential in the unstriated discharge through nitrogen, found that it was independent of the current through the gas, increased slowly with the pressure of the gas, and depended upon the material and state of surface of the electrodes. For Al and Mg, the metals for which the cathode fall is least, the anode fall is greatest. The anode fall for different metals and for different gaseous pressures is represented in Fig. 28. Both Skinner and H. A. Wilson found the potential gradient in the gas just in front of the anode beyond the region of the anode fall was exceedingly small, not amounting to a volt per centimetre. A. Herz showed that the potential gradient in the unstriated positive column diminished as the current increased, in such a way that if X is the electric intensity when the current is ι, X_0 when it is ι_0, then $X - X_0 = -b(\iota - \iota_0)$, where b is a constant.

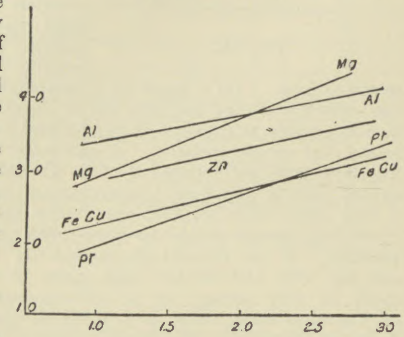


Fig. 28.

Heat produced by the Discharge.—The average temperature of a gas at low pressure conveying a luminous discharge is by no means high. E. Wiedemann[184] proved that the average temperature of the gas in a tube containing air at a pressure of 3 mm. of mercury is less than 100° C, though the discharge is luminous. These measurements refer to the average temperature of all the molecules in a considerable space, and the low average temperature does not of course preclude the possibility of a small number of molecules having velocities very much greater than the mean velocity corresponding to the temperature indicated by the thermometer. Hittorf,[185] measuring the mean temperature at three points in the discharge, one in the positive column, the second in the negative glow, and the third in the Crookes dark space, found that the temperature was highest in the darkest space, and lowest in the positive column. E. Wiedemann[186] showed that the distribution of temperature along the discharge depended on the pressure, and that while at low pressures the temperature at the cathode was higher than at the anode, the reverse was true when the pressure exceeded 26 mm. A very complete investigation of the distribution of temperature along the discharge has been made by Wood,[187] who observed that in the unstriated discharge the temperature is constant in the positive column, diminishes in the Faraday dark space, reaches a minimum at a point in this space a little in front of the negative glow, and rapidly increases in the dark space next the cathode. In the striated discharge the temperature is a maximum in the bright parts of the striations and a minimum in the dark parts; in no part of the discharge did Wood find the mean temperature to exceed 100° C. The distribution of temperature thus follows the same course as the distribution of electric force in the tube. The rate of work done by the current at any point of the path is proportional to the product of the current and the electric force, or since the current is constant all along the tube, to the electric force. If this work were entirely converted into heat, the temperature curves would be the same as the curves for the electric force, and from the investigations of Wood and Graham this would seem to be very approximately the case. We conclude that in tubes at moderate pressures the greater part of the electrical work done appears as heat in the gas at a place not very distant from where the work was done.

§ 27. *Cathode Rays.*—When the gas in the discharge tube is at a very low pressure some remarkable phenomena occur in the neighbourhood of the cathode. These seem to have been first observed by Plücker,[188] who noticed on the walls of the glass tube near the cathode a greenish phosphorescence, which he regarded as due to rays proceeding from the cathode, striking against the sides of the tube, and then travelling back to the cathode. He found that the action of a magnet on these rays was not the same as the action on the part of the discharge near the positive electrode. Hittorf[189] showed that the agent producing the phosphorescence was intercepted by a solid, whether conductor or insulator, placed between the cathode and the sides of the tube. He regarded the phosphorescence as caused by a motion starting from the cathode and travelling in straight lines through the gas. Goldstein[190] confirmed this discovery of Hittorf's, and further showed that a distinct, though not very sharp, shadow is cast by a small object placed near a large plane cathode. This is a proof that the rays producing the phosphorescence must be emitted almost normally from the cathode, and not, like the rays of light from a luminous surface, in all directions, for such rays would not produce a perceptible shadow if a small body were placed near the plane. Goldstein regarded the phosphorescence as due to waves in the ether, for whose propagation the gas was not necessary. Crookes,[191] who made many remarkable researches in this subject, took a different view. He regarded the rays as streams of negatively electrified particles projected normally from the cathode with great velocity, and, when the pressure is sufficiently low, reaching the sides of the tube, and by their impact producing phosphorescence and heat. The rays on this view are deflected by a magnet, because a magnet exerts a force on a charged moving body.

These rays striking against glass make it phosphorescent. The colour of the phosphorescence depends on the kind of glass; thus the light from soda glass is a yellowish green, and that from lead glass blue. Many other bodies phosphoresce when exposed to these rays, and in particular the phosphorescence of some gems, such as rubies and diamonds, is exceedingly vivid. The spectrum of the phosphorescent light is generally continuous, but Crookes has shown that the phosphorescence of some of the rare earths, such as yttrium, gives a spectrum of bright bands, and he has founded on this fact a spectroscopic method of great importance. Goldstein[192] discovered that the haloid salts of the alkali metals change colour under the rays, sodium chloride, for example, becoming violet. The coloration is a surface one, and has been traced by E. Wiedemann and Schmidt[193] to the formation of a sub-chloride. Chlorides of tin, mercury, and lead also change colour in the same way. E. Wiedemann[194] discovered another remarkable effect, which he called thermo-luminescence; he found that many bodies after being exposed to the cathode rays possess for some time the power of becoming luminous when their temperature is raised to a point far below that at which they become luminous in the normal state. Substances belonging to the class called by van't Hoff[195] solid solutions exhibit this property of thermo-luminescence to a remarkable extent. They are formed when two salts, one greatly in excess of the other, are simultaneously precipitated from a solution. A trace of $MnSO_4$ in $CaSO_4$ shows very brilliant thermo-luminescence. The impact of cathode rays produces after a time perceptible changes in the glass. Crookes[196] found that after glass has been phosphorescing for some time under the cathode rays it seems to get tired, and the phosphorescence is not so bright as it was initially. Thus, for example, when the shadow of a Maltese cross is thrown on the walls of the tube as in Fig. 29, if after the discharge has been going on for some time the cross is shaken down or a new cathode used whose line of fire does not cut the cross, the pattern of the cross will still be seen on the glass, but it will now be brighter instead of darker than the surrounding portion. The portions shielded by the cross, not being tired by being made to phosphoresce for a long time, respond more vigorously to the stimulus than those portions which have not been protected. Skinner[197] and the writer found on the glass which had been exposed to the rays gelatinous filaments, apparently silica, resulting from the reduction of the glass. A reducing action was also noticed by Villard[198] and Wehnelt.[199] It can be well shown by letting the rays fall on a plate of oxidized copper, when the part struck by the rays will become bright. The rays heat bodies on which they fall, and if they are concentrated by using as a cathode a portion of a spherical surface, the heat at the centre becomes so great that a piece of platinum wire can be melted or a diamond charred. Measurements of the heating effects of the rays have been made by the writer and Cady. Crookes[200] has shown that a vane mounted as in a radiometer is set in rotation by the rays, the direction of the rotation being the same as would be produced by a stream of particles proceeding from the cathode. Riecke[201] made a series of measurements of the pressure produced on the vanes.

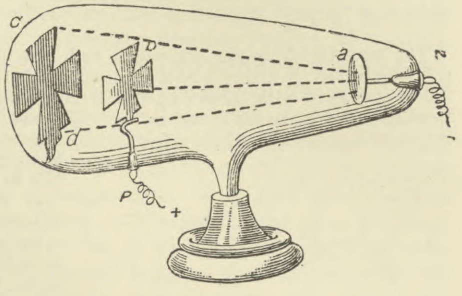


Fig. 29.

§ 28. *Effect of a Magnet.*—The rays are deflected by a magnet, so that the distribution of phosphorescence over the glass and the shape and position of the shadows cast by bodies in the tube are altered by the proximity of a magnet. The laws of magnetic deflexion of these rays have been investigated by Plücker,[202] Hittorf,[203] Crookes,[204] and Schuster.[205] The deflexion is the same as that of negatively electrified particles travelling along the path of the rays. Such particles would in a magnetic field be acted on by a force at right angles to the direction of motion of the particle and also to the magnetic force, the magnitude of the force being proportional to the product of the velocity of the particle, the magnetic force, and the sine of the angle between these vectors. In this case we have seen (§ 8) that if the particle is not acted on by an electrostatic field, the path in a uniform magnetic field is a spiral, which, if the magnetic force is at right angles to the direction of projection of the particle, becomes a circle in the plane at right angles to the magnetic force, the radius being mv/He, where m, v, e are respectively the mass, velocity, and charge on the particle, and H is the magnetic force. The smaller the difference of potential between the electrodes of the discharge tube the greater the deflexion produced by a magnetic field of given strength, and as the difference of potential rapidly increases with diminution of pressure, after a certain pressure has been passed, the higher the exhaustion of the tube the less the magnetic deflexion of the rays. Birkeland[206] has shown that when the discharge is from an induction coil the cathode rays produced in the tube at any one time are not equally deflected by a magnet, but that a narrow patch of phosphorescence when deflected by a magnet is split up into several distinct patches, giving rise to what Birkeland calls the magnetic spectrum. Strutt[207] has shown that this magnetic spectrum does not occur if the discharge of a large number of cells is employed instead of the coil. The writer[208] has shown that if the potential difference between the electrodes is kept the same the magnetic deflexion is independent of the nature of the gas filling the discharge tube; this was tested with gases so different as air, hydrogen, carbonic acid, and methyl iodide.

§ 29. *Charge of Negative Electricity carried by the Rays.*—We have seen that the rays are deflected by a magnet, as if they were particles charged with negative electricity. Perrin[209] showed by direct experiment that a stream of negative electricity is associated with the rays. A modification made by the writer of Perrin's experiment is sketched in Fig. 30.[210]

The rays start from the cathode A, and pass through a slit in a solid brass rod B fitting tightly into the neck of the tube. This rod is connected with earth and used as the anode. The rays after passing through the slit travel through the vessel C. D and E are two insulated metal cylinders insulated from each other, and each having a slit cut in its face so as to enable the rays to pass into the inside of the inner cylinder, which is connected with an electrometer, the outer cylinder being connected with the earth. The two cylinders are placed on the far side of the vessel, but out of the direct line of fire of the rays. When the rays go straight through the slit there is only a very small negative charge communicated to the inner cylinder, but when they are deflected by a magnet so that the phosphorescent patch falls on the slit in the outer cylinder the inner cylinder receives a very large negative charge, the increase coinciding very sharply with the appearance of the phosphorescent patch on the slit. When the patch is so much deflected by the magnet that it falls below the slit, the negative charge in the cylinder again disappears. This experiment shows that the cathode rays are accompanied by a stream of negative electrification. The same apparatus can be used to show that the passage of cathode rays through a gas makes it a conductor of electricity. For if the induction coil is kept running and a stream of the rays kept steadily going into the inner cylinder, the potential of the inner cylinder reaches a definite negative value below which it does not fall, however long the rays may be kept going. The cylinder reaches a steady state in which the gain of negative electricity from the cathode rays is equal to the loss by leakage through the conducting gas, the conductivity being produced by the passage of the rays through it. If the inner cylinder is charged up initially with a greater negative charge than corresponds to the steady state, on turning the rays on to the cylinder the negative charge will decrease and not increase until it reaches the steady state. The conductivity produced by the passage of cathode rays through a gas diminishes rapidly with the pressure. When rays pass through a gas at a low pressure, they are deflected by an electric field; when the pressure of the gas is higher the conductivity it acquires when the cathode rays pass through it is so large that the potential gradient cannot reach a sufficiently high value to produce an appreciable deflexion. In proving the existence of this deflexion the writer[211] used the apparatus represented in Fig. 31. The rays from the cathode C pass through a slit in the anode A, which is a metal plug fitting tightly into the tube and connected with the earth. After passing through a second slit in another earth-connected metal plug B, they travel between two aluminium plates D and E, and then fall on the end of the tube, where they produce a narrow, well-defined phosphorescent patch. At high exhaustions the rays were deflected when the aluminium plates were connected with the terminals of a battery of storage cells, the direction of the deflexion being such as would occur if the rays were negatively electrified particles.

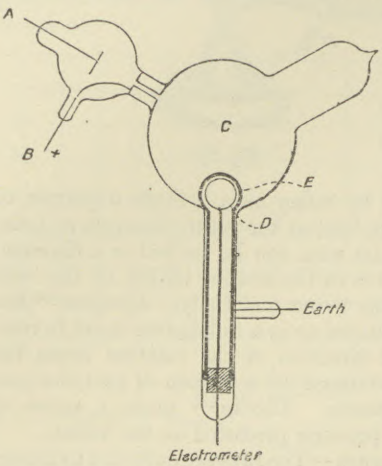


Fig. 30.

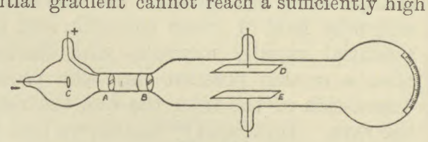


Fig. 31.

Thus the cathode rays carry a charge of negative electricity, they are deflected by an electric field as if they were negatively electrified, and are acted on by a magnetic force in just the way this force would act on a negatively electrified body moving along the path of the rays. There is therefore every reason for believing that they are charges of negative electricity in rapid motion, and by measuring the deflexion produced by magnetic and electric fields we can determine the velocity with which these particles move and the ratio of the mass of the particle to the charge carried by it.

If the rays travel through a space l in a uniform electric field acting at right angles to the direction of motion of the rays, and if the electric force is equal to F, the acceleration at right angles to the path is Fe/m, where e is the charge on the particle and m its mass. Hence, if θ is the angle through which the direction of motion is twisted, $\theta = Fel/mv^2$, where v is the velocity of the particle. Again, if the particle moves through a distance l in a uniform magnetic field of strength H at right angles to its direction of motion, the acceleration at right angles to the path is Hev/m. Hence if ϕ is the angle through which the direction of motion is twisted, $\phi = Hevl/mv^2 = Hel/mv$. Hence if we measure θ and ϕ we can determine the values of v and m/e. The easiest way of determining v is to make the electrostatic and magnetic forces act in opposite directions on the particle, and adjust the magnetic force until it just neutralizes the electric; then if H is the magnetic and F the electric force, $F = Hv$. From experiments made in this way at very low pressures by the writer[212] the value of m/e for the mean of seven determinations was $1 \cdot 3 \times 10^{-7}$, and was the same whatever the nature of the gas, the gases tried being air, hydrogen, and carbonic acid. The velocity v depends upon the pressure of the gas, increasing as the pressure decreases. The velocities observed in these experiments ranged between $2 \cdot 2 \times 10^9$ cm./sec. to $3 \cdot 6 \times 10^9$ cm./sec. Another method used by the writer to measure v and m/e was to allow a bundle of rays to enter a metal cylinder and measure the charge of negative electricity carried in by them. In the cylinder a thermo-electric junction was arranged, and the impact of the rays against this raised its temperature by an amount which could be measured by the current sent round the thermo-electric circuit. Thus with a knowledge of the thermal capacity of the junction it was possible to determine the mechanical equivalent of the heat given up by the rays to the surface on which they impinged. Let N be the number of charged particles entering the cylinder, and Q the negative charge it receives; then $Ne = Q$. If E is the mechanical equivalent of the heat produced by the impact, then assuming that the particles give up all their energy on collision, we have $\frac{1}{2}Nmv^2 = E$; hence $\frac{1}{2}mv^2e = 2E/Q$. Thus measurements of E and Q combined with measurements of the magnetic deflexion which gives mv/e will enable us to determine m/e and v. Measurements made by this method gave for m/e the value $\cdot 9 \times 10^{-7}$ with velocities ranging from $2 \cdot 4 \times 10^9$ cm./sec. to $3 \cdot 2 \times 10^9$ cm./sec. Kauffmann,[213] who has made an extensive series of measurements of the value of m/e and v, uses a somewhat different process. One of the quantities measured by him is the magnetic deflexion, and the other is the difference in potential between the cathode and anode. If V is this difference, and if we assume that the energy of the moving particle is due to passing between two places differing in potential by V, we have $mv^2 = 2Ve$. If V is measured this equation, combined with the equation for the magnetic deflexion, enables us to find m/e and v. In this way Kauffmann found $m/e = \cdot 54 \times 10^{-7}$. He confirms the result that this value is independent of the nature of the gas and of the electrodes. This method assumes that the potential at the commencement of the path of a particle is the same as the potential of the cathode. Now the potential close to the cathode changes with great rapidity, so that if the cathode particle started from a place close to but not absolutely in contact with the cathode a considerable correction would be necessary. The effect of this correction would be to increase the value of m/e. By measuring directly the value of v Wiechert[214] has deduced the value of m/e. He determined v by making the cathode rays pass through two equal spirals at a considerable distance from each other, the spirals being traversed by a very rapidly alternating current produced by discharging condensers. If the velocity of the cathode rays was infinite the currents in the two circuits would be in the same phase when the rays passed through them, and the magnetic deflexion would be the same. If, however, the rays took a time equal to half the time of oscillation of the current to pass from one spiral to another, the deflexions would be opposite. Therefore, by comparing the deflexions in the two spirals the velocity of the rays can be determined. The result was that any value of e/m between $1 \cdot 01 \times 10^7$ and $1 \cdot 55 \times 10^7$ was quite probable, but that it was unlikely that e/m was greater than $1 \cdot 84 \times 10^7$ or less than $\cdot 87 \times 10^7$.

We may conclude from these experiments that the value of m/e for the particles constituting the cathode rays is of the order 10^{-7}, and we have seen that m/e has the same value in all the other cases of negative ions in a gas at low pressure for which it has been measured—viz., for the ions produced when ultra-violet light falls on a metal plate, or when an incandescent carbon filament is surrounded by a gas at a low pressure. We have also seen that the value of the charge on the gaseous ion, in all cases in which it has been measured—viz., the ions produced by Röntgen and uranium radiation, by ultra-violet light, and by the discharge of electrification from a point—is the same in magnitude as the charge carried by the hydrogen atom in the electrolysis of solutions. The mass of the hydrogen alone is, however, 10^{-4} times this charge, while the mass of the carriers of negative electrification is only 10^{-7} times the charge; hence the mass of the carriers of the negative electrification is only $\frac{1}{1000}$ of the mass of the hydrogen atom. We are thus, by the study of the electric discharge, forced to recognize the existence of masses very much smaller than the smallest mass hitherto recognized in chemistry.

Direct determinations of the velocity of the cathode rays have been made by the writer[215] by measuring the interval between the appearance of phosphorescence on two pieces of glass placed at a known distance apart, and by Maiorana[216] and Battelli and Stefanini,[217] who measured the interval between the arrival of the negative charge carried by the rays at two places separated by a known distance. The values of the velocity got in this way are much smaller than the values got by the indirect methods previously described: thus the writer at a fairly high pressure found the velocity to be 2×10^7 cm./sec. Maiorana found values ranging between 10^7 and 6×10^7 cm./sec., and Battelli and Stefanini values ranging from 6×10^6 to $1{\cdot}2\times10^7$. In these methods it is very difficult to eliminate the effect of the interval which elapses between the arrival of the rays and the attainment by the means of detection, such as the phosphorescence of the glass or the deflexion of the electrometer, of sufficient intensity to affect the senses.

§ 30. *Transmission of Cathode Rays through Solids—Lenard Rays.*—It was for a long time believed that all solids were absolutely opaque to these rays, as Crookes and Goldstein had proved that very thin glass, and even a film of collodion, cast intensely black shadows. Hertz,[218] however, showed that behind a piece of gold-leaf or aluminium foil an appreciable amount of phosphorescence occurred on the glass, and that the phosphorescence moved when a magnet was brought near. A most important advance was next made by Lenard,[219] who got the cathode rays to pass from the inside of a discharge tube to the air outside. For this purpose he used a tube like that shown in Fig. 32. The cathode K is an aluminium disc 1·2 cm. in diameter fastened to a stiff wire, which is surrounded by a glass tube. The anode A is a brass strip partly surrounding the cathode. The end of the tube in front of the cathode is closed by a strong metal cap, fastened in with marine glue, in the middle of which a hole 1·7 mm. in diameter is bored, and covered with a piece of very thin aluminium foil about ·0026 mm. in thickness. The aluminium window is in metallic contact with the cap, and this and the anode are connected with the earth. The tube is then exhausted until the cathode rays strike against the window. Diffuse light spreads from the window into the air outside the tube, and can be traced in a dark room for a distance of several centimetres. From the window too proceed rays which, like the cathode rays, can produce phosphorescence, for certain bodies phosphoresce when placed in the neighbourhood of the window. This effect is conveniently observed by the platino-cyanide screens used to detect Röntgen radiation. The properties of the rays outside the tube resemble in all respects those of cathode rays; they are deflected by a magnet and by an electric field, they ionize the gas through which they pass and make it a conductor of electricity, and they affect a photographic plate and change the colour of the haloid salts of the alkali metals. As, however, it is convenient to distinguish between cathode rays outside and inside the tube, we shall call the former Lenard rays. In air at atmospheric pressure the Lenard rays spread out very diffusely. If the aluminium window, instead of opening into the air, opens into another tube which can be exhausted, it is found that the lower the pressure of the gas in this tube the farther the rays travel and the less diffuse they are. By filling the tube with different gases Lenard showed that the greater the density of the gas the greater is the absorption of these rays. Thus they travel farther in hydrogen than in any other gas at the same pressure. Lenard showed, too, that if he adjusted the pressure so that the density of the gas in this tube was the same—if, for example, the pressure when the tube was filled with oxygen was $\frac{1}{16}$ of the pressure when it was filled with hydrogen—the absorption was constant whatever the nature of the gas. The distance to which the Lenard rays penetrate into this tube depends upon the pressure in the discharge tube; if the exhaustion in the latter is very high, so that there is a large potential difference between the cathode and the anode, and therefore a high velocity for the cathode rays, the Lenard rays will penetrate farther than when the pressure in the discharge tube is higher and the velocity of the cathode rays smaller. Lenard showed that the greater the penetrating power of his rays the smaller was their magnetic deflexion, and therefore the greater their velocity; thus the greater the velocity of the cathode rays the greater is the velocity of the Lenard rays to which they give rise. Lenard[220] has studied the passage of his rays through solids as well as through gases, and has arrived at the very interesting result that the absorption of a substance depends only upon its density, and not upon its chemical composition or physical state; in other words, the amount of absorption of the rays when they traverse a given distance depends only on the quantity of matter they cut through in the distance. By measuring the magnetic and electric deflexion of these rays Lenard[221] determined the value of e/m and also v, m being the mass of the particle, e its charge, and v its velocity. He found $e/m = 6{\cdot}4\times10^6$, which agrees well with the value found for the cathode rays, and v in his experiments reached the value 8×10^9 cm./sec. for penetrating rays. M'Clelland[222] showed that the rays carry a charge of negative electricity, and M'Lennan measured the amount of ionization rays of given intensity produced in different gases, finding that if the pressure is adjusted so that the density of the different gases is the same the number of ions per cubic centimetre is also the same. In this case, as Lenard has shown, the absorption is the same, so that with the Lenard rays, as with uranium and probably with Röntgen rays, equal absorption corresponds to equal ionization. A convenient method for producing Lenard rays of great intensity has been described by Des Coudres.[223]

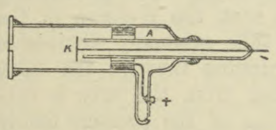


Fig. 32.

Diffuse Reflexion of Cathode Rays.—When cathode rays fall upon a surface, whether of an insulator or a conductor, cathode rays start from the surface in all directions. This phenomenon, which was discovered by Goldstein,[224] has been investigated by Starke,[225] Campbell-Swinton,[226] and Merrit; it is often regarded as analogous to the diffuse reflexion of light from such a surface as gypsum, and is spoken of as the diffuse reflexion of the cathode rays. According to Merritt the deviation in a magnetic field of these reflected rays is the same as that of the incident rays. The experiments, however, were confined to rays reflected so that the angle of reflexion was nearly equal to that of incidence. According to Campbell-Swinton the diffuse "reflexion" is accompanied by a certain amount of specular reflexion.

Repulsion of two Cathode Streams.—Goldstein[227] discovered that if in a tube there are two cathodes connected together, the cathodic rays from one cathode are deflected when they pass near the other. Experiments bearing on this subject have been made by Crookes[228] and Wiedemann and Ebert.[229] The phenomena may be described by saying that the repulsion of the rays from a cathode A by a cathode B is only appreciable when the rays from A pass through the Crookes dark space round B. This is what we should expect if we remember that the electric field in the dark space is far stronger than in the rest of the discharge, and that the gas in the other parts of the tube is rendered a conductor by the passage through it of the cathode rays, and therefore incapable of transmitting electrostatic repulsion.

§ 31. *Positive Rays or "Kanal-strahlen."*—Goldstein [230] found that with a perforated cathode certain rays occurred behind the cathode which were not appreciably deflected by a magnet; these he called *Kanal-strahlen*, but we shall, for reasons which will appear later, call them "positive rays."

Their appearance is well shown in Fig. 33, taken from a paper by Wehnelt,[231] in which they are represented at B. Goldstein found that their colour depends on the gas in which they are formed, being gold-colour in air and nitrogen, rose-colour in hydrogen, yellowish rose in oxygen, and greenish gray in carbonic acid. W. Wien [232] showed that by using very intense magnetic fields they can be deflected (although the deflexion is very small compared with that of the cathode rays) in a direction corresponding to that of positive ions moving away from the cathode. He proved directly that the rays carry a charge of positive electricity—a fact which was confirmed by Ewers.[233] Villard,[234] on the other hand, was unable to detect any positive charge until the rays had been started some time; then he observed a positive charge, which he ascribed to the diffusion of ions from the other part of the discharge tube. Wien also showed that the rays are deflected by an electric field, and by measuring the magnetic and electric deflexions he was able to determine m/e and v. For the former he found with iron electrodes the value $3{\cdot}2 \times 10^{-3}$, and for v $3{\cdot}6 \times 10^{7}$ cm./sec. The value of m/e contrasts very markedly with the value of the same quantity 10^{-7} for the cathode rays, for Wien's value is of the same order as the mass of a molecule divided by its charge, and suggests that the carriers of the positive electricity are chemical atoms or molecules. According to Ewers (*loc. cit.*) the value of m/e depends upon the nature of the electrodes, and he regards the metallic ions from the electrode as being the carriers of the positive electricity in the positive rays. The researches of Schuster,[235] Villard (*loc. cit.*), and Wehnelt have established that in the Crookes dark space there is a flow of positive electricity up to the cathode; according to Schuster a body placed in the dark space throws a shadow on the cathode. An example of these shadows is shown in Fig. 33. The flow of positive electricity to the cathode and of negative away from the cathode are mutually dependent; it is only from those parts of the cathode struck by the positive flow that cathode rays start, and it is only those parts of the gas which are struck by the cathode rays that furnish the stream of positive electricity. The positive rays seem to be the continuation of this positive stream through the perforations in the cathode.

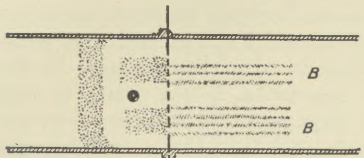


Fig. 33.

§ 32. *Röntgen Rays.*—Röntgen [236] discovered in 1895 a very remarkable effect arising from the cathode rays. He found that, in the neighbourhood of a discharge tube exhausted so highly that the cathode rays produced a vivid green phosphorescence on the glass, a plate covered with a phosphorescent substance such as potassium platinocyanide began to glow. He found that if a thick piece of metal were placed between the bulb and the phosphorescent screen, a sharp shadow of the metal was cast upon the screen, but that other substances, such as wood and thin pieces of aluminium, cast but slight shadows, showing that the agent which produced the phosphorescence could traverse with considerable freedom bodies which are opaque to ordinary light. He found that as a general rule the greater the density of the substance the greater its opacity to this agent. Thus while the effect produced by the phosphorescence could pass through the flesh, it was stopped by the bones of the hand, so that if a hand were held between the discharge tube and the phosphorescent screen the outline of the bones was distinctly visible as a shadow cast on the screen, or if a purse containing coins were placed between the tube and the screen the purse itself threw but little shadow, while the coins cast a dark one. Röntgen showed that the cause of the phosphorescence—now called Röntgen rays—was propagated in straight lines, and was not bent on passing from one medium to another, there thus being no refraction. Again, no deflexion by a magnet can be detected; Röntgen could discover none with the strongest magnetic fields at his disposal, and the writer has sent the rays through a magnetic field of about 8000 lines of force per sq. cm. for a distance of about a centimetre without producing any appreciable effect. Many attempts have been made to detect signs of polarization by measuring their absorption by two thin plates of tourmaline placed first with their axes parallel and then with their axes crossed, but no sensible difference has been detected in the two cases; the absorption of ordinary light would have been very much greater in the second case than in the first. The rays affect a photographic plate as well as a phosphorescent screen, and shadow photographs can be readily taken. The time of exposure depends on the intensity of the rays, and this depends on the discharge through the tube and on the substances traversed by the rays in their journey to the plate. In some cases an exposure of a few seconds is sufficient, in others hours may be required. The rays coming from different discharge tubes have very different penetrating power. If the pressure in the tube is fairly high, so that the potential difference between its electrodes is small and the velocity of the cathode rays low, the Röntgen rays will be very readily absorbed. Such rays are called "soft rays." If the exhaustion of the bulb is carried further, so that there is a considerable increase in the potential difference between the cathode and anode and therefore in the velocity of the cathode rays, the Röntgen rays have much greater penetrating power and are often called "hard rays." With a highly exhausted tube and a large induction coil it is possible to get appreciable effects from rays which have passed through sheets of iron or brass several millimetres thick. The penetrating power of the rays thus varies with the pressure in the tube; as the pressure in the tube gradually diminishes when the discharge is kept running through the tube, the type of discharge proceeding from the tube is continually changing. This lowering of the pressure finally leads to such a high degree of exhaustion that the discharge has great difficulty in passing, and the emission of the rays becomes very irregular. Heating the tube causes some gas to come off the sides, and by thus increasing the pressure causes a temporary improvement. Tubes are sometimes provided with pieces of carbon or caustic potash, which when heated give up gas and so tend to restore the original pressure. The lowering of pressure by the discharge is not confined to the very low pressures which occur in the tubes used to generate Röntgen rays, but is found also at pressures greater than 1 mm. of mercury. An appreciable amount of gas can be made to disappear in this way when introduced gradually into the tube; the writer in a small tube used up a quantity which would occupy a volume of 5 c.c. at atmospheric pressure. The gas seems to be absorbed by the glass rather than by the electrode, as the absorption goes on when a ring discharge is sent through a bulb without electrodes. Not only do different bulbs emit different kinds of rays, but the same bulb may emit at the same time rays of different kinds. The property by which it is most convenient to identify a ray is the absorption it suffers when it passes through a certain thickness of aluminium and tin-foil. In some experiments made by M'Clelland and the writer [237] on the absorption of the rays produced by sheets of tin-foil, it was found that the absorption by the first sheets of tin-foil traversed by the rays was much greater than that by the same number of sheets when the rays had already passed through several sheets of tin-foil. This effect is just what would occur if some of the rays were readily absorbed by tin-foil, whilst others passed through with greater facility; thus the first few layers would stop all the readily absorbable rays, while those left would get through. M'Clelland showed that if he took thicknesses of two different substances such as to give equal absorptions with the rays from one bulb, they would not necessarily give equal absorptions with the rays from another, again proving the variety which exists in these rays. The fact that the rays when they pass through a gas ionize it and make it a conductor of electricity (see § 15) provides one of the best means of investigating their intensity, as the measurement of the amount of conductivity they confer on a gas is both more exact and more convenient than measurements of photographic or phosphorescent effects.

When Röntgen rays impinge on a surface there is a diffuse return of rays. The absence of refraction would lead us to expect that there would be no regular reflexion, but the experiments of Rood,[238] Joly,[239] and Lord Blythswood [240] seem to prove that it does exist to a small extent. By far the larger part, however, of the effect produced when the rays strike a surface is the emission of secondary Röntgen radiation, which possesses the characteristic properties of primary Röntgen radiation, but differs in being far less penetrating. The effects produced when Röntgen rays fall upon the surfaces of solids or liquids have been investigated by Perrin,[241] Sagnac,[242] and Townsend.[243] The results obtained by these observers have already been discussed (§ 17).

§ 33. *Nature of Röntgen Rays.*—Whether Röntgen rays are a form of light, that is, are some form of electro-magnetic disturbance propagated through the ether, is a question on which at present the evidence is not quite decisive. They resemble light in their rectilinear propagation. They affect a photographic plate, and, as Brandes and Dorn [245] have shown, they produce an effect, though a small one, on the retina, giving rise to a very faint illumination of the whole field of view. They resemble light in not being deflected by either electric or magnetic forces, while the secondary rays, of small penetrating power, produced by the incidence of the more penetrating primary rays, may be compared with the fluorescent visible light given out by certain substances when illuminated with ultra-violet light. The absence of refraction is not an argument against the rays being a kind of light, for all theories of refraction make this property depend upon the relation between the period of vibration, T, of the refracting substance, and the period t of the light vibrations, the refraction vanishing when T/t is very small. Thus there would be no refraction for light of very small period, and this would also be true if instead of regular periodic undulations we have a pulse of electro-magnetic disturbance, provided the time taken by light to travel over the thickness of the pulse be small compared with the periods of vibration of the molecules of the refracting substance. The absence of polarization in Röntgen rays after passing through tourmaline is again not decisive; the structure of tourmaline may be too coarse to produce polarization by absorption in waves of such small wave-length, or of such thin pulses as we must, if we accept this view, regard as forming Röntgen rays. The difficulties of experiments on the diffraction of these rays are very great, apart from those which would be caused by the smallness of the wave-length or the thinness of the pulse. The secondary radiation produced when the rays strike against the photographic plate or pass through air might give rise to what might easily be mistaken for diffraction effects. Röntgen [246] has never succeeded in observing effects which prove the existence of diffraction. Fomm [247] observed, in the photograph of a narrow slit, light and dark bands which look like diffraction bands, but observations with slits of different sizes showed that they were not of this nature, and Haga and Wind [248] have explained them as contrast effects. The last two observers, however, noticed with a very narrow wedge-shaped slit a broadening of the image of the narrow part which they are satisfied could not be explained by the causes previously mentioned, and which they regard as conclusive proof of diffraction. Other observations on this point have been made by Maier.[249] We may sum up our present state of knowledge by saying that while there is nothing in the properties of these waves inconsistent with their being a form of light, the direct experimental proof of this result is not very strong. Sir George Stokes [250] has put forward the view that the disturbances which constitute them are not regular periodic undulations, but very thin pulses. The writer [251] has shown that when charged particles are suddenly stopped, pulses of very intense electric and magnetic disturbance are started; as the cathode rays consist of negatively electrified particles, the impact of these on a solid would give rise to these intense pulses. Electromagnetic theory thus shows that effects resembling light in being electro-magnetic disturbances propagated through the ether must be produced when the cathode rays strike against an obstacle. Since under these circumstances Röntgen rays are produced, it seems natural, unless direct evidence to the contrary is obtained, to connect the Röntgen rays with these pulses.

Absorption of Röntgen Rays.—Though as a rule dense bodies absorb Röntgen rays more powerfully than light ones, there does not appear to be that simple connexion between density and absorption which Lenard has shown to exist in the case of the Lenard rays. For the latter the absorption by slabs of different substances is the same, independent of the nature and physical condition of the substance, if the thickness of the slab is inversely proportional to the density of the substance. For the Röntgen rays Benoist [252] gives the following numbers for the absorption by slabs whose thicknesses are inversely proportional to their densities:—

Pt.	Pd.	Ag.	Cu.	Sn.	Mica.	Glass.	Al.	P.	Air. SO_2. CH_3Cl.
·81	·83	·75	·60	·74	·13	·26	·09	.1	·14

We do not know yet whether the proportion between the absorption of different substances is the same for the more penetrating rays as for those easily absorbed, and it is quite possible that the numbers in the preceding table only hold for one particular kind of ray. Gladstone and Hibbert,[253] Humphreys,[254] Novak and Sale,[255] have shown that the absorption of a compound is equal to the sum of the absorptions due to its components.

Apparatus for producing Röntgen Rays.—The tube now used most frequently for producing Röntgen rays is of the kind introduced by Porter,[256] and known as a focus tube (Fig. 34). The cathode is a portion of a hollow sphere, and the cathode rays come to a point on or near a metal plate A, connected with the anode; this plate is the source of the rays. The walls of the tube get strongly electrified. This electrification affects the working of the tube, and the production of rays can often be improved by having an earth-connected piece of tin-foil on the outside of the bulb, and moving it about until the best position is attained. To produce the discharge an induction coil is generally employed. Recently an interrupter called Wehnelt's [257] interrupter (though it was used by Spottiswoode many years ago) has been much used. One of its forms is shown in Fig. 35. A pointed platinum terminal forms the cathode, while the anode consists of a large lead plate. These are placed in a vessel containing dilute sulphuric acid, and an electromotive force of about 50 volts is applied to the terminals. In consequence there is a vigorous development of gas at the cathode, and the bubbles, interrupting the continuity of the circuit from the electrode to the electrolyte, render the current

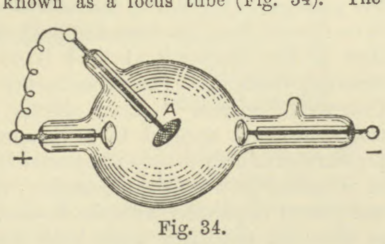


Fig. 34.

intermittent. With this device a very rapid rate of intermission can be obtained with large currents, but its use is apt to curtail the life of the bulb; there is also considerable waste of platinum in the interrupter, which is dissipated as fine powder from the cathode, and remains suspended in the electrolyte.

Phosphorescent Screens.—Screens which become fluorescent under the influence of the Röntgen rays are generally made of platino-cyanides; that of potassium is very efficacious, but others can be used. Scheelite prepared in a particular way is sometimes employed. Though bodies which fluoresce under the Röntgen rays generally do so under Lenard rays, yet according to Precht,[258] there are substances which fluoresce brightly under the latter which only do so to a very slight extent under the former.

§ 34. *Scattering of the Negative Electrodes.*—In addition to the cathode rays, portions of metal start normally from the cathode and form a metallic deposit on the walls of the tube. The amount of this deposit varies very much with the metal. Crookes[259] found that the quantities of metal torn from electrodes of the same size, in equal times, by the same current, are in the order Pd, Au, Ag, Pb, Sn, Pt, Cu, Cd, Ni, In, Fe. . . . In air there is very little deposit from an Al cathode, but it is abundant in tubes filled with the monatomic gases, mercury vapour, argon, or helium.[260] The scattering increases as the density of the gas diminishes. The particles of metal are at low pressures deflected by a magnet, though not nearly to the same extent as the cathode rays. According to Grandquist,[261] the loss of weight of the cathode in a given time is proportional to the square of the current; it is therefore not, like the loss of the cathode in ordinary electrolysis, proportional to the quantity of current which passes through it.

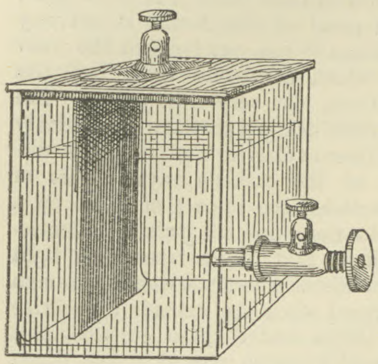


Fig. 35.

§ 35. *Action of a Magnet on the Discharge.*—The older observations on this point are described in the article ELECTRICITY, *Ency. Brit.* vol. viii. p. 74. More recent experiments have furnished some interesting results. The writer[262] found that with a ring discharge at low pressures a transverse magnetic field stopped the discharge, while a longitudinal one facilitated it. This can be explained by the fact that the ions left behind by one discharge facilitate the passage of the next; the action of the transverse field is to remove the ions from the path of the discharge, while that of the longitudinal field is to restrain them from straying from it. The experiments of Birkeland[263] and Campbell-Swinton[264] have shown that a longitudinal magnetic force applied to a vacuum tube at a very low pressure diminishes to a remarkable degree the difference of potential between the electrodes; thus when a spark gap was placed in parallel with the discharge tube, and adjusted so that the discharge went both across the air gap and through the tube, the length of the air gap when the magnetic field was present could be reduced to a small fraction of the value when the field was absent. Birkeland showed that the great diminution occurred suddenly when the magnetic force at the cathode reached a definite value, depending on the pressure of the gas. Warburg[265] discovered an effect of a magnetic field on the discharge from a small electrode in the neighbourhood of a large one, which was subsequently re-observed by Phillips.[266] When the small electrode is positively electrified and raised to a potential of a few hundred volts, the electricity escaped from it readily when a strong magnetic field was applied, although it insulated well when there was no field; when the small electrode was negatively electrified there was no such effect. This may be due to the velocity of the negative ion being greater than that of the positive, whereby the discharge is carried mainly by the negative ions. When the small electrode is negative, these ions will be shot off from places of strong electric force, and acquiring a high velocity, will consequently be but little affected by a magnet; when the small electrode is positive the negative ions starting from the weak parts of the field, having only a small velocity, will consequently be greatly affected by the magnetic field, and may by it be so concentrated that they form a conducting path and so cause the discharge. Phillips observed that if a discharge is first sent through a tube, then stopped and a strong magnetic field started, a luminous ring discharge appears, which rotates around a line of magnetic force as axis.

[1] J. J. Thomson, *Proc. Camb. Phil. Soc.* ix. p. 61; Righi, *Acc. dei Lincei*, v. p. 143, 1896; Benoist and Hurmuzescu, *Comptes Rendus*, cxxii. p. 235, 1896. [2] Becquerel, *Comptes Rendus*, 1896, cxxii. pp. 420, 501, 559, 689, 762, 1086. [3] Schmidt, *Wied. Ann.* lxv. p. 141. [4] Curie, *Comptes Rendus*, cxxvii. pp. 175, 1215, 1898; Debierne, *Comptes Rendus*, 129, p. 543; 130, p. 906. [5] J. J. Thomson, *Phil. Mag.* xliv. p. 293, 1897. [6] Lenard, *Wied. Ann.* lxiii. p. 253. [7] E. Wiedemann, *Zeitschrift für Elektro-chemie*, ii. p. 159. [8] Schuster, *Proc. Roy. Soc.* xlvii. p. 526. [9] Naccari, *Atti della Science de Torino*, 25, p. 252, 1890; Elster and Geitel, *Wied. Ann.* xxxix. 1890, p. 321. [10] J. J. Thomson and E. Rutherford, *Phil. Mag.* xlii. p. 392. [11] J. J. Thomson, *Nature*, April 23, 1896. [12] J. J. Thomson and E. Rutherford, *Phil. Mag.* xlii. p. 392. [13] *Phil. Mag.* xliv. p. 422. [14] *Phil. Mag.* xlvi. p. 29. [15] *Phil. Trans.* cxciii. p. 157. [16] *Phil. Mag.* xliv. p. 422. [17] *Phil. Mag.* xlvi. p. 120. [18] *Phil. Mag.* xlvii. p. 109. [19] *Proc. Camb. Phil. Soc.* ix. p. 401. [20] *Phil, Trans.* cxcii. p. 499. [21] *Phil. Mag.* xlvi. p. 29. [22] *Phil. Mag.* xlviii. p. 401. [23] *Proc. Camb. Phil. Soc.* ix. p. 401. [24] *Phil. Trans.* cxciii. p. 129. [25] *Phil. Trans.* cxciii. p. 289; cf. Thomson. *Phil. Mag.* xlvi. p. 528. [26] *Phil. Mag.* xlvi. p. 29. [27] *Phil. Trans.* cxcii. p. 499. [28] J. J. Thomson, *Phil. Mag.* xlvi. p. 528. [29] *Phil. Trans.* clxxxix. p. 265. [30] *Wied. Ann.* lxv. p. 440. [31] *Wied. Ann.* lxix. p. 167. [32] *Phil. Mag.* xlvi. p. 120. [33] *Wied. Ann.* lxv. p. 152. [34] *Phil. Mag.* xxx. p. 188. [35] *Physikal. Revue*, i. p. 765. [36] *Journ. de Phys.* [2], vii. p. 153. [37] *Wied. Ann.* xxxiv. p. 731. [38] *Wied. Ann.* xxxiii. p. 638. [39] *Proc. Roy. Soc.* lix. p. 333. [40] *Phil. Mag.* xlvi. p. 82. [41] Matteucci, *Comptes Rendus*, xxv. p. 244; xxviii. p. 508; Warburg, *Pogg. Ann.* cxlv. p. 578; Boys, *Phil. Mag.* xxviii. p. 14; Linss, *Meteorol. Zeitsch.* iv. p. 352; Elster and Geitel, *Ann. d. Physik.* [4], ii. p. 425; C. T. R. Wilson, *Proc. Camb. Phil. Soc.* xi. p. 32. [42] *Ann. de Chim. et de Phys.* [3], xxxix. p. 355. [43] *Comptes Rendus*, civ. p. 283. [44] *Phil. Mag.* [5], xxix. pp. 358, 441. [45] *Phil. Trans.* cxcii. p. 499. [46] *Wied. Ann.* lv. p. 507. [47] *Wied. Ann.* xvii. pp. 1, 236, 519; xviii. p. 403. [48] J. J. Thomson, *Phil. Mag.* xl. p. 511; Wesendonck, *Wied. Ann.* lxvi. p. 121. [49] *Phil. Mag.* xlvi. p. 29. [50] *Wied. Ann.* xlii. p. 18. [51] *Pogg. Ann.* cxxxvi. p. 233. [52] *Acc. dei Lincei* [5], v. p. 118. [53] *Wied. Ann.* xvi. p. 193; xix. p. 588; xxii. p. 123; xxvi. p. 1; xxxi. p. 109; xxxvii. p. 315; xxxviii. p. 27. [54] *Phil. Mag.* [4], xlvi. p. 257. [55] *Comptes Rendus*, cxiv. p. 1531. [56] *Proc. Roy. Soc.* xlvii. p. 559. [57] *Phil. Mag.* xlvi. p. 29. [58] *Wied. Ann.* xxxviii. p. 27. [59] J. J. Thomson, *Proc. Roy. Soc.* liii. p. 90. [60] *Phil. Mag.* xlvi. p. 29; *Proc. Camb. Phil. Soc.* x. p. 241. [61] *Physical Review*, vii. p. 129. [62] *Wied. Ann.* vii. p. 614. [63] *Proc. Roy. Soc.* xlii. p. 371. [64] *Nature*, liii. p. 207. [65] *Wied. Ann.* xxxi. p. 983. [66] *Wied. Ann.* xxxiii. p. 308. [67] *Repertorium der Physik*, xxv. p. 105. [68] *Comptes Rendus*, cvii. p. 560. [69] *Comptes Rendus*, cvi. pp. 1149, 1593; cvii. p. 91; cviii. p. 1241; *Physikal. Revue*, i. p. 747. [70] *Phil. Mag.* xlv. p. 272. [71] *Wied. Ann.* lvii. p. 24. [72] *Wied. Ann.* xxxviii. pp. 40, 497; xli. p. 161; xlii. p. 564; xliii. p. 225; lii. p. 433; lv. p. 684. [73] *Wied. Ann.* xxxvii. p. 666. [74] *Journ. de Phys.* [2], ix. p. 468. [75] *Mem. della R. Acc. de Bologna* [4], x. p. 85. [76] *Wied. Ann.* lii. p. 438. [77] *Wied. Ann.* xli. p. 166. [78] *Journ. de Phys.* ix. p. 468. [79] *Mem. della R. Acc. de Bologna* [4], x. p. 85. [80] *Wied. Ann.* lv. p. 684; lxi. p. 445; *Wied. Beiblätter*, xxiii. p. 1051. [81] *Pogg. Ann.* cxxix. p. 177. [82] Perrin, *Thèses présentées à la faculté des Sciences de Paris*, 1897, p. 31. [83] *Proc. Camb. Phil. Soc.* ix. p. 319. [84] *Ann. d. Phys.* [4]. i. p. 486; iii. p. 298. [85] *Phil. Trans.* cxc. 11, p. 403. [86] *Wied. Ann.* xli. p. 166. [87] *Wied. Ann.* xxxvii. p. 443. [88] *Trans. Roy. Soc. Ed.* xxx. p. 337; xxxv. p. 1. [89] *Phil. Mag.* xliii. p. 241. [90] *Electrician*, March 27, 1896. [91] *Thèses présentées à la faculté des Sciences de Paris*, 1897. [92] *Phil. Mag.* xliv. p. 422. [93] *Proc. Camb. Phil. Soc.* x. p. 10. [94] *Proc. Camb. Phil. Soc.* x. p. 217.

[95] *Wied. Ann.* lxiv. p. 18. [96] *Comptes Rendus*, July and Dec. 1897, Jan. 1898. [97] *Comptes Rendus*, 1896, pp. 420, 501, 559, 689, 762, 1086; 1897, pp. 438, 800. [98] *Wied. Ann.* lxv. p. 141. [99] *Comptes Rendus*, cxxvii. 1898, p. 175. [100] *Phil. Mag.* xlvii. p. 109; xlix. p. 1. [101] *Phil. Mag.* xlviii. p. 360. [102] *Phil. Mag.* xliii. p. 418. [103] *Wied. Ann.* lxix. p. 83. [104] *Phil. Mag.* xliv. p. 293. [105] *Wied. Ann.* lxiii. p. 253. [106] *Phil. Trans.* cxcv. p. 49. [107] *Wied. Ann.* lvi. p. 255. [108] *Experimental Researches*, § 1417, [109] *Phil. Mag.* xxxvi. p. 313. [110] *Wied. Ann.* lxii. p. 385; *Sitz. Akad. Wissensch. zu Berlin*, 1896, p. 223. [111] *Wied. Ann.* xxxi. p. 983. [112] *Wied. Ann.* xxxiii. p. 241. [113] *Comptes Rendus*, cxxii. p. 131. [114] *Wied. Ann.* lv. p. 656. [115] *Wied. Ann.* lxii. p. 385. [116] *Wied. Ann.* lxvi. p. 636; lxviii. p. 776. [117] *Phil. Mag.* xxx. p. 248. [118] *Ann. de Chim. et de Phys.* [5], xxv. p. 486. [119] *Wied. Ann.* xxxvii. p. 79. [120] *Phil. Mag.* xxiv. p. 106. [121] R. J. Strutt, *Phil. Trans.* cxciii. p. 377. [122] *Reprint of Papers on Electrostatics and Magnetism*, p. 250. [123] *Ann. de Chim. et de Phys.* [5], xxv. p. 531. [124] *Wied. Ann.* xxxvii. p. 79. [125] *Wied. Ann.* xxxviii. p. 231. [126] *Phil. Mag.* [5], xxix. p. 182. [127] *Experimental Researches*, § 1482. [128] *Phil. Trans.* 1878, Pt. i. p. 55. [129] *Wied. Ann.* xxxviii. p. 222. [130] *Nuovo Cimento* [2], xvi. p. 97. [131] *Proc. Roy. Soc.* lii. p. 99. [132] *Proc. Roy. Soc.* lii. p. 99. [133] *Ann. de Chim. et de Phys.* [5], xxix. p. 181. [134] *Phil. Mag.* [5], x. p. 389. [135] *Wied. Ann.* xxxvii. p. 69. [136] *Experimental Researches*, § 1421 *et seq.* [137] *Ann. de Chim. et de Phys.* [5], xxix. p. 181. [138] *Phil. Mag.* [5], xxiv. p. 106. [139] *Wied. Ann.* xxxvii. p. 69. [140] *Wied. Ann.* xxxvii. p. 306. [141] *Göttingen. Nachrichten*, 1878, p. 390. [142] *Wied. Ann.* xxxviii. p. 663. [143] *Wied. Ann.* lxix. p. 372. [144] *Wied. Ann.* lxvi. p. 676. [145] *Phil. Trans.* cxciii. p. 189. [146] *Phil. Mag.* xxxii. p. 285. [147] *Phil. Trans.* cxcv. p. 259. [148] *Wien Berichte*, c. II. 1891, p. 127. [149] *Göttingen. Nachrichten*, 1878, p. 390. [150] *Wied. Ann.* xlix. p. 150. [151] *Wied. Ann.* lxiii. p. 305. [152] *Sitz. Akad. d. Wissensch. zu Berlin*, xl. 1899, p. 770. [153] Harvey and Herd, *Phil. Mag.* xxxvi. p. 45; Himstedt, *Wied. Ann.* lii. p. 473; J. J. Thomson, *Phil. Mag.* xl. p. 511. [154] *Comptes Rendus*, cxv. 1892, p. 1273. [155] *Proc. Inst. Elec. Engin.* xxviii. p. 400. [156] *Proc. Roy. Soc.* lv. p. 174. [157] *Elektrotechnische Zeitschrift*, iv. 1883, p. 150. [158] *Electrician*, 1895, i. p. 319 *et seq.*; xi. p. 418 *et seq.* [159] *Wied. Ann.* xxxi. 1887, p. 384. [160] *Wied. Ann.* xxxiii. 1888, p. 609. [161] *Wied. Ann.* lviii. 1896, p. 73. [162] *Lumière El.* xlv. p. 79. [163] *Electrician*, xxxi. p. 60. [164] *Physikal. Zeitschrift*, i. p. 53. [165] *Wien. Berichte*, xcviii. p. 1192. [166] *Wied. Ann.* lviii. p. 73. [167] *Proc. Roy. Soc.* xlvii. 1890, p. 118. [168] *Phil. Mag.* [3], xvi. 1840, p. 478. [169] *Comptes Rendus*, xxx. 1850, p. 201. [170] *Pogg. Ann.* cxlix. 1873, p. 521. [171] *Cantor Lectures on the Electric Arc.* [172] *Proc. Roy. Soc.* lvi. p. 262. [173] *Proc. Roy. Soc.* xlvii. 1890, p. 557. [174] *Wied. Ann.* xxi. 1884, p. 112. [175] Schuster, *Brit. Ass. Rep. on Spectrum Analysis*, 1880; Goldstein, *Wied. Ann.* xv. 1882, p. 280. [176] *Wied. Ann.* xx. 1883, p. 705. [177] *Wied. Ann.* lxiv. 1898, p. 49. [178] *Wied. Ann.* liv. 1895, p. 243. [179] *Wied. Ann.* lxviii. 1899, p. 752. [180] *Phil. Mag.* xlix. p. 505. [181] *Wied. Ann.* xxxi. 1887, p. 545; xl. 1890, p. 1. [182] *Proc. Roy. Soc.* lxiii. p. 356. [183] *Phil. Trans.* cxciii. p. 377. [184] *Wied. Ann.* vi. 1879, p. 298. [185] *Wied. Ann.* xxi. 1884, p. 128. [186] *Wied. Ann.* x. 1880, p. 225. [187] *Wied. Ann.* lix. 1896, p. 238. [188] *Pogg. Ann.* cvii. 1859, p. 77; cxvi. 1862, p. 45. [189] *Pogg. Ann.* cxxxvi. 1869, p. 8. [190] *Monat. der Berl. Akad.* 1876, p. 284. [191] *Phil. Trans.* 1879, Pt. i. p. 135; Pt. ii. pp. 587, 661. [192] *Wied. Ann.* liv. 1895, p. 371. [193] *Wied. Ann.* liv. 1898, p. 618. [194] *Wied. Ann.* lvi. 1898, p. (209) 201. [195] *Ztschr. f. physik. Chemie*, v. 1890, p. 322. [196] *Phil. Trans.* Pt. ii. 1879, p. 645. [197] *Proc. Camb. Phil. Soc.* 1898, ix. p. 371. [198] *Journ. de Phys.* [3], viii. 1899, p. 140. [199] *Wied. Ann.* lxvii. 1899, p. 421. [200] *Phil. Trans.* 1879, Pt. i. p. 152. [201] *Wied. Ann.* lxvi. 1898, p. 954. [202] *Pogg. Ann.* ciii. 1858, p. 88. [203] *Pogg. Ann.* cxxxvi. 1869, p. 213. [204] *Phil. Trans.* 1879, Pt. i. p. 557. [205] *Proc. Roy. Soc.* xlvii. 1890, p. 526. [206] *Comptes Rendus*, 1896, p. 492. [207] *Phil. Mag.* xlviii. p. 478. [208] *Proc. Camb. Phil. Soc.* ix. p. 243. [209] *Comptes Rendus*, cxxi. 1898, p. 1130. [210] *Phil. Mag.* Oct. 1897. [211] *Phil. Mag.* xliv. p. 293. [212] *Phil. Mag.* xliv. p. 293. [213] *Wied. Ann.* lxi. 1897, p. 544; lxv. 1898, p. 431. [214] *Wied. Ann.* lxix. p. 739. [215] *Phil. Mag.* xxxviii. p. 358. [216] *Nuovo Cimento* [4], vi. p. 336. [217] *Physikal. Zeitschrift*, i. p. 51. [218] *Wied. Ann.* xlv. p. 28. [219] *Wied. Ann.* li. p. 225. [220] *Wied. Ann.* lvi. p. 255. [221] *Wied. Ann.* lxiv. p. 279. [222] *Proc. Roy. Soc.* lxi. p. 227. [223] *Wied. Ann.* lxii. p. 134. [224] *Wied. Ann.* xv. 254. [225] *Wied. Ann.* lxvi. p. 49. [226] *Proc. Roy. Soc.* lxiv. p. 377. [227] *Eine neue Form der Elektrische Abstossung*, Berlin, 1880. [228] *Phil. Trans.* 1879, Pt. ii. p. 682. [229] *Wied. Ann.* xlvi. p. 158. [230] *Berlin Sitzungsberichte*, xxxix. p. 691. [231] *Wied. Ann.* lxvii. p. 421. [232] *Wied. Ann.* lxv. p. 440. [233] *Wied. Ann.* lxix. p. 167. [234] *Journ. de Phys.* viii. pp. 5, 148. [235] *Proc. Roy. Soc.* xlvii. p. 526. [236] *Wied. Ann.* lxiv. p. 1 (reprinted from the original paper in the *Sitzungsber. der Würzburger Physik. Medic. Gesellsch.* 1895). [237] *Proc. Camb. Phil. Soc.* ix. p. 126. [238] *Nature*, liii. p. 614. [239] *Nature*, liii. p. 522. [240] *Proc. Roy. Soc.* lix. p. 330. [241] *Comptes Rendus*, cxxiv. p. 455. [242] *Journ. de Phys.* [3], viii. 1899, p. 65. [243] *Proc. Camb. Phil. Soc.* x. p. 217, 1899. [244] *Wied. Ann.* lxiv. p. 18. [245] *Wied. Ann.* lx. p. 478. [246] *Wied. Ann.* lxiv. p. 18. [247] *Wied. Ann.* lix. p. 350. [248] *Wied. Ann.* lxviii. p. 884. [249] *Wied. Ann.* lxviii. p. 903. [250] *Proc. Manchester Literary and Philosophical Society*, 1898. [251] *Phil. Mag.* xlv. p. 172. [252] *Comptes Rendus*, cxxiv. p. 146, 1897. [253] *Chemical News*, lxxviii. p. 199. [254] *Phil. Mag.* xliv. p. 401. [255] *Zeitschrift für Physikal. Chem.* xix. p. 489. [256] *Nature*, liii. p. 413. [257] *Elektrotech. Ztschr.* xx. p. 76. [258] *Wied. Ann.* lxi. p. 330. [259] *Proc. Roy. Soc.* l. p. 88. [260] Callendar, *Nature*, lvi. p. 624. [261] *Öfversigt Kgl. Vetensk. Akad. Förh. Stockholm*, 1898, p. 709. [262] *Phil. Mag.* xxxii. p. 321. [263] *Comptes Rendus*, 1896, p. 492. [264] *Proc. Roy. Soc.* lx. p. 179. [265] *Wied. Ann.* lxii. 1897, p. 385. [266] *Proc. Roy. Soc.* lxv. p. 320.

(J. J. T.)

VI. Electric Waves.

§ 1. Maxwell proved that on his theory electromagnetic disturbances are propagated as a wave motion through the dielectric, while Lord Kelvin[1] had in 1853 proved from electromagnetic theory that the discharge of a condenser is oscillatory, a result which Feddersen[2] verified by a beautiful series of experiments. The oscillating discharge of a condenser had been inferred by Henry as long ago as 1842 from his experiments on the magnetization produced in needles by the discharge of a condenser. From these two results it follows that electric waves must be passing through the dielectric surrounding a condenser in the act of discharging, but it was not until 1887 that the existence of such waves was demonstrated by direct experiment. This great step was made by Hertz,[3] whose experiments on this subject form one of the greatest contributions ever made to experimental physics. The difficulty which had stood in the way of the observations of these waves was the absence of any method of detecting electrical and magnetic forces, reversed some millions of times per second, and only lasting for an exceedingly short time. This was removed by Hertz, who showed that such forces would produce small sparks between pieces of metal very nearly in contact, and that these sparks were sufficiently regular to be used to detect electric waves and to investigate their properties. Other and more delicate methods have subsequently been discovered, but the results obtained by Hertz with his detector were of such signal importance, that we shall begin our account of experiments on these waves by a description of some of Hertz's more fundamental experiments. To produce the waves he used two forms of vibrator. The first is represented in Fig. 36. A and B are two zinc plates about

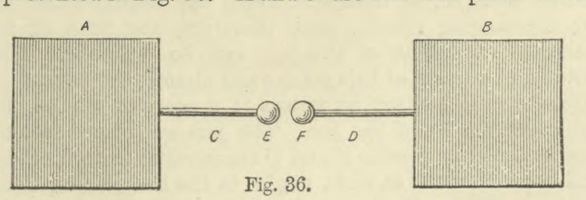


Fig. 36.

40 cm. square; to these brass rods, C,D, each about 30 cm. long, are soldered, terminating in brass balls E and F. To get good results it is necessary that these balls should be very brightly polished, and as they get roughened by the sparks which pass between them it is necessary to repolish them at short intervals; they should be shaded from light and from sparks, or other source of ultra-violet light. In order to excite the waves, C and D are connected to the two poles of an induction coil; sparks cross the air-gap which becomes a conductor, and the charges on the plates oscillate backwards and forwards like the charges on the coatings of a Leyden jar when it is short circuited. The object of polishing the balls and screening off light is to get a sudden and sharp discharge: if the balls are rough there will be sharp points from which the

charge will gradually leak, and the discharge will not be abrupt enough to start electrical vibrations, as these have an exceedingly short period. From the open form of this vibrator we should expect the radiation to be very large and the rate of decay of the amplitude very rapid. Bjerknes[4] found that the amplitude fell to $1/e$ of the original value, after a time 4T where T was the period of the electrical vibrations. Thus after a few vibrations the amplitude becomes inappreciable. To detect the waves produced by this vibrator Hertz used a piece of copper-wire bent into a circle, the ends being furnished with two balls, or a ball and a point connected by a screw, so that the distance between them admitted of very fine adjustment. The radius of the circle for use with the vibrator just described was 35 cm., and was so chosen that the free period of the detector might be the same as that of the vibrator, and the effects in it increased by resonance. It is evident, however, that with a primary system as greatly damped as the vibrator used by Hertz, we could not expect very marked resonance effects, and as a matter of fact the accurate timing of vibrator and detector in this case is not very important. With electrical vibrators which can maintain a large number of vibrations, resonance effects are very striking, as is beautifully shown by the following experiment due to Lodge,[5] whose researches have greatly advanced our knowledge of electric waves. A and C (Fig. 37)

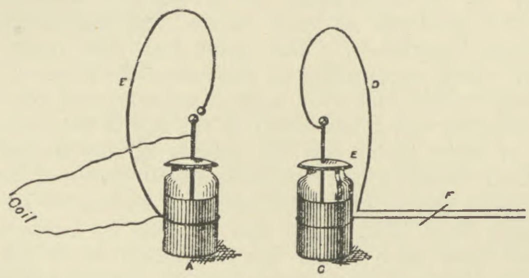


Fig. 37.

are two Leyden jars, whose inner and outer coatings are connected by wires, B and D, bent so as to include a considerable area. There is an air-break in the circuit connecting the inside and outside of one of the jars, A, and electrical oscillations are started in A by joining the inside and outside with the terminals of a coil or electrical machine. The circuit in the jar C is provided with a sliding piece, F, by means of which the self-induction of the discharging circuit, and, therefore, the time of an electrical oscillation of the jar, can be adjusted. The inside and outside of this jar are put almost, but not quite, into electrical contact by means of a piece of tin-foil, E, bent over the lip of the jar. The jars are placed face to face so that the circuits B and D are parallel to each other, and approximately at right angles to the line joining their centres. When the electrical machine is in action sparks pass across the air-break in the circuit in A, and by moving the slider F it is possible to find one position for it in which sparks pass from the inside to the outside of C across the tin-foil, while when the slider is moved a short distance on either side of this position the sparks cease.

Hertz found that when he held his detector in the neighbourhood of the vibrator minute sparks passed between the balls. These sparks were not stopped when a large plate of non-conducting substance, such as the wall of a room, was interposed between the vibrator and detector, but a large plate of very thin metal stopped them completely.

To illustrate the analogy between electric waves and waves of light Hertz found another form of apparatus more convenient. The vibrator consisted of two equal brass cylinders, 12 cm. long and 3 cm. in diameter, placed with their axes coincident, and in the focal line of a large zinc parabolic mirror about 2 metres high, with a focal length of 12·5 cm. The ends of the cylinders nearest each other, between which the sparks passed, were carefully polished. The detector, which was placed in the focal line of an equal parabolic mirror, consisted of two lengths of wire, each having a straight piece about 50 cm. long and a curved piece about 15 cm. long bent round at right angles so as to pass through the back of the mirror. The ends which came through the mirror were connected with a spark micrometer, the sparks being observed from behind the mirror. The mirrors are shown in Fig. 38.

§ 2. *Reflexion and Refraction.*—To show the reflexion of the waves Hertz placed the mirrors side by side, so that their openings looked in the same direction, and their axes

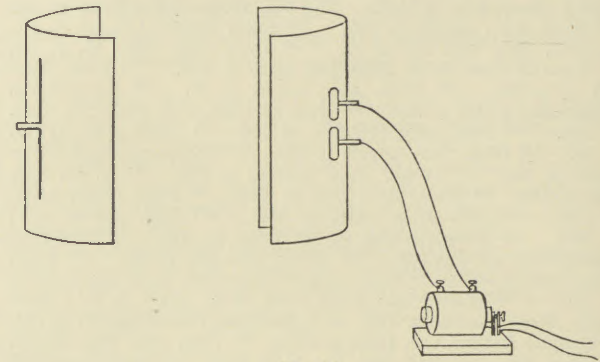


Fig. 38.

converged at a point about 3 m. from the mirrors. No sparks were then observed in the detector when the vibrator was in action. When, however, a large zinc plate about 2 m. square was placed at right angles to the line bisecting the angle between the axes of the mirrors sparks became visible, but disappeared again when the metal plate was twisted through an angle of about 15° to either side. This experiment showed that electric waves are reflected, and that, approximately at any rate, the angle of incidence is equal to the angle of reflexion. To show refraction Hertz used a large prism made of hard pitch, about 1·5 m. high, with a slant side of 1·2 m. and an angle of 30°. When the waves from the vibrator passed through this the sparks in the detector were not excited when the axes of the two mirrors were parallel, but appeared when the axis of the mirror containing the detector made a certain angle with the axis of that containing the vibrator. When the system was adjusted for minimum deviation the sparks were most vigorous, when the angle between the axes of the mirrors was 22°. This corresponds to an index of refraction of 1·69.

§ 3. *Analogy to a Plate of Tourmaline.*—If a screen be made by winding wire round a large rectangular framework, so that the turns of the wire are parallel to one pair of sides of the frame, and if this screen be interposed between the parabolic mirrors when placed so as to face each other, there will be no sparks in the detector when the turns of the wire are parallel to the focal lines of the mirror; but if the frame is turned through a right angle so that the wires are perpendicular to the focal lines of the mirror the sparks will recommence. If the framework is substituted for the metal plate in the experiment on the reflexion of electric waves, sparks will appear in the detector when the wires are parallel to the focal lines of the mirrors, and will disappear when the wires are at right angles to these lines. Thus the framework reflects but does not transmit the waves when the electric force in them is parallel to the wires, while it transmits but does not reflect waves in which the electric force is at right angles to the wires.

The wire framework behaves towards the electric waves exactly as a plate of tourmaline does to waves of light. Du Bois and Rubens,[6] by using a framework wound with very fine wire placed very close together, have succeeded in polarizing waves of radiant heat, whose wave length, although longer than that of ordinary light, is very small compared with that of electric waves.

§ 4. *Angle of Polarization.*—When light polarized at right angles to the plane of incidence falls on a refracting substance at an angle $\tan^{-1}\mu$, where μ is the refractive index of the substance, all the light is refracted and none reflected; whereas when light is polarized in the plane of incidence some of the light is always reflected whatever the angle of incidence. Trouton[7] has shown that similar effects take place with electric waves. From a paraffin wall 3 feet thick, reflexion always took place when the electric force in the incident wave was at right angles to the plane of incidence, whereas at a certain angle of incidence there was no reflexion when the vibrator was turned, so that the electric force was in the plane of incidence. This shows that on the electromagnetic theory of light the electric force is at right angles to the plane of polarization.

§ 5. *Stationary Electrical Vibrations.*—Hertz[8] made his experiments on these in a large room about 15 m. long. The vibrator, which was of the type first described, was placed at one end of the room, its plates being parallel to the wall, at the other end a piece of sheet zinc about 4 m. by 2 m. was placed vertically against the wall. The detector—the circular ring previously described—was held so that its plane was parallel to the metal plates of the vibrator, its centre on the line at right angles to the metal plate, bisecting at right angles the spark gap of the vibrator, and with the spark gap of the detector parallel to that of the vibrator. The following effects were observed when the detector was moved about. When it was close up to the zinc plate there were no sparks, but they began to pass feebly as soon as it was moved forward a little way from the plate, and increased rapidly in brightness until it was about 1·8 m. from the plate when they attained their maximum. When its distance was still further increased they diminished in brightness, and vanished again at a distance of about 4 m. from the plate. When the distance was still further increased they reappeared, attained another maximum, and so on. They thus exhibited a remarkable periodicity similar to that which occurs when stationary vibrations are produced by the interference of direct waves with those reflected from a surface placed at right angles to the direction of propagation. Similar periodic alterations in the spark were observed by Hertz when the waves, instead of passing freely through the air and being reflected by a metal plate at the end of the room, were led along wires, as in the arrangement shown in Fig. 39. L and K are metal plates placed parallel to the plates of the vibrator, long parallel wires being attached to act as guides to the waves which were reflected from the isolated end. (Hertz only used one plate and one wire, but the double set of plates and wires introduced by Sarasin and De la Rive make the results more definite.) In this case the detector is best placed so that its plane is at right angles to the wires, while the air space is parallel to the plane containing the wires. The sparks instead of vanishing when the detector is at the far end of the wire are a maximum in this position, but wax and wane periodically as the detector is moved along the wires. The most obvious interpretation of these experiments was the one given by Hertz—that there was interference between the direct waves given out by the vibrator and those reflected either from the plate or from the ends of the wire, this interference giving rise to stationary waves. The places where the electric force was a maxima were the places where the sparks were brightest, and the places where the electric force was zero were the places where the sparks vanished. On this explanation the distance between two consecutive places where the sparks vanished would be half the wave length of the waves given out by the vibrator. Some very interesting experiments made by Sarasin and De la Rive[9] showed that this explanation could not be the true one, since by using detectors of different sizes they found that the distance between two consecutive places where the sparks vanished depended mainly upon the size of the detector, and very little upon that of the vibrator. With small detectors they found the distance small, with large detectors, large; in fact it is directly proportional to the diameter of the detector. We can see that this result is a consequence of the large damping of the oscillations of the vibrator and the very small damping of those of the detector. Bjerknes showed that the time taken for the amplitude of the vibrations of the vibrator to sink to $1/e$ of their original value was only 4T, while for the detector it was 500T′, when T and T′ are respectively the times of vibration of the vibrator and the detector. The rapid decay of the oscillations of the vibrator will stifle the interference between the direct and the reflected wave, as the amplitude of the direct wave will, since it is emitted later, be much smaller than that of the reflected one, and not able to annul its effects completely; while the well-maintained vibrations of the detector will interfere and produce the effects observed by Sarasin and De la Rive. To see this let us consider the extreme case in which the oscillations of the vibrator are absolutely dead-beat. Here an impulse, starting from the vibrator on its way to the reflector, strikes against the detector and sets it in vibration; it then travels up to the plate and is reflected, the electric force in the impulse being reversed by reflexion. After reflexion the impulse again strikes the detector, which is still vibrating from the effects of the first impact; if the phase of this vibration is such that the reflected impulse tends to produce a current round the detector in the same direction as that which is circulating from the effects of the first impact, the sparks will be increased, but if the reflected impulse tends to produce a current in the opposite direction the sparks will be diminished. Since the electric force is reversed by reflexion, the greatest increase in the sparks will take place when the impulse finds, on its return, the detector in the opposite phase to that in which it left it; that is, if the time which has elapsed between the departure and return of the impulse is equal to an odd multiple of half the time of vibration of the detector. If d is the distance of the detector from the reflector when the sparks are brightest, and V the velocity of propagation of electromagnetic disturbance, then $2d/V = (2n+1)(T'/2)$; where n is an integer and T′ the time of vibration of the detector, the distance between two spark maxima will be VT′/2, and the places where the sparks are a minimum will be midway between the maxima. Sarasin and De la Rive found that when the same detector was used the distance between two spark maxima was the same with the waves through air reflected from a metal plate and with those guided by wires and reflected from the free ends of the wire, the inference being that the velocity of waves along wires is the same as that through the air. This result, which as we shall see follows from Maxwell's theory, when the wires are not

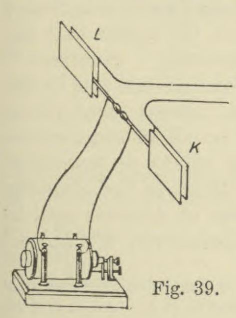


Fig. 39.

too fine, had been questioned by Hertz on account of some of his experiments on wires.

§ 6. *Detectors.*—The use of a detector with a period of vibration of its own thus tends to make the experiments more complicated, and many other forms of detector have been employed by subsequent experimenters. For example, in place of the sparks in air the luminous discharge through a rarefied gas has been used by Dragoumis,[10] Lecher [11] (who used tubes without electrodes laid across the wires in an arrangement resembling that shown in Fig. 42); and Arons.[12] Zehnder [13] used an exhausted tube to which an external electromotive force almost but not quite sufficient of itself to produce a discharge was applied; here the additional electromotive force due to the waves was sufficient to start the discharge. Detectors depending on the heat produced by the rapidly alternating currents have been used by Paalzow and Rubens,[14] Rubens and Ritter,[15] and Klemencic.[16] Rubens measured the heat produced by a bolometer arrangement, and Klemencic used a thermo-electric method for the same purpose. Boltzmann [17] used an electroscope as a detector. The spark gap consisted of a ball and a point, the ball being connected with the electroscope and the point with a battery of 200 dry cells. When the spark passed the cells charged up the electroscope. Ritter [18] utilized the contraction of a frog's leg as a detector, Lucas and Garrett [19] the explosion produced by the sparks in an explosive mixture of hydrogen and oxygen; while Bjerknes [20] and Franke [21] used the mechanical attraction between oppositely charged conductors. If the two sides of the spark gap are connected with the two pairs of quadrants of a very delicate electrometer, the needle of which is connected with one pair of quadrants, there will be a deflexion of the electrometer when the detector is struck by electric waves. A very efficient detector, indeed by far the simplest and best for metrical work, is that invented by Rutherford [22]; it consists of a bundle of fine iron wires magnetized to saturation and placed inside a small magnetizing coil, through which the electric waves cause rapidly alternating currents to pass which demagnetize the soft iron. If the instrument is used to detect waves in air, long straight wires are attached to the ends of the demagnetizing coil to collect the energy from the field; to investigate waves in wires it is sufficient to make a loop or two in the wire and place the magnetized piece of iron inside it. The amount of demagnetization, which can be observed by the change in the deflexion of a magnetometer placed near the iron, measures the intensity of the electric waves, and very accurate determinations can be made with ease with this apparatus. It is also very delicate, though in this respect it does not equal the detector to be next described, the coherer; Rutherford got indications in 1895 when the vibrator was $\frac{3}{4}$ of a mile away from the detector, and where the waves had to traverse a thickly populated part of Cambridge. It can also be used to measure the coefficient of damping of the electric waves, for since the wire is initially magnetized to saturation, if the direction of the current when it first begins to flow in the magnetizing coil is such as to tend to increase the magnetization of the wire, it will produce no effect, and it will not be until the current is reversed that the wire will lose some of its magnetization. The effect then gives the measure of the intensity half a period after the commencement of the waves. If the wire is put in the coil the opposite way, *i.e.*, so that the magnetic force due to the current begins at once to demagnetize the wire, the demagnetization gives a measure of the initial intensity of the wave. Comparing this result with that obtained when the wires were reversed, we get the coefficient of damping.

§ 7. *Coherers.* — The most sensitive detector of electric waves is the "coherer," although for metrical work it is not so suitable as that just described. It depends upon the fact discovered by Branly,[23] that the resistance between loose metallic contacts, such as a pile of iron turnings, diminishes when they are struck by an electric wave. One of the forms made by Lodge [24] on this principle consists simply of a glass tube containing iron turnings, in contact with which are wires led into opposite ends of the tube. The arrangement is placed in series with a galvanometer (one of the simplest kind will do) and a battery; when the iron turnings are struck by electric waves their resistance is diminished and the deflexion of the galvanometer is increased. Thus the deflexion of the galvanometer can be used to indicate the arrival of electric waves. The tube must be tapped between each experiment, and the deflexion of the galvanometer brought back to about its original value. This detector is marvellously delicate, but not metrical, the change produced in the resistance depending upon so many things besides the intensity of the waves, that the magnitude of the galvanometer deflexion is to some extent a matter of chance. Instead of the iron turnings we may use two iron wires, one resting on the other; the resistance of this contact will be altered by the incidence of the waves. To get greater regularity Bose [25] uses instead of the iron turnings spiral springs, which are pushed against each other by means of a screw until the most sensitive state is attained. The sensitiveness of the coherer depends on the electromotive force put in the galvanometer circuit. Very sensitive ones can be made by using springs of very fine silver wire coated electrolytically with nickel. Though the impact of electric waves generally produces a diminution of resistance with these loose contacts, yet there are exceptions to the rule. Thus Branly [26] showed that with lead oxide, PbO_2, there is an increase in resistance. Aschkinass [27] proved the same to be true with copper sulphide, CuS; and Bose [28] has shown that with potassium there is an increase of resistance and great power of self-recovery of the original resistance after the waves have ceased. Several theories of this action have been proposed. Branly (*loc. cit.*) thought that the small sparks which certainly pass between adjacent portions of metal cleared away layers of oxide or some other kind of non-conducting film, and in this way improved the contact. It would seem that if this theory is true the films must be of a much more refined kind than layers of oxide or dirt, for the coherer effect has been observed with clean non-oxidizable metals. Lodge (*loc. cit.*) explains the effect by supposing that the heat produced by the sparks fuses adjacent portions of metal into contact and hence diminishes the resistance; it is from this view of the action that the name coherer is applied to the detector. Auerbeck [29] thought that the effect was a mechanical one due to the electrostatic attractions between the various small pieces of metal. It is probable that some or all of these causes are at work in some cases, but the effects of potassium make us hesitate to accept any of them as the complete explanation. The coherer is the form of detector used in telegraphy without wires. (See TELEGRAPHY, WIRELESS.)

Bose [30] has designed an instrument which generates electric waves with a length of not more than a centimetre or so, and therefore allows their properties to be demonstrated with apparatus of moderate dimensions. The waves are excited by sparking between two platinum beads carried by jointed electrodes; a platinum sphere is placed between the beads, and the distance between the beads and the sphere can be adjusted by bending the electrodes. The diameter of the sphere is 8 mm., and the wave length of the shortest electrical waves generated is said to be about 6 mm. The beads are connected with the terminals of a small induction coil, which, with the battery to work it and the sparking arrangement, are enclosed in a metal box, the radiation passing out through a metal tube opposite to the spark gap. The ordinary vibrating break of the coil is not used, a single spark made by making and breaking the circuit by means of a button outside the box being employed instead. The detector is one of the spiral spring coherers previously described; it is shielded from external disturbance by

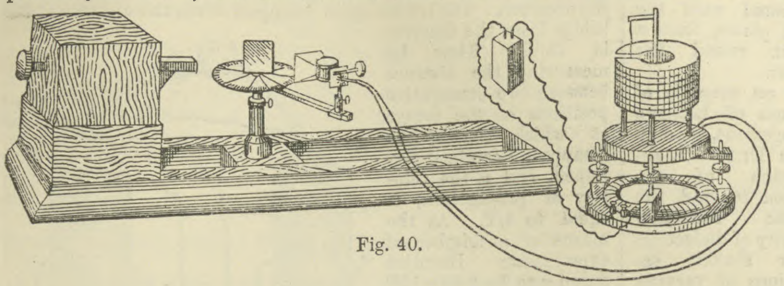


Fig. 40.

being enclosed in a metal box provided with a funnel-shaped opening to admit the radiation. The wires leading from the coherers to the galvanometer are also surrounded by metal tubes to protect them from stray radiation. The radiating apparatus and the receiver are mounted on stands sliding in an optical bench. If a parallel beam of radiation is required, a cylindrical lens of ebonite or sulphur is mounted in a tube fitting on to the radiator tube and stopped by a guide when the spark is at the principal focal line of the lens. For experiments requiring angular measurements a spectrometer circle is mounted on one of the sliding stands, the receiver being carried on a radial arm and pointing to the centre of the circle. The arrangement is represented in Fig. 40.

With this apparatus the laws of reflexion, refraction, and polarization can readily be verified, and also the double refraction of crystals, and of bodies possessing a fibrous or laminated structure such as jute or books. (The double refraction of electric waves seems first to have been observed by Righi,[31] and other researches on this subject have been made by Garbasso[32] and Mack.[33]) Bose[34] showed the rotation of the plane of polarization by means of pieces of twisted jute rope; if the pieces were arranged so that their twists were all in one direction and placed in the path of the radiation, they rotated the plane of polarization in a direction depending upon the direction of twist; if they were mixed so that there were as many twisted in one direction as the other, there was no rotation.

A series of experiments showing the complete analogy between electric and light waves is described by Righi in his book *L'Ottica delle Oscillazioni Elettriches.* Righi's exciter, which is especially

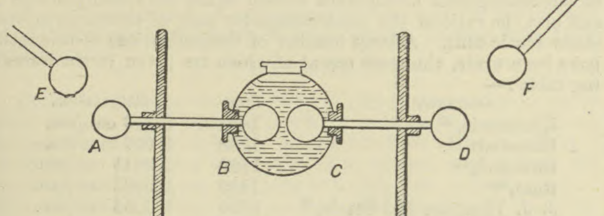


Fig. 41.

convenient when large statical electric machines are used instead of induction coils, is shown in Fig. 41. E and F are balls con-

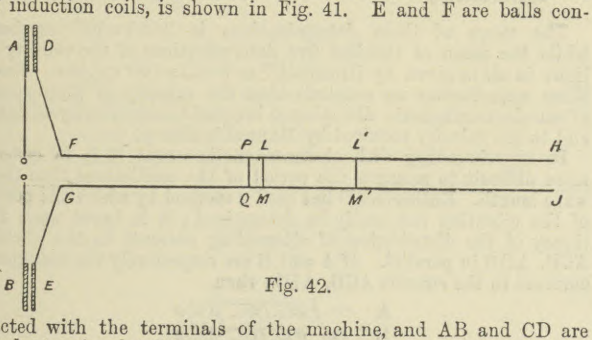


Fig. 42.

nected with the terminals of the machine, and AB and CD are conductors insulated from each other, the ends B, C, between which the sparks pass, being immersed in vaseline oil. The period of the vibrations given out by the system is adjusted by means of metal plates M and N attached to AB and CD.

§ 8. *Waves in Wires.*—Many problems on electric waves along wires can readily be investigated by a method due to Lecher,[35] and known as Lecher's bridge, which furnishes us with a means of dealing with waves of a definite and determinable wave-length. In this arrangement (Fig. 42) two large plates A and B are, as in Hertz's exciter, connected with the terminals of an induction coil; opposite these and insulated from them are two smaller plates D, E, to which ·ng parallel wires DFH, EGJ are attached. These wires are bridged across by a wire LM, and their farther ends H, J, may be insulated, or connected together, or with the plates of a condenser. To detect the waves in the circuit beyond the bridge, Lecher used an exhausted tube placed across the wires, and Rubens a bolometer, but Rutherford's detector is the most convenient and accurate. If this detector is placed in a fixed position at the end of the circuit, it is found that the deflexions of this detector depend greatly upon the position of the bridge

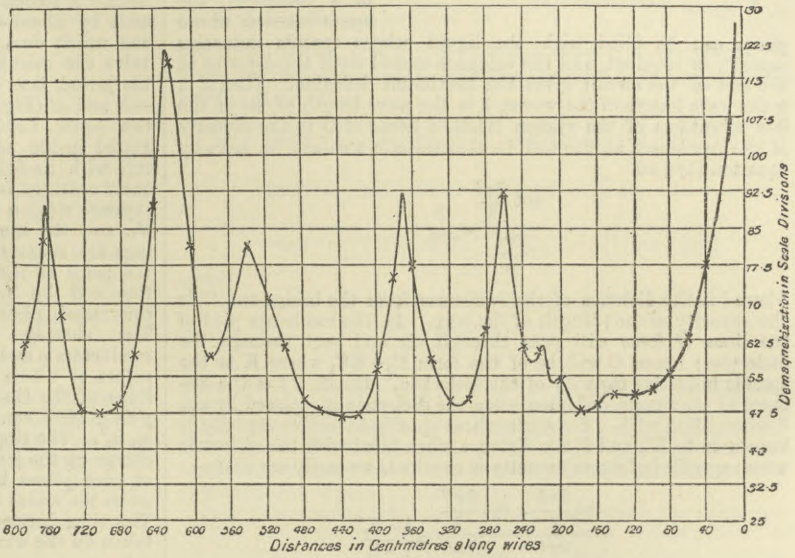


Fig. 43.

LM, rising rapidly to a maximum for some positions, and falling rapidly away when the bridge is displaced. As the bridge is moved from the coil end towards the detector the deflexions show periodic variations, such as are represented in Fig. 43 when the ordinates represent the deflexions of the detector and the abscissæ the distance of the bridge from the ends D, E. The maximum deflexions of the detector correspond to the positions in which the two circuits DFLMGE, HLMJ (in which the vibrations are but slightly damped), are in resonance. For since the self-induction and resistance of the bridge LM is very small compared with that of the circuit beyond, it follows from the theory of circuits in parallel that only a small part of the current will in general flow round the longer circuit; it is only when the two circuits DFLMGE, HLMJ are in resonance that a considerable current will flow round the latter. Hence when we get a maximum effect in the detector we know that the waves we are dealing with are those corresponding to the free periods of the system HLMJ, so that if we know the free periods of this circuit we know the wave length of the electric waves under consideration. Thus if the ends of the wires H, J are free and have no capacity, the current along them must vanish at H and J, which must be in opposite electric condition. Hence half the wave length must be an odd submultiple of the length of the circuit HLMJ. If H and J are connected together the wave length must be a submultiple of the length of this circuit. When the capacity at the ends is appreciable the wave length of the circuit is determined by a somewhat complex expression (see § 30). To facilitate the determination of the wave length in such cases, Lecher introduced a second bridge L'M', and moved this about until the deflexion of the detector was a maximum; when this occurs the wave length is one of those corresponding to the closed circuit LMM'L', and must therefore be a submultiple of the length of the circuit. Lecher showed that if instead of using a single wire LM to form the bridge, he used two parallel wires PQ, LM, placed close together, the currents in the further circuit were hardly appreciably diminished when the main wires were cut between PL and QM. Blondlot[36] used a modification of this apparatus better suited for the production of short waves. In his form (Fig. 44) the exciter consists of two semicircular arms connected with the terminals of an induction coil, and the long wires, instead of being connected with the small plates, form a circuit round the exciter.

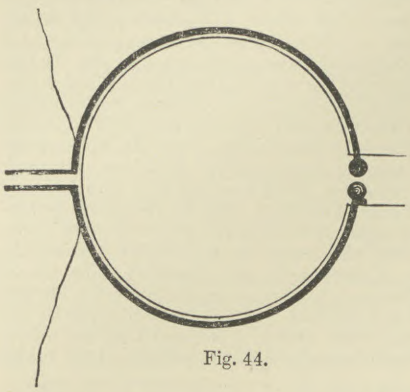


Fig. 44.

As an example of the use of Lecher's arrangement, we may quote Drude's[37] application of the method to find the specific induction capacity of dielectrics under electric oscillations of varying frequency. In this application the ends of the wire are connected to the plates of a condenser, the space between whose plates can be filled with the liquid whose specific inductive capacity is required, and the bridge is moved until the detector at the end of the circuit gives the maximum deflexion. Then if λ is the wave length of the waves, λ is the wave length of one of the free vibrations of the system HLMJ; hence if C is the capacity of the condenser at the end in electrostatic measure we have by equation (1) § 30

$$\frac{\cot\frac{2\pi l}{\lambda}}{\frac{2\pi l}{\lambda}} = \frac{C}{C'l}$$

where l is the distance of the condenser from the bridge and C′ is the capacity of unit length of the wire. In the condenser part of the lines of force will pass through air and part through the dielectric; hence C will be of the form $C_0 + KC_1$ where K is the specific inductive capacity of the dielectric. Hence if l is the distance of maximum deflexion when the dielectric is replaced by air, l' when filled with a dielectric whose specific inductive capacity is known to be K′, and l'' the distance when filled with the dielectric whose specific inductive capacity is required, we easily see that—

$$\frac{\cot\frac{2\pi l}{\lambda} - \cot\frac{2\pi l'}{\lambda}}{\cot\frac{2\pi l}{\lambda} - \cot\frac{2\pi l''}{\lambda}} = \frac{1-K'}{1-K}$$

an equation by means of which K can be determined. It was in this way that Drude investigated the specific inductive capacity with varying frequency, and found a falling off in the specific inductive capacity with increase of frequency when the dielectrics contained the radicle OH. In another method used by him[38] the wires were led through long tanks filled with the liquid whose specific inductive capacity was required; the velocity of propagation of the electric waves along the wires in the tank being the same as the velocity of propagation of an electromagnetic disturbance through the liquid filling the tank, if we find the wave length of the waves along the wires in the tank, due to a vibration of a given frequency, and compare this with the wave lengths corresponding to the same frequency when the wires are surrounded by air, we obtain the velocity of propagation of electromagnetic disturbance through the fluid, and hence the specific inductive capacity of the fluid.

§ 9. *Velocity of Propagation of Electromagnetic Effects through Air.*—The experiments of Sarasin and De la Rive already described (see § 5) have shown that, as theory requires, the velocity of propagation of electric effects through air is the same as along wires. The same result had been arrived at by the writer,[39] although from the method he used greater differences between the velocities might have escaped detection than was possible by Sarasin and De la Rive's method. The velocity of waves along wires has been directly determined by Blondlot[40] by two different methods. In the first the detector consisted of two parallel plates about 6 cm. in diameter placed a fraction of a millimetre apart, and forming a condenser whose capacity C was determined in electromagnetic measure by Maxwell's method. The plates were connected by a rectangular circuit whose self-induction L was calculated from the dimensions of the rectangle and the size of the wire. The time of vibration T is equal to $2\pi\sqrt{LC}$. (The wave length corresponding to this time is long compared with the length of the circuit, so that the use of this formula is legitimate.) This detector is placed between two parallel wires, and the waves produced by the exciter are reflected from a movable bridge. When this bridge is placed just beyond the detector vigorous sparks are observed, but as the bridge is pushed away a place is reached where the sparks disappear; this place is distance $\lambda/4$ from the detector, when λ is the wave length of the vibration given out by the detector. The sparks again disappear when the distance of the bridge from the detector is $3\lambda/4$. Thus by measuring the distance between two consecutive positions of the bridge at which the sparks disappear λ can be determined, and v, the velocity of propagation, is equal to λ/T. As the means of a number of experiments Blondlot found v to be $3{\cdot}02 \times 10^{10}$ cm./sec. which, within the errors of experiment, is equal to 3×10^{10} cm./sec., the velocity of light. A second method used by Blondlot,[41] and one which does not involve the calculation of the period, is as follows:—A and A′ (Fig. 45) are two equal Leyden jars coated inside and outside with tin-foil. The outer coatings form two separate rings a, a_1; a', a'_1, and the inner coatings are connected with the poles of the induction coil by means of the metal pieces b, b'. The sharply pointed conductors p and p', the points of which are about ½ mm. apart, are connected with the rings of the tin-foil a and a', and two long copper wires pca_1, $p'c'a'_1$, 1029 cm. long connect these points with the other rings a_1, a_1'. The rings aa', a_1a_1', are connected by wet strings so as to charge up the jars. When a spark passes between b and b', a spark at once passes between pp', and this is followed by another spark when the waves travelling by the paths $a_1\,cp$, $a_1'c'p'$ reach p and p'. The time between the passage of these sparks, which is the time taken by the waves to travel 1029 cm., was observed by means of a rotating mirror, and the velocity measured in 15 experiments varied between $2{\cdot}92 \times 10^{10}$ and $3{\cdot}03 \times 10^{10}$ cm./sec., thus agreeing well with that deduced by the preceding method. Other determinations of the velocity of electromagnetic propagation have been made by Lodge and Glazebrook,[42] and by Saunders.

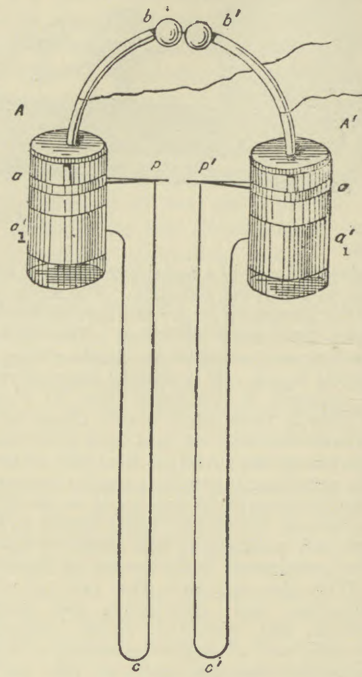


Fig. 45.

On Maxwell's electromagnetic theory the velocity of propagation of electromagnetic disturbance should equal the velocity of light, and also the ratio of the electromagnetic unit of electricity to the electrostatic unit. A large number of determinations of this ratio have been made, the more recent of which are given in the following table:—

Observer.	Date.	Ratio $10^{10}\times$.
Klemencic,[43]	1884	3·019 cm./sec.
Himstedt,[44]	1888	3·009 cm./sec.
Rowland,[45]	1889	2·9815 cm./sec.
Rosa,[46]	1889	2·9993 cm./sec.
J. J. Thomson and Searle,[47]	1890	2·9955 cm./sec.
Webster,[48]	1891	2·987 cm./sec.
Pellat,[49]	1891	3·009 cm./sec.
Abraham,[50]	1892	2·992 cm./sec.
Hurmuzescu,[51]	1895	3·002 cm./sec.

The mean of these determinations is $3{\cdot}001 \times 10^{10}$ cm./sec., while the mean of the last five determinations of the velocity of light in air is given by Himstedt[52] as $3{\cdot}002 \times 10^{10}$ cm./sec. From these experiments we conclude that the velocity of propagation of an electromagnetic disturbance is equal to the velocity of light, and to the velocity required by Maxwell's theory.

In experimenting with electromagnetic waves it is in general more difficult to measure the period of the oscillations than their wave length. Rutherford[53] has used a method by which the period of the vibration can easily be determined; it is based upon the theory of the distribution of alternating currents in two circuits ACB, ADB in parallel. If A and B are respectively the maximum currents in the circuits ACB, ADB, then

$$\frac{A}{B} = \sqrt{\frac{S^2+(N-M)^2p^2}{R^2+(L-M)^2p^2}}$$

when R and S are the resistances, L and N the coefficients of self-induction of the circuits ACB, ADB respectively, M the coefficient of mutual induction between the circuits, and p the frequency of the currents. Rutherford detectors were placed in the two circuits, and the circuits adjusted until they showed that A=B; when this is the case

$$p^2=\frac{R^2-S^2}{N^2-L^2-2M(N-L)}.$$

If we make one of the circuits, ADB, consist of a short length of a high liquid resistance, so that S is large and N small, and the other circuit ACB of a low metallic resistance bent to have considerable self-induction, the preceding equation becomes approximately $p=S/L$, so that when S and L are known p is readily determined.

Theory of Some Simple Cases of Electromagnetic Waves.

§ 10. *Equations of the Electromagnetic Field when the Medium is at Rest.*—Faraday's law of the induction of currents in a variable magnetic field (viz., that the electromotive force taken round a closed circuit is equal to the rate of diminution in the number of lines of magnetic induction passing through the circuit), when expressed analytically, leads to the three equations

$$\left.\begin{aligned}-\frac{da}{dt}&=\frac{dZ}{dy}-\frac{dY}{dz}\\ -\frac{db}{dt}&=\frac{dX}{dz}-\frac{dZ}{dx}\\ -\frac{dc}{dt}&=\frac{dY}{dx}-\frac{dX}{dy}\end{aligned}\right\}\text{A},$$

where X, Y, Z are the components of the electric intensity parallel to the axes of x, y, z respectively, and a, b, c are the components of the magnetic induction. The vector whose components are $\frac{dZ}{dy}-\frac{dY}{dz}$, $\frac{dX}{dz}-\frac{dZ}{dx}$, $\frac{dY}{dx}-\frac{dX}{dy}$ is often called the curl of the vector whose components are X, Y, Z; thus if B is the magnetic induction and E the electric force, we may write equations A in the form

$$\frac{dB}{dt}=-\text{cl. E},$$

where cl. E denotes the curl of the vector E. Another fundamental law of electromagnetic action is that the work done on a unit pole travelling round any closed circuit is equal to 4π times the current passing through the circuit, whatever the nature of the substances through which the circuit passes: the analytical expression of this law is

$$\left.\begin{aligned}4\pi u&=\frac{d\gamma}{dy}-\frac{d\beta}{dz}\\ 4\pi v&=\frac{da}{dz}-\frac{d\gamma}{dx}\\ 4\pi w&=\frac{d\beta}{dx}-\frac{da}{dy}\end{aligned}\right\}\text{B},$$

where u, v, w are the components of the electric current, and a, β, γ the components of the magnetic force. If i is the current, H the magnetic force (i and H being vectors), we may write these equations as

$$4\pi i=\text{cl. H}.$$

The electric current contemplated in this law may arise in one or other of three ways:—it may be wholly or in part an ordinary conduction current obeying Ohm's law, such as flows through metals or electrolytes, or it may be a convection current arising from the motion of charged ions, or it may be a dielectric current which on Maxwell's theory exists whenever the electric field is changing. In order that all currents may flow in closed circuits, which is essential on Maxwell's theory, the magnitude of the dielectric current must be $\frac{K}{4\pi}\frac{dE}{dt}$; hence if σ is the specific resistance of the medium we have

$$i=\frac{E}{\sigma}+\frac{K}{4\pi}\frac{dE}{dt}+\Sigma qe,$$

where e is the charge on an ion and q its velocity (q is to be regarded as a vector), while Σ denotes the sum of the product of these quantities for all the ions in the field.

§ 11. We shall begin with the case of an insulating medium in which there are no ions; in this case $i=\frac{K}{4\pi}\frac{dE}{dt}$, and equations B become

$$\left.\begin{aligned}K\frac{dX}{dt}&=\frac{d\gamma}{dy}-\frac{d\beta}{dz}\\ K\frac{dY}{dt}&=\frac{da}{dz}-\frac{d\gamma}{dx}\\ K\frac{dZ}{dt}&=\frac{d\beta}{dx}-\frac{da}{dy}\end{aligned}\right. \quad . \quad . \quad . \quad . \quad (1).$$

If μ is the magnetic permeability, and if the variable magnetization is entirely induced, we may put $a, b, c=\mu(a, \beta, \gamma)$, and from equations A and (1) on elimination of X, Y, Z, remembering that

$$\frac{da}{dx}+\frac{d\beta}{dy}+\frac{d\gamma}{dz}=0$$

$$\frac{dX}{dx}+\frac{dY}{dy}+\frac{dZ}{dz}=0,$$

we get

$$\mu K\frac{d^2a}{dt^2}=\frac{d^2a}{dx^2}+\frac{d^2a}{dy^2}+\frac{d^2a}{dz^2}.$$

We have equations of precisely the same form for β, γ, and X, Y, Z; hence these quantities all satisfy Poisson's equation [54]

$$\frac{1}{v^2}\frac{d^2\phi}{dt^2}=\frac{d^2\phi}{dx^2}+\frac{d^2\phi}{dy^2}+\frac{d^2\phi}{dz^2} \quad . \quad . \quad . \quad (2),$$

which is known to represent an effect propagated with a velocity v through the medium, hence changes in magnetic and electric force travel through the medium with the finite velocity $1/\sqrt{\mu K}$.

If the electric disturbance travels as a plane wave, so that X, Y, Z, a, β, γ, are proportional to $\epsilon^{\iota\frac{2\pi}{\lambda}(vt-(lx+my+nz))}$ where λ is the wave length, l, m, n, the direction cosines of the normal to the wave front, and $v=1/\sqrt{\mu K}$, then we have from equations (A) and (1), if $p=2\pi v/\lambda$

$$\iota p\mu a=\iota\frac{2\pi}{\lambda}(mZ-nY); \qquad K\iota pX=\iota\frac{2\pi}{\lambda}(n\beta-m\gamma);$$

$$\iota p\mu\beta=\iota\frac{2\pi}{\lambda}(nX-lZ); \qquad K\iota pY=\iota\frac{2\pi}{\lambda}(l\gamma-na);$$

$$\iota\pi\mu\gamma=\iota\frac{2\pi}{\lambda}(lY-mX); \qquad K\iota pZ=\iota\frac{2\pi}{\lambda}(ma-l\beta);$$

hence

$$la+m\beta+n\gamma=0,\ lX+mY+nZ=0,$$

$$aX+\beta Y+\gamma Z=0,$$

$$v\mu H=E,$$

where H is the resistant magnetic force and E the resultant electric force. Hence we see that both the magnetic and electric forces are at right angles to the direction of propagation of the wave, the electric and magnetic forces are at right angles to each other, and the product of the magnetic induction and the velocity of propagation is equal to the electric force.

Poisson's equation takes a very simple form when the solution is periodic and depends only on the distance from a fixed point. If the frequency of the solution is p, and if r is the distance from the point, then since ϕ varies as $\epsilon^{\iota pt}$, $\frac{d^2\phi}{dt^2}=-p^2\phi$, and since ϕ only depends upon r,

$$\frac{d^2\phi}{dx^2}+\frac{d^2\phi}{dy^2}+\frac{d^2\phi}{dz^2}=\frac{d^2\phi}{dr^2}+\frac{2}{r}\frac{d\phi}{dr};$$

hence

$$\frac{d^2\phi}{dr^2}+\frac{2}{r}\frac{d\phi}{dr}+\frac{p^2}{v^2}\phi=0,$$

or

$$\frac{d^2}{dr^2}(r\phi)+\frac{p^2}{v^2}r\phi=0$$

The solution of this equation is

$$r\phi=A\epsilon^{\iota\frac{p}{v}r}+B\epsilon^{-\iota\frac{p}{v}r},$$

or restoring the time factor

$$\phi=A'\frac{\epsilon^{\iota p\left(t+\frac{r}{v}\right)}}{r}+B'\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}.$$

If the waves start from the origin and there is no reflexion the solution will consist of the second term only, as the first term represents a wave travelling towards the origin. When there is reflexion both terms must be retained. Since Poisson's equation is linear if ϕ is a solution, $\frac{d^l}{dx^l}\frac{d^m}{dy^m}\frac{d^n}{dz^n}\phi$ will also be a solution when l, m, n, are positive integers; and starting with this primary solution we may by differentiation arrive at the solution of more complicated problems, just as in electrostatics, starting with $1/r$ as the potential due to a unit charge, we obtain the potential for complex distributions of electricity. In the case of electric waves we substitute $\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}$ for $1/r$.

§ 12. We shall now proceed to consider some special cases of electric waves, taking first a case investigated by Hertz,[55] that of the vibrating electric doublet. By a doublet is meant a system of two equal and oppositely electrified particles placed near together. The direction of the line joining the particles is the axis of the doublet, and the product of one of the charges into the distance between them is its moment. We shall suppose that the moment varies harmonically, and is proportional to the real part of $\epsilon^{\iota pt}$; such a doublet would be produced if we had a positive charge e moving parallel to the axis of z, its distance from the origin being $l \cos pt$, while the distance of the negative charge is $-l \cos pt$. The moment of this doublet is the real part of $m\epsilon^{\iota pt}$ where $m=2le$. For a doublet of constant moment m with its axis along the axis of z, and its centre at the origin, the components X, Y, Z of the electric force at a point at a distance r from the origin are given by the equations

$$X=\frac{m}{K}\frac{d^2}{dxdz}\frac{1}{r},\quad Y=\frac{m}{K}\frac{d^2}{dydz}\frac{1}{r},\quad Z=-\frac{m}{K}\left(\frac{d^2}{dx^2}+\frac{d^2}{dy^2}\right)\frac{1}{r}.$$

Hence if the moment is $m\epsilon^{\iota pt}$, and if the greatest distance between the charges is small compared with v/p, the components of the electric force due to the vibrating doublet will be given by the equations

$$X=\frac{m}{K}\frac{d^2}{dxdz}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r},\quad Y=\frac{m}{K}\frac{d^2}{dydz}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r};$$

$$Z=-\frac{m}{K}\left(\frac{d^2}{dx^2}+\frac{d^2}{dy^2}\right)\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}.$$

It follows from equations A that α, β, γ, the components of the magnetic force, will be given by the equations

$$\mu\alpha=\frac{m\iota p}{Kv^2}\frac{d}{dy}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r};\quad \mu\beta=-\frac{m\iota p}{Kv^2}\frac{d}{dx}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r};\quad \gamma=0;$$

or since $\mu K v^2=1$, by

$$\alpha=m\iota p\frac{d}{dy}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r};\quad \beta=-m\iota p\frac{d}{dx}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r};\quad \gamma=0 \qquad (3).$$

Performing the differentiations and taking the real parts of the expressions, we find

$$X=\frac{xzm}{r^2K}\left\{\frac{3}{r^3}\cos p\left(t-\frac{r}{v}\right)-\frac{3}{r^2}\frac{p}{v}\sin p\left(t-\frac{r}{v}\right)-\frac{p^2}{v^2}\frac{1}{r}\cos p\left(t-\frac{r}{v}\right)\right\},$$

$$Y=\frac{yz}{r^2}\frac{m}{K}\left\{\frac{3}{r^3}\cos p\left(t-\frac{r}{v}\right)-\frac{3}{r^2}\frac{p}{v}\sin p\left(t-\frac{r}{v}\right)-\frac{p^2}{v^2}\frac{1}{r}\cos p\left(t-\frac{r}{v}\right)\right\}$$

$$Z=\frac{m}{K}\left[\frac{3z^2-r^2}{r^2}\left\{\frac{1}{r^3}\cos p\left(t-\frac{r}{v}\right)-\frac{1}{r^2}\frac{p}{v}\sin p\left(t-\frac{r}{v}\right)\right\}+\frac{x^2+y^2}{r^2}\frac{p^2}{v^2}\frac{1}{r}\cos p\left(-\frac{r}{v}\right)\right]$$

$$\alpha=mp\frac{y}{r}\left\{\frac{1}{r^2}\sin p\left(t-\frac{r}{v}\right)+\frac{p}{v}\frac{1}{r}\cos p\left(t-\frac{r}{v}\right)\right\}$$

$$\beta=-mp\frac{x}{r}\left\{\frac{1}{r^2}\sin p\left(t-\frac{r}{v}\right)+\frac{p}{v}\frac{1}{r}\cos p\left(t-\frac{r}{v}\right)\right\}$$

$$\gamma=0.$$

Thus $\alpha X+\beta Y+\gamma Z=0$, so that the electric force is everywhere at right angles to the magnetic force, and is in the plane through the axis of z; the lines of magnetic force are circles with their centres along and their planes at right angles to the axis of z. At a distance from the centre large compared with v/p, the last terms inside the brackets are the most important, and retaining only these, the equations take the simple form,

$$X=-\frac{m}{K}\frac{p^2}{v^2}\frac{xz}{r^2}\frac{1}{r}\cos p\left(t-\frac{r}{v}\right),$$

$$Y=-\frac{m}{K}\frac{p^2}{v^2}\frac{yz}{r^2}\frac{1}{r}\cos p\left(t-\frac{r}{v}\right),$$

$$Z=\frac{m}{K}\frac{p^2}{v^2}\frac{x^2+y^2}{r^2}\frac{1}{r}\cos p\left(t-\frac{r}{v}\right),$$

$$\alpha=\frac{mp^2}{v}\frac{y}{r}\frac{1}{r}\cos p\left(t-\frac{r}{v}\right),$$

$$\beta=-\frac{mp^2}{v}\frac{x}{r}\frac{1}{r}\cos p\left(t-\frac{r}{v}\right),$$

$$\gamma=0.$$

In this case $Xx+Yy+Zz=0$, so that the electric force is at right angles to the radius. If E is the resultant electric force, and H the resultant magnetic force,

$$E=\frac{m}{K}\frac{p^2}{v^2}\frac{\sin\theta}{r}\cos p\left(t-\frac{r}{v}\right),$$

$$H=\frac{mp^2}{v}\frac{\sin\theta}{r}\cos p\left(-\frac{r}{v}\right).$$

The magnetic force is at right angles to the radius and also to the electric force, and we see that, as in the plane wave, $v\mu H=E$. The lines of electric force at a great distance from the oscillator are represented in Fig. 46; it will be seen that they consist of a series of detached bundles, which travel outwards with the velocity v. The detachment of these bundles from the lines of force which originally stretched from one pole to the other of the doublet is shown in Fig. 47, which is taken from Hertz's paper. It will be noticed that a dent gradually develops in the lines of force and gets deeper and deeper until two portions of the lines meet. When this happens the line of force breaks off into two portions, one of which rushes into the doublet while the other travels outwards and produces one of the bundles of lines of force shown in Fig. 46. The point at which the lines break off is evidently in the plane $z=0$, and since at this point the equation $Z=0$ has two equal roots, the point is determined by $Z=0$, $\frac{dZ}{dr}=0$. These equations give $r=\sqrt{2}v/p$, so that the rupture of the lines of force always occurs at a fixed point. Diagrams of the lines of force of a vibrator whose vibrations are damped by radiation have been drawn by Pearson and Lee.[56]

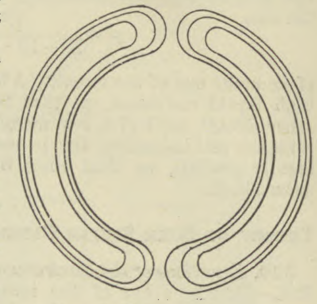


Fig. 46.

§ 13. *Energy radiated from the Vibrator.*—The movement of these bundles of lines of electric force away to an infinite distance from the vibrator is accompanied by a flow of energy outwards through space, as the lines of force carry energy with them. Thus if the oscillations of the vibrator are to be maintained energy must be supplied to it. To calculate the amount of energy radiated per unit time we make use of a theorem due to Poynting,[57] which states that the movement of energy in the electromagnetic field is the same as if the energy at any point moved along the normal to the plane containing the magnetic force and the electric force at that point, the amount of energy flowing in unit time across a unit area at right angles to the flow being equal to $HE\sin\theta/4\pi$ where H is the magnetic and E the electric force, and θ the angle between these vectors. If we apply this theorem to find the flow of energy across a sphere with its centre at the centre of the vibrator, and with so great a radius that over its surface the magnetic and electric forces are both transverse, the quantity of energy flowing per unit time across unit area of the surface of this sphere is equal to

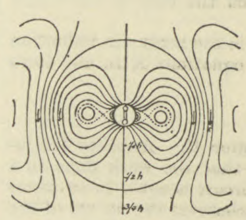


Fig. 47.

$$\frac{1}{4\pi}\frac{m^2}{K}\frac{p^4}{v^3}\frac{1}{r^2}\sin^2\theta\cos^2 p\left(t-\frac{r}{v}\right).$$

The total flow of energy across the surface of the sphere is therefore

$$\frac{2}{3}\frac{m^2}{K}\frac{p^4}{v^3}\cos^2 p\left(t-\frac{r}{v}\right) \quad . \quad . \quad . \quad (4),$$

the average value of which is $\frac{1}{3}\frac{m^2}{K}\frac{p^4}{v^3}$. If the vibrations are to be maintained energy must be supplied at this rate to the vibrator.

§ 14. *Magnetic Force due to a moving electrified Sphere.*—Let us consider the doublet as arising from the motion in opposite directions with equal velocity along the axis of z, of two oppositely charged particles, the distance of one particle from the origin being represented by $l\cos pt$, that of the other by $-l\cos pt$. Now the magnetic force by equation (3) due to this doublet is equal to

$$2el\sin\theta p\sin p\left(t-\frac{r}{v}\right)\frac{1}{r^2}+2el\sin\theta p^2\cos p\left(t-\frac{r}{v}\right)\frac{1}{vr}.$$

This may be written

$$-2eu\sin\theta\frac{1}{r^2}-2e\dot{u}\sin\theta\frac{1}{vr} \qquad . \quad (5),$$

where u, $\dot{u}$ are respectively the velocities and accelerations of the positive particle at the time $t-r/v$. Now since the electromagnetic effects are propagated with a velocity v, the magnetic effect at a point r at the time t must have started from the moving particle at the time $t-r/v$, and must depend on the condition of the sphere at that time. It is also clear that the magnetic effects due to the positive and negative particles are equal. Thus equation (5) shows that from a moving particle there starts a wave of magnetic force proportional to the velocity, whose magnitude at a distance r from the particle is $uc \sin\theta/r^2$, where u is the velocity of the particle, the lines of magnetic forces being circles with the direction of motion of the particle as axis. Accompanying this is another wave proportional to the acceleration, producing at a distance r a magnetic force equal to $e\dot{u}\sin\theta/vr$, the direction of the magnetic force being the same as in the velocity wave.[58] Thus while the magnetic force in the velocity wave varies inversely as the square of the distance, that in the "acceleration" wave only varies inversely as the distance. The importance of the second wave in comparison with the first will increase as the distance increases. If the particle is moving uniformly there is no "acceleration" wave, and the magnetic force at a distance r is $eu\sin\theta/r^2$. Thus a uniformly moving particle produces the same magnetic field as an element of current placed at the particle and pointing along its direction of motion.[59] The magnetic effects due to moving electrified charges have been detected by Rowland[60] in experiments made for this purpose.

From equation (4) we see that the rate at which energy is leaving the vibrating doublet is on the average

$$\frac{1}{3}\frac{m^2}{\mathrm{K}}\frac{p^4}{v^3};$$

this is equal for each particle to

$$2.\frac{2}{3}\frac{e^2}{\mathrm{K}v^3}(\text{mean value of } \dot{u}^2).$$

Thus work must be done on the particle to replace the energy radiated into space; in other words, there will be a resistance offered to the motion of the particle if its acceleration is finite. This resistance is such that the work spent in overcoming it in a time δt is equal to the energy radiated in that time.

§ 15. *Electric Oscillations on a perfectly conducting Sphere.*—We can apply the preceding analysis to the case of a conducting sphere, charged so that the density of the surface electrification at a point is proportional to $\cos\theta$ where θ is the angle which the radius to the point makes with the axis of z. If the field were steady the components of the electric force would be given by equations of the form

$$\mathrm{X}=m\frac{d^2}{dxdz}\frac{1}{r},\quad \mathrm{Y}=m\frac{d^2}{dydz}\frac{1}{r},\quad \mathrm{Z}=-m\left\{\frac{d^2}{dx^2}+\frac{d^2}{dy^2}\right\}\frac{1}{r};$$

hence when the charge is free to move over the surface and the electric field to vary, the components of the force will be given by the equations

$$\mathrm{X}=m\frac{d^2}{dxdz}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r},\quad \mathrm{Y}=m\frac{d^2}{dydz}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r},$$

$$\mathrm{Z}=-m\left\{\frac{d^2}{dx^2}+\frac{d^2}{dy^2}\right\}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}.$$

In this case it is one of the objects of the problem to determine p. This can be done from the condition that the electric force at the surface of the sphere must be radial, as a finite tangential force at the surface of the sphere would in consequence of the perfect conductivity correspond to an infinite current. If a is the radius of the sphere, then when $r=a$ we must have

$$\frac{\mathrm{X}}{x}=\frac{\mathrm{Y}}{y}=\frac{\mathrm{Z}}{z}.$$

Substituting the values of X, Y, Z we find that this condition leads to the equation

$$\frac{p^2}{v^2}a^2-\iota\frac{p}{v}a=1,$$

the roots of which are

$$\frac{pa}{v}=\frac{1}{2}\iota\pm\frac{\sqrt{3}}{2}.$$

Thus the time of vibration is $4\pi a/\sqrt{3}v$, and the wave length $4\pi a/\sqrt{3}$.[61] The amplitude of the vibration falls to $1/e$ of its original value after a time $2a/\mathrm{V}$, that is, after the time taken by light to pass across the diameter of the sphere. In the time occupied by one complete vibration the amplitude falls to $\epsilon^{-2\pi/\sqrt{3}}$ or about $\frac{1}{35}$ of its original value. Thus the vibrations will hardly make a complete oscillation before they are practically extinguished. This very rapid extinction is due to the radiation of energy from the sphere. The state of a sphere charged initially so that the normal force at its surface is equal to $2s\cos\theta$ is after a time t represented by the equations

$$\mathrm{P}=\frac{4s\cos\theta}{\sqrt{3}r^2}a^3\left\{1-\frac{a}{r}+\frac{a^2}{r^2}\right\}^{\frac{1}{2}}\epsilon^{-\frac{vt-(r-a)}{2a}}\cos(\phi+\delta)$$

$$\Theta=\frac{2s\sin\theta}{\sqrt{3}}\frac{a}{r}\left(1-\frac{a}{r}\right)\left(1+\frac{a}{r}+\frac{a^2}{r^2}\right)^{\frac{1}{2}}\epsilon^{-\left(\frac{vt-(r-a)}{2a}\right)}\cos(\phi+\delta')$$

$$\gamma=\frac{2s\sin\theta}{\sqrt{3}}\frac{a}{vr}\left\{1-\frac{a}{r}+\frac{a^2}{r^2}\right\}^{\frac{1}{2}}\epsilon^{-\frac{vt-(r-a)}{2a}}\cos(\phi+\delta''),$$

P, Θ being the normal and tangential components of the electric force, and γ the magnetic force.

$$\phi=\frac{\sqrt{3}}{2a}\{vt-(r-a)\};\quad \tan\delta=\left(\frac{2r}{a}-1\right)\Big/\sqrt{3}$$

$$\tan\delta'=\frac{r-a}{r+a}\frac{1}{\sqrt{3}},\quad \tan\delta''=\frac{1-\frac{2a}{r}}{\sqrt{3}}$$

those equations hold for positive values of ϕ, *i.e.*, after a wave starting from the sphere and travelling with velocity v has had time to reach the point under consideration. When r is very great compared with a, P is small compared with Θ and $\Theta=v\gamma$.

We can get the time of vibration of distributions of electricity represented by the higher harmonics by a similar process. If the electrification is proportional to the n^{th} zonal harmonic we put

$$\mathrm{X}=m\frac{d^{n+1}}{dxdz^n}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r},\quad \mathrm{Y}=m\frac{d^{n+1}}{dydz^n}\frac{\epsilon^{p\left(t-\frac{r}{v}\right)}}{r},$$

$$\mathrm{Z}=-m\left(\frac{d^2}{dx^2}+\frac{d^2}{dz^2}\right)\frac{d^{n-1}}{dz^{n-1}}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r.},$$

and proceed as before.

§ 16. *Scattering of Electric Waves by small dielectric Spheres.*—This problem may be solved by analysis similar to that used in the preceding investigations. If the length of the incident wave is long compared with the radius of the sphere, the intensity of the electric field due to the incident wave will be practically constant over the sphere. Let the incident wave be travelling parallel to the axis of x, let the electric intensity in it be parallel to the axis of z, and equal to the real part of $\mathrm{Z}_0\epsilon^{\iota p\left(t-\frac{x}{v}\right)}$, let K be the specific inductive capacity of the sphere, and a its radius; then if this sphere were placed in a constant electric field where the external force was Z_0, the components X, Y, Z at a point outside the sphere of the electric intensity due to the polarization of the dielectric sphere would be given by the equations

$$\mathrm{X}=\frac{\mathrm{K}-1}{\mathrm{K}+2}\mathrm{Z}_0a^3\frac{d^2}{dxdz}\frac{1}{r},\quad \mathrm{Y}=\frac{\mathrm{K}-1}{\mathrm{K}+2}\mathrm{Z}_0a^3\frac{d^2}{dydz}\frac{1}{r},$$

$$\mathrm{Z}=-\frac{\mathrm{K}-1}{\mathrm{K}+2}\mathrm{Z}_0a^3\left(\frac{d^2}{dx^2}+\frac{d^2}{dy^2}\right)\frac{1}{r}.$$

These equations suggest that when the field is variable the components of the electric intensity due to the sphere are given by the equations

$$\mathrm{X}=\frac{\mathrm{K}-1}{\mathrm{K}+2}\mathrm{Z}_0a^3\frac{d^2}{dxdz}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r},\quad \mathrm{Y}=\frac{\mathrm{K}-1}{\mathrm{K}+2}\mathrm{Z}_0a^3\frac{d^2}{dydz}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}$$

$$\mathrm{Z}=-\frac{\mathrm{K}-1}{\mathrm{K}+2}\mathrm{Z}_0a^3\left(\frac{d^2}{dx^2}+\frac{d^2}{dy^2}\right)\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}.$$

The forces inside the sphere may easily be calculated, but they are not required for the present investigations. Corresponding to these values of the electric force we have, if α, β, γ are the components of the magnetic force,

$$\alpha=\frac{\mathrm{K}-1}{\mathrm{K}+2}\mathrm{Z}_0a^3\iota p\frac{d}{dy}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r},\quad \beta=-\frac{\mathrm{K}-1}{\mathrm{K}+2}\mathrm{Z}_0a^3\iota p\frac{d}{dx}\frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r},\quad \gamma=0$$

when it is to be understood that only the real part of these expressions is to be taken. The magnetic force inside the sphere corresponding to the internal electric field is continuous with that outside. These expressions satisfy all the boundary conditions if the sphere is not magnetic, for since pa/v is by hypothesis very small, the expressions for the electric force close to the sphere are very approximately the same as those in the electrostatic problem, which satisfy the boundary conditions of continuity of the tangential electric force and of the normal electric polarization; if the sphere is non-magnetic there is no discontinuity in the magnetic force and magnetic induction. Both the external field and that calculated from the preceding equations satisfy this condition. The values of X, Y, Z, α, β, γ can be got from the equations in § 12 by putting $m=\frac{\mathrm{K}-1}{\mathrm{K}+2}\mathrm{Z}_0a^3$; at a considerable number of wave lengths from the sphere they take the simple form

$$\mathrm{X}=-\mathrm{Z}_0a^3\frac{\mathrm{K}-1}{\mathrm{K}+2}\frac{xz}{r^2}\frac{p^2}{v^2}\cos p\left(t-\frac{r}{v}\right)\frac{1}{r}$$

$$\mathrm{Y}=-\mathrm{Z}_0a^3\frac{\mathrm{K}-1}{\mathrm{K}+2}\frac{yz}{r^2}\frac{p^2}{v^2}\cos p\left(t-\frac{r}{v}\right)\frac{1}{r}$$

$$Z = Z_0 a^3 \frac{K-1}{K+2} \frac{x^2+y^2}{r^2} \frac{p^2}{v^2} \cos p\left(t-\frac{r}{v}\right)\frac{1}{r}$$

$$\alpha = Z_0 a^3 \frac{K-1}{K+2} \frac{p^2}{v} \frac{y}{r} \frac{\cos p\left(t-\frac{r}{v}\right)}{r},$$

$$\beta = -Z_0 a^3 \frac{K-1}{K+2} \frac{p^2}{v} \frac{x}{r} \frac{\cos p\left(t-\frac{r}{v}\right)}{r}, \gamma = 0.$$

Thus X, Y, Z, α, β all vanish along the axis of z, and there is no wave scattered by the sphere in this direction. This problem of the scattering of waves by dielectric spheres was solved by Lord Rayleigh.[62] We see that for a given value of Z_0 and a, the magnitude of the forces in the scattered wave vary as p^2, that is, inversely as the square of the wave length of the incident wave. The energy in the scattered wave varies inversely as the fourth power of the wave length. Thus on the electromagnetic theory of light, according to which light consists of electromagnetic waves, the intensity of the light scattered by small particles varies inversely as the fourth power of the wave length. The part of the incident light in which the electric force is along the axis of z does not give rise to any scattered light along this axis. Thus when ordinary light is incident on small particles the scattered light in a direction at right angles to the incident light must be plane polarized, the plane of polarization being such that the electric force is at right angles to the plane through the observer and the incident beam; this implies that the scattered light is polarized in the plane through the observer and the incident beam. For the application of the theory of the scattering of light by small particles to the explanation of the blue of the sky the reader is referred to a series of papers by Lord Rayleigh;[63] in one of these he has shown that the scattering may be produced by the molecules of the air without the aid of any extraneous small particles.

§ 17. *Scattering of Electric Waves by perfectly conducting Spheres.*—When a train of plane electric waves is incident on a perfectly conducting sphere, the expressions for the scattered waves are not quite so simple as those in the last case. In the perfectly conducting sphere the total electric force at the surface must be radial, and the total magnetic force entirely tangential; in the case of the dielectric sphere just treated the magnetic force in the scattered wave is entirely tangential, and so there is nothing to balance the normal component of the magnetic force in the incident wave. The following values of the components of the electric and magnetic forces will be found to satisfy the conditions that the tangential electric, and normal magnetic force vanish over the sphere. The electric intensity in the incident wave is supposed to be represented by the real part of $Z_0\epsilon^{\iota p\left(t-\frac{x}{v}\right)}$, and to be parallel to z; the magnetic force will be parallel to y and equal to the real part of $(Z_0/v)\epsilon^{\iota p\left(t-\frac{x}{v}\right)}$. The radius, a, of the conducting sphere is very small compared with the length of the wave.

$$X = Z_0 a^3 \frac{d^2}{dxdz} \frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r} - \frac{1}{2}\iota p \frac{Z_0 a^3}{v} \frac{d}{dz} \frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}$$

$$Y = Z_0 a^3 \left(\frac{d^2}{dydz}\right) \frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}$$

$$Z = -Z_0 a^3 \left(\frac{d^2}{dx^2}+\frac{d^2}{dy^2}\right) \frac{\epsilon^{\iota p\left(-\frac{r}{v}\right)}}{r} + \frac{1}{2}\iota p \frac{Z_0 a^3}{v} \frac{d}{dx} \frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}$$

$$\alpha = Z_0 a^3 \iota p \frac{d}{dy} \frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r} - \frac{1}{2} \frac{Z_0 a^3}{v} \frac{d^2}{dxdy} \frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}$$

$$\beta = -Z_0 a^3 \iota p \frac{d}{dx} \frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r} + \frac{1}{2} \frac{Z_0 a^3}{v} \left(\frac{d^2}{dx^2}+\frac{d^2}{dz^2}\right) \frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}$$

$$\gamma = -\frac{1}{2} \frac{Z_0 a^3}{v} \frac{d^2}{dydz} \frac{\epsilon^{\iota p\left(t-\frac{r}{v}\right)}}{r}$$

At a distance from the sphere, large compared with the wave length, these expressions reduce to

$$X = Z_0 \frac{a^3}{r} \frac{p^2}{v^2} \left(\frac{xz}{r^2}+\frac{1}{2}\frac{z}{r}\right) \cos p\left(t-\frac{r}{v}\right)$$

$$Y = Z_0 \frac{a^3}{r} \frac{p^2}{v^2} \frac{yz}{r^2} \cos p\left(t-\frac{r}{v}\right)$$

$$Z = -Z_0 \frac{a^3}{r} \frac{p^2}{v^2} \left(1-\frac{z^2}{r^2}+\frac{1}{2}\frac{x}{r}\right) \cos p\left(t-\frac{r}{v}\right)$$

$$\alpha = -\frac{Z_0}{V} \frac{a^3}{r} \frac{p^2}{v^2} \left(\frac{1}{2}\frac{xy}{r^2}+\frac{y}{r}\right) \cos p\left(t-\frac{r}{v}\right)$$

$$\beta = -\frac{Z_0}{V} \frac{a^3}{r} \frac{p^2}{v^2} \left(\frac{y^2-r^2}{2r^2}-\frac{x}{r}\right) \cos p\left(t-\frac{r}{v}\right)$$

$$\gamma = -\frac{Z_0}{V} \frac{a^3}{r} \frac{p^2}{v^2} \frac{1}{2} \frac{yz}{r^2} \cos p\left(t-\frac{r}{v}\right)$$

Thus $xX+yY+zZ=0$, $\alpha x+\beta y+\gamma z=0$, $X\alpha+Y\beta+Z\gamma=0$, so that both the electric and magnetic forces are at right angles to the radius, and the magnetic and electric forces are at right angles to each other. We see from the preceding expressions that the electric and magnetic forces both vanish when $y=0$ and $x/r=-\frac{1}{2}$, thus the scattered wave due to the incidence of a plane wave on a conducting sphere vanishes along a line making an angle of 60° with the direction of the incident wave measured backwards from the sphere, and in the plane through the centre of the sphere at right angles to the magnetic force in the incident wave. In the case of the non-conducting sphere this angle was 90° instead of 60°.[64] The preceding investigation applies to a perfect conductor. We shall show later that when a wave in which the frequency of vibration is p falls upon a conductor of specific resistance σ, it only penetrates the conductor to a depth comparable with $\sqrt{\sigma/p}$. If, then $\sqrt{\sigma/p}$ is small compared with the radius of the sphere, *i.e.*, if σ/pa^2 is small, we may treat the sphere as a perfect conductor. As p is equal to $2\pi V/\lambda$, this condition requires $\sigma\lambda/2\pi Va^2$ to be small, hence as by hypothesis λ/a is very large we can only apply this theory when σ/Va is exceedingly small.

§ 18. *Reflexion and Refraction of Electric Waves by Insulators.*—Let us take the plane of the paper as the plane of incidence and of xy, and let $x=0$ be the equation to the reflecting surface. In the case when the electric force in the wave is in the plane of incidence, if V is the velocity of the wave in air, λ its wave length in air, and i the angle of incidence, the incident wave may be represented by the real part of $A\epsilon^{\iota\frac{2\pi}{\lambda}(x\cos i+y\sin i+Vt)}$. This will give rise to a reflected wave which may be represented by the real part of $A'\epsilon^{\iota\frac{2\pi}{\lambda}(-x\cos i+y\sin i+Vt)}$. If r is the angle of refraction, V′ the velocity, and λ' the wave length in the refracting medium, the refracted wave may be represented by the real part of

$$A''\epsilon^{\iota\frac{2\pi}{\lambda'}(x\cos r+y\sin r+V't)}.$$

Since at the reflecting surface, $x=o$, the incident and reflected and refracted waves must keep time with each other, the coefficients of t in all the exponentials must be the same; the coefficients of y must also be the same, since the relation between the waves must be the same at all parts of the reflecting surface. Hence we have

$$\frac{\sin i}{\lambda}=\frac{\sin r}{\lambda'}\,;\ \frac{V}{\lambda}=\frac{V'}{\lambda'},\ \text{or}\ \frac{\sin i}{V}=\frac{\sin r}{V'}.$$

The last equation is the well-known law of refraction. To determine the values of A′ and A″ in terms of A, we have the condition that the electric force parallel to the surface of separation must be continuous as we pass from one medium to another. The electric force parallel to the surface in the air is

$$(A-A')\cos i\,\epsilon^{\iota\frac{2\pi}{\lambda}(y\sin i+Vt)},$$

and in the refracting medium it is

$$A''\cos r\,\epsilon^{\iota\frac{2\pi}{\lambda'}(y\sin r+V't)},$$

hence we have

$$(A-A')\cos i = A''\cos r.$$

The electric polarization normal to the surface must also be continuous; in the air this is

$$(A+A')\sin i\,\epsilon^{\iota\frac{2\pi}{\lambda}(y\sin i+Vt)} \div 4\pi;$$

in the refracting medium it is

$$KA''\sin r\,\epsilon^{\iota\frac{2\pi}{\lambda'}(y\sin r+V't)} \div 4\pi,$$

when K is the specific inductive capacity of the refracting medium. Equating these expressions we have

$$(A+A')\sin i = KA''\sin r;$$

hence we find

$$A' = A\frac{K\tan r-\tan i}{K\tan r+\tan i}$$

$$A'' = A\frac{\sin 2i}{\sin i\cos r+K\cos i\sin r}.$$

If the refracting medium is non-magnetic $V^2/V'^2 = \sin^2 i/\sin^2 r = K$. Substituting this value for K we find

$$A' = A\frac{\tan(i-r)}{\tan(i+r)}$$

$$A'' = 4A\frac{\sin r\cos i}{\sin 2i + \sin 2r}.$$

Thus the reflected wave vanishes when $i+r=\frac{\pi}{2}$. Trouton,[65] who has investigated experimentally the reflexion of electric waves from a paraffin wall 3 feet thick, found that when the electric force was in the plane of incidence the reflected wave vanished at a particular angle of incidence; but if the electric force was at right angles to the plane of incidence the reflected ray never vanished. This observation has an important application to the electromagnetic theory of light, for we know that when light is polarized at right angles to the plane of incidence the reflected wave vanishes when the directions of the refracted and reflected waves are at right angles, but that it never vanishes when the light is polarized in the plane of incidence. Thus the electric force is at right angles to the plane of polarization while the magnetic force is in that plane.

§ 19. We can easily verify that the energy transmitted along the incident beam is equal to the sum of the energies transmitted along the reflected and refracted beams; for by Poynting's theorem the energy passing unit section of a beam per unit time is $EH/4\pi$, where E is the electric and H the magnetic force. But in a plane wave $E=V\mu H$, where μ is the magnetic permeability, hence the rate at which energy passes through unit area of the beam is $E^2/V\mu 4\pi$. Thus the average rate at which it passes across unit area of the incident beam is $A^2/8\pi V$, across the reflected beam $A'^2/8\pi V$, and across unit area of the refracted beam $A''^2/8\pi\mu V'$. Now, if the area of cross section of the incident beam is unity, that of the reflected beam will also be unity, and that of the refracted beam $\cos r/\cos i$; hence the energy transmitted along the incident beam will equal the sum of the energies transmitted along the reflected and refracted beam if

$$\frac{A^2}{V} = \frac{A'^2}{V} + \frac{A''^2}{\mu V'}\,\frac{\cos r}{\cos i}$$

This relation follows at once from the values of A′ and A″ given above.

Let us next consider the case when the electric force is at right angles to the plane of incidence. Let, as before,

$$A\epsilon^{\iota\frac{2\pi}{\lambda}(x\cos i + y\sin i + Vt)},\quad A'\epsilon^{\iota\frac{2\pi}{\lambda}(-x\cos i + y\sin i + Vt)}$$

represent respectively the electric force in the incident and reflected waves, and

$$A''\epsilon^{\iota\frac{2\pi}{\lambda'}(x\cos r + y\sin r + V't)}$$

that in the refracted wave; then the magnetic forces will be in the plane of incidence and will be proportional to A/V, A'/V, $A''/V'\mu$. Since the magnetic force parallel to the surface of separation is continuous we have

$$(A - A')\cos i = A''\frac{V}{V'\mu}\cos r,$$

and since the magnetic induction at right angles to the surface of separation is continuous,

$$(A + A')\sin i = A''\frac{V}{V'}\sin r.$$

Solving these equations we get

$$A' = A\frac{(\mu\tan r - \tan i)}{\mu\tan r + \tan i};\quad = -A\frac{\sin(i-r)}{\sin(i+r)}\text{ if } \mu=1,$$

$$A'' = \frac{2A\mu\cos i\sin r}{\cos r\sin i + \mu\cos i\sin r},\quad = \frac{2A\cos\iota\sin r}{\sin(\iota+r)}\text{ if } \mu=1.$$

In this case the reflected wave never vanishes. Assuming the electromagnetic theory of light, these and the preceding investigations give the intensity of the reflected and refracted beams when plane polarized light is incident upon a reflecting surface.

§ 20. *Reflexion of Electric Waves by a Plate of Dielectric of finite thickness.*—We shall suppose that the plate is bounded by the parallel planes $x=0$, $x=-h$, and shall limit ourselves to the case of normal incidence; the general case of oblique incidence is discussed in J. J. Thomson's *Recent Researches on Electricity and Magnetism*, p. 407. Let the incident ray be represented by $A\epsilon^{\iota\frac{2\pi}{\lambda}(x+Vt)}$, and the reflected ray by $A'\epsilon^{\frac{2\pi}{\lambda}(-x+Vt)}$. In the plate there will be waves travelling in both directions; let one of these be represented by $B\epsilon^{\iota\frac{2\pi}{\lambda'}(x+V't)}$, and the other by $B'\epsilon^{\iota\frac{2\pi}{\lambda'}(-x+V't)}$, and let the emergent wave be represented by $C\epsilon^{\iota\frac{2\pi}{\lambda}(x+Vt)}$. Then introducing the boundary conditions at $x=0$ and $x=-h$, and solving the four equations we find if the plate is non-magnetic

$$A' = -A(K-1)\left(\epsilon^{\iota\frac{2\pi}{\lambda'}h} - \epsilon^{-\iota\frac{2\pi}{\lambda'}h}\right)\div\Delta,$$

$$B = 2A\left(\frac{V}{V'}+1\right)\epsilon^{\iota\frac{2\pi}{\lambda'}h}\div\Delta,$$

$$B' = 2A\left(\frac{V}{V'}-1\right)\epsilon^{\iota\frac{-2\pi}{\lambda'}h}\div\Delta,$$

$$C = 4A\frac{V}{V'}\epsilon^{\frac{2\pi}{\lambda}h}\div\Delta,$$

where

$$\Delta = (K+1)\left(\epsilon^{\iota\frac{2\pi}{\lambda'}h} - \epsilon^{-\iota\frac{2\pi}{\lambda'}h}\right) + 2\sqrt{K}\left(\epsilon^{\iota\frac{2\pi}{\lambda'}h} - \epsilon^{\iota\frac{2\pi}{\lambda'}h}\right).$$

Thus corresponding to the incident wave $A\cos\frac{2\pi}{\lambda}(x+Vt)$ we have a reflected wave represented by

$$-A(K-1)\sin\frac{2\pi}{\lambda'}h\,\cos\left\{\frac{2\pi}{\lambda}(-x+Vt)+\frac{\pi}{2}-\vartheta\right\}\div D,$$

two waves in the plate represented respectively by

$$A\left(\frac{V}{V'}+1\right)\cos\left\{\frac{2\pi}{\lambda'}(x+h+V't)-\vartheta\right\}\div D$$

and

$$A\left(\frac{V}{V'}-1\right)\cos\left\{\frac{2\pi}{\lambda'}(-(x+h)+V't)-\vartheta\right\}\div D,$$

and a wave emerging from the plate represented by

$$2A\frac{V}{V'}\cos\left\{\frac{2\pi}{\lambda}(x+h+Vt)-\vartheta\right\}\div D,$$

where $D^2=(K+1)^2\sin^2\frac{2\pi}{\lambda'}h + 4K\cos^2\frac{2\pi}{\lambda'}h$; $\tan\vartheta = \frac{K+1}{2\sqrt{K}}\tan\frac{2\pi}{\lambda'}h$.

Thus we see that when $2\pi h/\lambda'$ is very small the reflected wave is very feeble. This is what we should naturally expect, as we could not expect to get appreciable reflexion unless the thickness of the plate were comparable with the length of the wave. Trouton[66] has verified that there is no appreciable reflexion of electric waves from window glass unless it is covered with moisture which makes it a conductor. The reflected wave vanishes whenever $2\pi h/\lambda'$ is a multiple of π, or whenever the thickness of the plate is a multiple of half the wave length of the wave in the plate. Trouton used as a reflecting plate a wall built of paraffin bricks, a method which enabled him to try the effect of varying the thickness of the plate; he found that after reaching the thickness at which the reflected wave became sensible by making the wall still thicker, the reflected wave became again insensible when the wall reached a certain thickness. The case is analogous to the colours of thin plates where we have darkness when the thickness of the plate is a multiple of half the wave length. The intensity of the electric force in the plate is proportional to

$$\frac{V}{V'}\cos\frac{2\pi}{\lambda'}(x+h)\cos\left(\frac{2\pi}{\lambda'}V't-\vartheta\right) - \sin\frac{2\pi}{\lambda'}(x+h)\sin\left(\frac{2\pi}{\lambda'}V't-\vartheta\right);$$

thus the average value of the square of the electric force is proportional to

$$\frac{V^2}{V'^2}\cos^2\frac{2\pi}{\lambda'}(x+h) + \sin^2\frac{2\pi}{\lambda'}(x+h).$$

The maxima of this expression occur when $x+h$ is a multiple of $\lambda^1/_2$. Thus if the substance of the plate is changed by the action of the electric field the plate would develop a periodic structure, the wave length of which would be half that of the electric waves in the plate.

§ 21. *Reflexion of Waves by Conductors; Opacity of Conductors.*—In conductors there are, in addition to the polarization currents which are proportional to the rate of increase of the electric intensity, conduction currents which, obeying Ohm's law, are proportional to the electric intensity. Thus in a conductor, if i is the current and E the electric intensity,

$$i = \frac{K}{4\pi}\frac{dE}{dt} + \frac{E}{\sigma},$$

where σ is the specific resistance of the substance. Substituting this value for the current in equations B we find that the components of the electric intensity and of the magnetic force satisfy equations of the form

$$K\mu\frac{d^2X}{dt^2}+\frac{4\pi\mu}{\sigma}\frac{dX}{dt}=\frac{d^2X}{dx^2}+\frac{d^2X}{dy^2}+\frac{d^2X}{dz^2}.$$

Suppose now we have an electric wave travelling through the air and striking normally against a conductor, the plane of separation between the air and the conductor being the plane $x=0$. Let the electric intensity in the incident wave be represented by the real part of $A\epsilon^{\iota\frac{2\pi}{\lambda}(Vt+x)}$. Then if E is the electric intensity in the wave in the conductor, it satisfies the differential equation

$$K\mu\frac{d^2E}{dt^2}+\frac{4\pi\mu}{\sigma}\frac{dE}{dt}=\frac{d^2E}{dx^2}.$$

The frequency of the electric intensity in the conductor must be the same as that in the air; hence E must be proportional to $\epsilon^{\iota pt}$ if $p=2\pi V/\lambda$. On this supposition the equation for E becomes

$$\frac{d^2E}{dx^2}+E\left(\mu Kp^2-\frac{4\pi\mu\iota p}{\sigma}\right)=0;$$

hence E will be of the form $\epsilon^{\iota(pt+nx)}$ where $n^2=\mu Kp^2-\frac{4\pi\iota\mu p}{\sigma}$. Thus n is a complex quantity of the form $a+\iota\beta$. We must take the root which has β negative, for in the conductor x is negative, and if β were positive the expression would represent a disturbance continually increasing in intensity as the distance from the surface of the conductor increases. Let the electric intensity in the conductor be represented by $B\epsilon^{\iota(pt+nx)}$, and let the reflected wave in the air be represented by $A'\epsilon^{\iota\frac{2\pi}{\lambda}(Vt-x)}$; then since the electric force parallel to the surface of separation is continuous

$$A+A'=B,$$

and since the magnetic force parallel to the surface is, by equations A (§ 10), $(1/\mu\iota p)$ (dE/dx) and is continuous, we have

$$\frac{2\pi}{\lambda}(A-A')=\frac{Bn}{\mu},$$

hence

$$A'=A\frac{\left(1-\frac{\lambda n}{2\pi\mu}\right)}{1+\frac{\lambda n}{2\pi\mu}}$$

$$B=\frac{2A}{1+\frac{\lambda n}{2\pi\mu}}.$$

Now $n^2=\mu Kp^2-4\pi\frac{\mu\iota p}{\sigma}$; the ratio of the first term in this expression to the real part of the second is $\mu Kp\sigma/4\pi\mu$. But $K=K'/V^2$ where K′ is the ratio of the specific inductive capacity of the conductor to that of air, and V the velocity of light, *i.e.*, 3×10^{10} cm./sec.; hence the preceding ratio is equal to $K'p\sigma/36\pi\times10^{20}$. If we put in the value of σ for the ordinary metals we see that unless K′ is enormous this ratio is exceedingly small even when the frequency is as large as it is in the waves which constitute visible light. Even for electrolytes it is exceedingly small for electric waves a few millimetres in wave length, and the longer the wave length the smaller it becomes. We shall, therefore, in the expression for n^2 neglect the term μKp^2 in comparison with $4\pi\mu p/\sigma$, but when we can do this $n\lambda/2\pi\mu$ is exceedingly large; hence approximately $A'=-A$

$$B=\left\{\frac{2\mu\sigma}{V\lambda}\right\}^{\frac{1}{2}}\epsilon^{\iota\frac{\pi}{4}}A.$$

Thus the reflected wave is represented by $-A\cos\frac{2\pi}{\lambda}(Vt-x)$. To this approximation the electric force parallel to the surface of the conductor vanishes at the surface. The transmitted wave is represented by

$$A\sqrt{\frac{2\mu\sigma}{V\lambda}}\epsilon^{2\pi\sqrt{\frac{\mu V}{\sigma\lambda}}x}\cos\left(\frac{2\pi}{\lambda}Vt+2\pi\sqrt{\frac{\mu V}{\sigma\lambda}}x+\frac{\pi}{4}\right).$$

In the conductor x is always negative, so that the amplitude of the transmitted wave is small to begin with, and diminishes rapidly in consequence of the exponential term.

§ 22. *Transmission of Electric Waves through a conducting Plate.*[67]—Let us take the case of electric waves incident normally upon a conducting plate bounded by the planes $x=0$, $x=-h$. Using the same notation as before, let the incident wave be represented by $A\epsilon^{\iota\frac{2\pi}{\lambda}(Vt+x)}$, the reflected wave by $A'\epsilon^{\iota\frac{2\pi}{\lambda}(Vt-x)}$, the wave in the plate by $B\epsilon^{\iota(pt+nx)}$ and $B'\epsilon^{\iota(pt-nx)}$, and the transmitted wave by $C\epsilon^{\iota\frac{2\pi}{\lambda}(Vt+x)}$. The boundary conditions at the two surfaces of the plate give four equations from which we deduce

$$A'=-A(n^2/\mu^2-4\pi^2/\lambda^2)\left(\epsilon^{\iota nh}-\epsilon^{-\iota nh}\right)\div D,$$

$$B=\frac{4\pi A}{\lambda}(n/\mu+2\pi/\lambda)\epsilon^{\iota nh}\div D,$$

$$B'=\frac{4\pi}{\lambda}A(n/\mu-2\pi/\lambda)\epsilon^{-\iota nh}\div D,$$

$$C=\frac{8\pi}{\lambda}A(n/\mu)\epsilon^{\iota\frac{2\pi}{\lambda}h}\div D,$$

where

$$D=(n^2/\mu^2+4\pi^2/\lambda^2)\left(\epsilon^{\iota nh}-\epsilon^{-\iota nh}\right)+(4\pi/\lambda)(n/\mu)\left(\epsilon^{\iota nh}+\epsilon^{-\iota nh}\right).$$

When nh is large we see that $A'=-A$, and the electric force parallel to the plate vanishes at the surface of the plate. The magnitude of nh is $(4\pi\mu ph^2/\sigma)^{\frac{1}{2}}$, and the condition that the force should vanish at the surface is that this quantity should be large. For metals very small values of h are sufficient to satisfy this condition; thus for waves one metre in length in air and for an iron plate, nh is about 1500 h, so that if the plate were only 1/15 mm. thick nh would be equal to 10, and as ϵ^{10} is a very large number the reflexion is practically perfect. We see from this example how it is that tin-foil and gold-leaf are practically perfect reflectors for very rapid electric waves. With electrolytes, on the other hand, for which σ may easily be as large as 10^{10}, it will require a plate many millimetres thick to produce complete reflexion. The case of nh large is practically that of the infinitely thick plate previously considered. Let us now consider the case of a plate so thin that nh is small; in this case there are two subcases to consider—(1) when $n^2h\lambda/2\pi\mu$ or $4\pi Vh/\sigma$ is small; (2) when it is large. In case (1)

$$A'=-\frac{\iota\lambda n^2h}{2\pi\mu A},\ B=\frac{1}{2}A,\ B'=\frac{1}{2}A,\ C=A;$$

thus the reflected wave is represented by $\frac{4\pi Vh}{\sigma}A\cos\frac{2\pi}{\lambda}(Vt-x)$, the waves in the plate by

$$\frac{1}{2}A\cos\left(\frac{2\pi}{\lambda}Vt+2\pi\sqrt{\frac{\mu V}{\sigma\lambda}}x\right)+\frac{1}{2}A\cos\left(\frac{2\pi}{\lambda}Vt-2\pi\sqrt{\frac{\mu V}{\sigma\lambda}}x\right),$$

and the transmitted wave by $A\cos\frac{2\pi}{\lambda}(Vt+x+h)$.

In the second case when $n^2h\lambda/2\pi\mu$ is large we have approximately

$$A'=-A;\ B=2\pi A\mu/\iota n^2h\lambda,\ B'=2\pi A\mu/\iota n^2h\lambda,\ C=4\pi A\epsilon^{\frac{\iota 2\pi h}{\lambda}}/n^2h\lambda.$$

Thus the reflected wave is approximately $-A\cos\frac{2\pi}{\lambda}(Vt-x)$, the waves in the plate

$$\frac{\sigma}{4\pi Vh}A\left\{\cos\left(\frac{2\pi}{\lambda}Vt+2\pi\sqrt{\frac{\mu V}{\sigma\lambda}}x\right)+\cos\left(\frac{2\pi}{\lambda}Vt-2\pi\sqrt{\frac{\mu V}{\sigma\lambda}}x\right)\right\},$$

and the transmitted wave $\frac{\sigma}{2\pi Vh}A\cos\frac{2\pi}{\lambda}(Vt+x+h)$.

Thus the thickness of the slab which produces a given diminution in the intensity of the transmitted wave is proportional to the specific resistance. This result has been applied by the writer[68] and Erskine[69] to compare the resistance of electrolytes under the very rapidly alternating electric forces which occur in electric waves. These investigations have shown that the ratio of the resistances of electrolytes under electric forces changing their direction several million times a second is the same as under steady currents. Similar measurements by a somewhat different method have been made by Zeemann.[70]

The preceding equations are general, and if we know the values of λ, σ, and h, we can from them calculate the amplitudes of the various waves. Thus. take the case of a wave of light for which $\lambda=6\times10^{-5}$ cm. incident on a plate of gold-leaf whose thickness is $\lambda/25$, σ for gold under steady current may be taken as 2×10^3. Substituting these values in the equations when nh is large we find $C/A=\cdot0001$ approximately, so that the intensity of the transmitted wave would only be about 10^{-8} of the incident wave. This indicates that such a film would be practically opaque. Experiments on the transparency of thin metallic plates made by W. Wien[71] and others have shown that such plates have a much greater transparency than is indicated by the preceding figures. For example, the intensity of the transmitted wave in the case of the film of gold-leaf just considered is found to be not much less than

$\frac{1}{3}$ of that of the incident one. This enormous discrepancy seems to indicate that when the electric force is changing its direction with the rapidity which it does in the case of waves of light, the effective resistance of metals is much greater than under steady currents; we shall return to this point when we consider the propagation of an electric wave through a medium containing ions.

The theory of reflexion of electric waves from a grating of parallel wires has been discussed by the writer [72] and Lamb. [73]

§ 23. *Waves along Wires.*—A most important case of electric waves is when there is a wire in the field parallel to the direction of their propagation. The wire acts as a guide to the waves, which may in a certain sense be said to run along it. The reader will find a full discussion of this problem in papers by the writer, [74] by Heaviside, [75] and in recent ones by Sommerfeld [76] and by Mie. [76] We shall confine ourselves here to an outline of the method by which the problem can be solved. Let us first take the case when the only conductor in the field is a cylindrical wire of radius a, the axis of which we shall take as the axis of z. Let P, Q, R, a, b, c be the components of the electric force and the magnetic induction respectively parallel to the axes of x, y, z, and let us suppose that the electric field is symmetrical about the axis of z. Then in the air around the wire R satisfies the equation

$$\frac{d^2R}{dx^2}+\frac{d^2R}{dy^2}+\frac{d^2R}{dz^2}=\frac{1}{v^2}\frac{d^2R}{dt^2},$$

where v is the velocity of propagation of electromagnetic disturbance through the air. If R varies as $\epsilon^{\iota(mz+pt)}$ this equation becomes

$$\frac{d^2R}{dx^2}+\frac{d^2R}{dy^2}-R\left(m^2-\frac{p^2}{v^2}\right)=0 \quad . \quad . \quad . \quad (1),$$

or since the field is symmetrical about the axis of z

$$\frac{d^2R}{d\rho^2}+\frac{1}{\rho}\frac{dR}{d\rho}-R\left(m^2-\frac{p^2}{v^2}\right)=0 \quad . \quad . \quad . \quad (2),$$

where $\rho^2=x^2+y^2$.

Since the field is symmetrical about the axis of z we may put

$$P=\frac{dX}{dx},\quad Q=\frac{dX}{dy},$$

where X is a function of ρ and z, which satisfies a differential equation of the type (1) or (2). Since

$$\frac{dP}{dx}+\frac{dQ}{dy}+\frac{dR}{dz}=0,$$

we have

$$\frac{d^2X}{dx^2}+\frac{d^2X}{dy^2}+\iota mR=0,$$

or

$$X\left(m^2-\frac{p^2}{v^2}\right)+\iota mR=0;$$

hence

$$P=-\frac{\iota m}{m^2-\frac{p^2}{v^2}}\frac{dR}{dx},\quad Q=-\frac{\iota m}{m^2-\frac{p^2}{v^2}}\frac{dR}{dy};$$

From the equations of the type

$$\frac{da}{dt}=\frac{dQ}{dz}-\frac{dR}{dy}$$

we get

$$a=-\frac{\iota p}{v^2}\frac{1}{m^2-\frac{p^2}{v^2}}\frac{dR}{dy},\quad b=\frac{\iota p}{v^2}\frac{1}{m^2-\frac{p^2}{v^2}}\frac{dR}{dx},\quad c=0.$$

or

$$a=\frac{p}{mv^2}Q,\quad b=-\frac{p}{mv^2}P,\ c=0.$$

Thus the lines of magnetic force are circles with their centres long the axis of z, and their planes at right angles to it.

In the wire itself, R satisfies an equation of the form

$$\frac{d^2R}{dx^2}+\frac{d^2R}{dy^2}+\frac{d^2R}{dz^2}=\frac{4\pi\mu}{\sigma}\frac{dR}{dt},$$

where μ is the magnetic permeability, and σ the specific resistance of the wire. In this equation we have neglected the term $\mu K d^2R/dt^2$ in comparison with $(4\pi\mu/\sigma)(dR/dt)$, and for all metallic conductors this is legitimate unless the waves are smaller than the wave length of light. Introducing the conditions that the field is symmetrical about the axis of z, and that R varies as $\epsilon^{\iota(mz+pt)}$, we get

$$\frac{d^2R}{d\rho^2}+\frac{1}{\rho}\frac{dR}{d\rho}-R\left(m^2+\frac{4\pi\mu\iota p}{\sigma}\right)=0.$$

We find also

$$P=-\frac{\iota m}{m^2+\frac{4\pi\mu\iota p}{\sigma}}\frac{dR}{dx};\quad Q=-\frac{\iota m}{m^2+\frac{4\pi\mu\iota p}{\sigma}}\frac{dR}{dy};$$

and

$$a=-\frac{\frac{4\pi\mu}{\sigma}}{m^2+\frac{4\pi\mu\iota p}{\sigma}}\frac{dR}{dy},\quad b=\frac{\frac{4\pi\mu}{\sigma}}{m^2+\frac{4\pi\mu\iota p}{\sigma}}\frac{dR}{dx},\quad c=0.$$

Thus all the quantities both in the air and the metal can be expressed in terms of the z component of the electric force. Now, both in the air and the metal, R satisfies a differential equation of the form

$$\frac{d^2R}{d\rho^2}+\frac{1}{\rho}\frac{dR}{d\rho}-q^2R=0 \quad . \quad . \quad . \quad . \quad (3),$$

where in the air $q^2=m^2-\frac{p^2}{v^2}$; in the metal $q^2=m^2+4\pi\mu\iota p/\sigma$.

The solution of this equation is

$$R=AJ_0(\iota q\rho)+BK_0(\iota q\rho),$$

where J_0 and K_0 are Bessel's functions of the first and second kinds. The expressions for $J_0(x)$ and $K_0(x)$ are (see Art. SPHERICAL HARMONICS)

$$J_0(x)=1-\frac{1}{(1!)^2}\left(\frac{x}{2}\right)^2+\frac{1}{(2!)^2}\left(\frac{x}{2}\right)^4-\frac{1}{(3!)^2}\left(\frac{x}{2}\right)^6+\dots$$

$$K_0(x)=J_0(x)\left\{\log\frac{2}{x}+\frac{\pi}{2}+C\right\}-2\left\{J_2(x)-\frac{1}{2}J_4(x)+\frac{1}{3}J_6(x)\dots\right\}$$

where

$$J_n(x)=\frac{1}{n!}\left(\frac{x}{2}\right)^n\left(1-\frac{1}{1.n+1}\left(\frac{x}{2}\right)+\frac{1}{1.2(n+1)(n+2)}\left(\frac{x}{2}\right)\dots\right)$$

and $C=\cdot577\dots=\log\gamma$, where $\gamma=1\cdot781\dots$

For large values of x the following approximate expressions are useful:—

$$J_0(x)=\sqrt{\frac{1}{\pi\iota x}}\left(\epsilon^{\iota\left(x+\frac{\pi}{4}\right)}-\epsilon^{-\iota\left(x+\frac{\pi}{4}\right)}\right),$$

$$K_0(x)=\sqrt{\frac{\pi}{2x}}\,\epsilon^{\iota\left(x+\frac{\pi}{4}\right)}.$$

From these expressions we see that when $x=0$, $K_0(\iota x)$ is infinite, and when x is infinite $J_0(\iota x)$ is infinite. Thus in the wire where ρ may vanish R is represented by the J_0 function, and in the air where ρ may become infinite R is represented by the K_0 function. Thus in the wire we have

$$R=AJ_0(\iota n\rho)\epsilon^{\iota(mz+pt)},$$

where $n^2=m^2+4\pi\mu\iota p/\sigma$, and in the air

$$R=BK_0(\iota\kappa\rho)\epsilon^{\iota(mz+pt)},$$

where $\kappa^2=m^2-p^2/v^2$.

The magnetic induction at right angles to ρ in the wire is

$$\frac{4\pi\mu}{\sigma n^2}\frac{dR}{d\rho}=\frac{4\pi\mu\iota}{\sigma n}AJ'_0(\iota n\rho)\epsilon^{\iota(mz+pt)}$$

where

$$J'_0(\iota n\rho)=\frac{dJ_0(\iota n\rho)}{d(\iota n\rho)}.$$

The magnetic induction at right angles to ρ in the air is equal to

$$\frac{\iota p}{v^2\kappa^2}\frac{dR}{d\rho}=-\frac{p}{v^2\kappa}BK'_0(\iota\kappa\rho)\epsilon^{\iota(mz+pt)}$$

where

$$K'_0(\iota\kappa\rho)=\frac{d.K_0(\iota\kappa\rho)}{d.\iota\kappa\rho}.$$

The boundary conditions at the surface of the wire when $\rho=a$ are (1) that the electric force parallel to the surface is continuous, *i.e.*, that R is continuous; this gives $AJ_0(\iota na)=BK_0(\iota\kappa a)$; and (2) that the magnetic force parallel to the surface is continuous; this gives

$$\frac{4\pi\iota}{\sigma n}AJ'_0(\iota na)=-\frac{p}{v^2\kappa}BK'_0(\iota\kappa a).$$

Eliminating A and B from these equations we get

$$\frac{\sigma nJ'_0(\iota na)}{4\pi\iota J'_0(\iota na)}=-\frac{\kappa v^2}{p}\frac{K_0(\iota\kappa a)}{K'_0(\iota\kappa a)} \quad . \quad . \quad (4),$$

a transcendental equation to determine n. In all cases of electric waves along wires where the wave length is large compared with the radius of the wire κa is very small. When κa is very small

$$K_0(\iota\kappa a)=\log\frac{2\gamma}{\iota\kappa a},\ \text{and}\ K'_0(\iota\kappa a)=-\frac{1}{\iota\kappa a}.$$

Substituting these values in (4) we get

$$\frac{\iota na\sigma}{4\pi}\frac{J_0(\iota na)}{J'_0(\iota na)}=-\frac{2\gamma^2v^2}{p}\left(\frac{\iota\kappa a}{2\gamma}\right)^2\log\left(\frac{2\gamma}{\iota\kappa a}\right)^2$$

or if $z=\left(\frac{\iota\kappa a}{2\gamma}\right)^2$

$$\frac{\iota na\sigma}{4\pi}\frac{J_0(\iota na)}{J'_0(\iota na)}=\frac{2\gamma^2v^2}{p}z\log z \quad . \quad . \quad (5).$$

§ 24. *Slowly Varying Currents.*—Let us first take the case when na is small. Then we have approximately $J_0(\iota na)=1, J'_0(\iota na)=-\frac{1}{2}(\iota na)$, and equation (5) becomes

$$z\log z=-\frac{\iota\sigma p}{4\pi\gamma^2v^2}\quad . \quad . \quad . \quad . \quad (6).$$

As $v=3\times10^{10}$, it follows that with the specific resistances which are possessed by the metals the right-hand side of this equation will be very small, since to make it large would require a value of p which would be practically incompatible with the condition na small. An approximate solution of the equation $z\log z=-y$ where y is small is $z_1=-y/\log y$, a second approximation is $z_2=-y/\log z_1$, a third $z_3=-y/\log z_2$, and so on. Proceeding in this way, we find for a first approximation to the solution of equation (6)

$$\kappa^2=\frac{p\sigma}{\pi v^2a^2\log(p\sigma/4\pi\gamma^2v^2)}\left\{\iota+\frac{\pi}{2}\frac{1}{\log(p\sigma/4\pi\gamma^2v^2)}\right\};$$

therefore

$$m^2=\frac{p^2}{v^2}-\frac{p\sigma}{\pi v^2a^2\log(p\sigma/4\pi\gamma^2v^2)}\left\{\iota+\frac{\pi}{2}\frac{1}{\log(p\sigma/4\pi\gamma^2v^2)}\right\}.$$

The second term within the bracket is very small and may be neglected, and except in special cases p^2/v^2 will be small compared with the remaining term, as the ratio of this term to p^2/v^2 is $(\sigma/\pi a^2p)/\log(p\sigma/4\pi\gamma^2v^2)$; but since na is small $\sigma/\pi a^2p$ is large, and the logarithm will not in general be sufficiently large to neutralize the large numerator of this fraction. Neglecting p^2/v^2 we have

$$m^2=\frac{p\sigma\iota}{\pi v^2a^2\log(p\sigma/4\pi\gamma^2v^2)}$$

or

$$m=-\sqrt{\frac{-p\sigma}{2\pi v^2a^2\log(p\sigma/4\pi\gamma^2v^2)}}(1-i).$$

Now R varies as $\epsilon^{\iota(mz+pt)}$, hence R will be proportional to

$$\epsilon^{-\alpha z}\cos(pt-\alpha z),\text{ where }\alpha=\{-p\sigma/2\pi v^2a^2\log(p\sigma/4\pi\gamma^2v^2)\}^{\frac{1}{2}}.$$

This indicates a velocity of propagation equal to p/α or to

$$v\{2\pi pa^2\log(4\pi\gamma^2v^2/p\sigma)/\sigma\}^{\frac{1}{2}},$$

the amplitude of the vibration dying away to $1/e$ of its original value after traversing a length $1/\alpha$, which is only $(1/2\pi)$ of the wave length. Thus waves of this kind move more slowly than disturbances which are propagated through the dielectric. If **R** is the resistance of unit length of the wire, *i.e.*, $\sigma/\pi a^2$, and if $\Gamma=1/v^2\log(p\sigma/4\pi\gamma^2v^2)$, the wave along the wire is represented by

$$\epsilon^{-(p\mathbf{R}\Gamma/2)^{\frac{1}{2}}z}\cos\left((p\mathbf{R}\Gamma/2)^{\frac{1}{2}}z-pt\right).$$

§ 25. *Wire with Return Metallic Circuit.*—The physical meaning of Γ becomes clearer when the electric conditions are made precise by supposing that the dielectric is enclosed by a conducting cylinder coaxial with the wire. If the radius of the internal boundary of this cylinder is b, proceeding as in the simpler problem we find the following equation connecting p and m—

$$\kappa^2=-\frac{\iota p^2}{v^2}\left\{\frac{\mu}{na}\frac{J_0(\iota na)}{J'_0(\iota na)}-\frac{\mu'}{n'b}\frac{K_0(\iota n'b)}{K'_0(\iota n'b)}\right\}\frac{1}{\log(b/a)}\quad . \quad (7),$$

where μ' is the magnetic permeability of the outer conduction and

$$n'^2=m^2+4\pi\mu'\iota p/\sigma'$$

σ' being the specific resistance of the outer conductor. When na is very small equation (7) becomes

$$\kappa^2=-\frac{\iota p^2}{V^2}\left\{\frac{2\iota\mu}{n^2a^2}-\frac{\mu'}{n'b}\frac{K_0(\iota n'b)}{K'_0(\iota n'b)}\right\}\frac{1}{\log(b/a)}\quad . \quad (8).$$

The first term is very large as na is small, the second term is zero when b is infinite, and even when b is so small that $n'b$ is a small quantity. For the ratio of the second term inside the bracket to the first is equal to

$$\frac{\mu'}{2\mu}n^2a^2\log\frac{2\gamma}{\iota n^2b}$$

and is thus exceedingly small unless $n'b$ is vanishingly small compared with na. Hence very approximately equation (8) gives since $\kappa^2=m^2-p^2/v^2$

$$m^2=\frac{p^2}{v^2}\left\{1-\frac{\iota\sigma}{2\pi pa^2}\frac{1}{\log(b/a)}\right\},$$

or approximately

$$m^2=-\frac{p}{v^2}\frac{\iota\sigma}{2\pi a^2}\frac{1}{\log(b/a)}$$

If **R** is the resistance and Γ the capacity of unit length of the wire in electromagnetic measure, $\mathbf{R}=\sigma/\pi a^2$ and $\Gamma=1/2V^2\log(b/a)$, hence

$$m^2=-\iota p\mathbf{R}\Gamma\text{ or }m=-(p\mathbf{R}\Gamma)^{\frac{1}{2}}\left(\frac{1}{\sqrt{2}}-\frac{\iota}{\sqrt{2}}\right).$$

Thus the velocity of propagation is $(2p/\mathbf{R}\Gamma)^{\frac{1}{2}}$, the amplitude dies away to $1/e$ of its original value after passing over a distance $(2/\mathbf{R}\Gamma p)^{\frac{1}{2}}$; the greater the frequency the greater the velocity and the more rapid the damping. As a numerical example, let us take the case of a cable transmitting electrical vibrations, whose period is 1/100 of a second; let the copper core be 4 millimetres in diameter, and the external radius of the gutta-percha covering be 2·5 times the radius of the copper. In this case **R** is $1{\cdot}3\times10^{-5}$ ohms and in absolute units $1{\cdot}3\times10^4$, while Γ is about 15×10^{-22}; hence the velocity of propagation is about 8×10^9 cm./sec., and the disturbance will travel about $1{\cdot}28\times10^7$ cm. before falling to $1/e$ of its initial value. This is an illustration of the velocity of a very long wave. With very fine wires the condition na small can be fulfilled with quite short waves. Thus take the case of a platinum wire 2×10^{-4} cm. in radius, carrying a wave whose wave length in air would be 1 metre; then since σ for platinum is about $1{\cdot}4\times10^4$, and p for this wave length $2\pi\times3\times10^8$, we see that na is small. Substituting the value of p, a, σ in equation (6), we find that the velocity of propagation is only about 80 per cent. of that of an electromagnetic disturbance through air, and the amplitude of the vibration will fall to $1/e$ of its original value after passing over a distance of about 17 cm.

The relation $m^2=-\iota p\mathbf{R}\Gamma$ is the one at which we should arrive for the propagation of a disturbance along a cable if we neglected the effects of electromagnetic induction. The equation satisfied by the current I along the wire is in this case $\mathbf{R}\Gamma\frac{dI}{dt}=\frac{d^2I}{dz^2}$. As in this case the effects of self-induction are neglected, the disturbance is propagated by "diffusion" rather than by ordinary wave propagation. This remark applies to the case we are considering. Whenever na is small we are dealing with diffusion and not true wave propagation; hence when we study electric waves by their effects along wires we must be careful that na is large. For if this quantity is small, the velocity of propagation depends upon the frequency, and there is no more a definite velocity of propagation of an arbitrary disturbance lasting for not too short a time, than there is a definite velocity of propagation of heat through a conducting solid.

If na is small nr will be small everywhere within the wire, and if nr is small $J_0(\iota nr)$ is approximately unity. Hence the electric force parallel to the axis of the wire, and therefore the electric current, is in this case uniform over the cross section of the wire; when this is the case the problem of waves along wires is one of diffusion. A reference to the equations giving the components of the electric force along and perpendicular to the axis of the wire shows that inside the wire the force is everywhere approximately parallel to the axis, while in the dielectric at the surface of the wire the electric force is approximately radial. At a distance from the wire comparable with the wave length this ceases to be true, and the lines of force are bent so that at some points they are parallel to the axis of the wire. The strong damping of the waves in this case is due to the absorption of energy caused by the heating of the wire by the current flowing through it. Fig. 48 represents the lines of electric force in a case of this kind. It is taken from Sommerfeld's paper.[76]

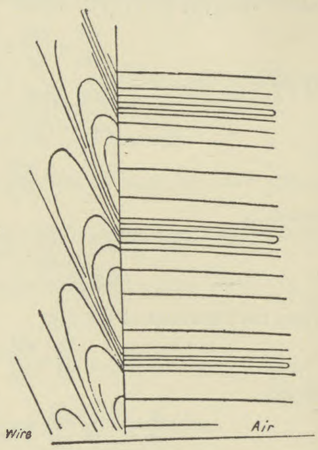


Fig. 48.

§ 26. *Case of High Frequency Currents or very good Conductors.*—When p is so large or σ so small that na is a very large quantity, the preceding considerations no longer hold. If na is very large $J'_0(\iota na)=-iJ_0(\iota na)$ and equation (5) becomes

$$z\log z=-\frac{ip\sigma}{8\pi\gamma^2v^2}na$$
$$=M(1-i),$$

where

$$M=\frac{a}{4\gamma^2v^2}\left\{\frac{\mu\sigma p^3}{2\pi}\right\}^{\frac{1}{2}}.$$

In deducing this equation we have substituted for na the approximate value $\sqrt{4\pi\mu p/\sigma}$. The approximate solution of this equation is

$$z=z_0\epsilon^{\iota\phi} \text{ where } z_0=-\frac{M\sqrt{2}}{\log M\sqrt{2}} \text{ and } \phi=-\pi/4.$$

Since $z=(\iota\kappa a/2\gamma)^2$ and $\kappa^2=m^2-p^2/v^2$, we get

$$m^2=\frac{p^2}{v^2}+\frac{a}{v^2a}\left(\frac{\mu\sigma p^3}{2\pi}\right)^{\frac{1}{2}}\frac{1}{\log M\sqrt{2}}(1-i),$$

as the real part of the second term on the right-hand side is very small compared with p^2/v^2, we have approximately

$$m^2=\frac{p^2}{v^2}\left\{1-\left(\frac{\mu\sigma}{2\pi pa^2}\right)^{\frac{1}{2}}\frac{1}{\log M\sqrt{2}}i\right\},$$

or

$$m=\frac{p}{v}\left\{1-\tfrac{1}{2}\left(\frac{\mu\sigma}{2\pi pa^2}\right)^{\frac{1}{2}}\frac{1}{\log M\sqrt{2}}i\right\} \quad . \quad . \quad . \quad (9).$$

If we take the case when the air is bounded by a conducting cylinder whose internal radius is b, we arrive at a similar expression, the only difference being that instead of log M$\sqrt{2}$ we have 2 log b/a. Since p/m is the velocity with which a disturbance is propagated along the wire, we see from equation (9) that in this case the velocity of propagation is v, and is independent of the frequency; the amplitude of the disturbance falls to $1/e$ after passing over a distance equal to $\lambda(2pa^2/\mu\pi\sigma)^{\frac{1}{2}}\log(M\sqrt{2})$, when λ is the wave length $2\pi v/p$. By hypothesis pa^2/σ is large, so that the disturbance will travel over many wave lengths before falling to $1/e$ of its original value. The phenomena in this case are much simpler than in the preceding ones. All disturbances now travel with the velocity with which light travels through the dielectric, and the electric force in the dielectric is at right angles to the wire (this follows at once from the equations for P and Q in terms of R, § 23, as in this case κ is very small compared with m). The electric force in the wire is approximately parallel to the axis of the wire, but a very interesting feature of this case is that the electric force, and therefore the current, are practically confined to the skin close to the surface of the wire.

§ 27. *Distribution of the Currents in the Wire.*—To calculate the variation in the electric force as the distance from the surface of the wire increases, we may proceed as follows. Let the total current flowing through the cross section of the wire at the place z, and the time t, be the real part of $I_0\epsilon^{\iota(mz+pt)}$; now the magnetic force tangential to the surface of the wire is at the surface

$$\frac{4\pi\iota}{\sigma n}AJ'_0(\iota na)\epsilon^{\iota(mz+pt)},$$

and since the line integral of this taken round the circumference of the wire is equal to $4\pi I_0\epsilon^{\iota(mz+pt)}$, we get

$$A=-\frac{\iota\sigma n}{2\pi a}\,\frac{I_0}{J'_0(\iota na)}.$$

Thus in the wire

$$R=-\frac{\iota\sigma n}{2\pi a}\,\frac{I_0}{J'_0(\iota na)}J_0(\iota nr)\epsilon^{\iota(mz+pt)}.$$

When as in this case na is large, then at a point near the surface of the wire,

$$J'_0(\iota na)=-\frac{\iota\epsilon^{na}}{\sqrt{2\pi na}};\quad J_0(\iota nr)=\frac{\epsilon^{nr}}{\sqrt{2\pi nr}}.$$

Substituting these values, and taking the real part of R, we get

$$R=\left\{\frac{\mu p\sigma}{\pi ar}\right\}^{\frac{1}{2}}I_0\epsilon^{-(2\pi\mu p/\sigma)^{\frac{1}{2}}(a-r)}\cos\psi,$$

where

$$\psi=mz+pt-(2\pi\mu p/\sigma)^{\frac{1}{2}}(a-r)+\frac{\pi}{4}.$$

Similarly we find that the radial electric force in the cylinder is equal to

$$-\frac{p}{v}\frac{\sigma I_0}{2\pi\sqrt{ar}}\epsilon^{-(2\pi\mu p/\sigma)^{\frac{1}{2}}(a-r)}\sin\left(\psi-\frac{\pi}{4}\right),$$

and the tangential magnetic force to

$$\frac{2}{\sqrt{ar}}I_0\epsilon^{-(2\pi\mu p/\sigma)^{\frac{1}{2}}(a-r)}\cos\left(\psi-\frac{\pi}{4}\right).$$

Since all these expressions contain the factor $\epsilon^{-(2\pi\mu p/\sigma)^{\frac{1}{2}}(a-r)}$, we see that the maximum values of these quantities at a distance $(\sigma/2\pi\mu p)^{\frac{1}{2}}$ from the surface are only $(1/e)$ of their maximum values at the surface, and they diminish in geometrical progression as the distance from the boundary increases in arithmetical progression. Thus the currents are practically confined to a thin skin at the surface of the wire, and we may take $(\sigma/2\pi\mu p)^{\frac{1}{2}}$ as the measure of the thickness of this skin. For currents making 100 vibrations per second, the thickness of the skin for soft iron with a magnetic permeability of 1000 is about ·5 mm., and for copper it is about 7·5 mm. For electric waves 1 metre wave length, the skin for iron is only about ·0001 mm., while for copper it is about 15 times as great. In these cases there is an enormous concentration of the current in the surface layers, producing a great increase in the apparent resistance. We see from the equation for R that the maximum value of R = (maximum value of current through the wire) × $(\mu p\sigma/\pi a^2)^{\frac{1}{2}}$. Thus we may look upon $(\mu p\sigma/\pi a^2)^{\frac{1}{2}}$ as the apparent resistance per unit length of the wire to these alternating currents. It is the same as the resistance to a steady current of a tube whose radius is a, and whose thickness is $1/\sqrt{2}$ times the thickness of the skin.

It is instructive to look upon the transmission of waves along wires from the point of view of Poynting's theorem (see § 13). According to this view the energy does not travel through the wire, but through the dielectric; when the energy from the dielectric passes into the wire it is gradually converted into heat. Now when we were considering the reflexion of waves from metallic plates we saw that we got practically complete reflexion when h, the thickness of the plate, was great enough to make nh large, while the waves were transmitted through the plate when nh is small. Thus in the case of wires when na is large the waves striking against the wires will be completely reflected, and their energy will remain in the dielectric, which when nh is small they will pass through the metal, and part of their energy will be dissipated in heating the wire. We should thus expect that there would be considerable damping in the second case and very little in the first, and this, as we have seen, is the case.

There will be a surface charge of electricity on the wires, and this will give rise to an electrostatic potential ϕ, whose value can be easily calculated. If s is the surface density of the electricity on the wire, the charge on unit length is $2\pi as$; hence if KC is the capacity per unit length of the wire, K being the specific inductive capacity of the dielectric, and C a function of the size of the wire and its distance from other conductors, we have, ϕ being the value of the surface of the wire,

$$\phi=\frac{2\pi as}{KC}.$$

If $I_0\epsilon^{\iota(mz+pt)}$ is the total current through the wire at the place z and the time t, then—

$$\frac{d}{dz}(I_0\epsilon^{\iota(mz+pt)})=-2\pi a\frac{ds}{dt},$$

or since all the quantities vary, as $\epsilon^{\iota(mz+pt)}$, we have

$$\frac{m}{p}I_0\epsilon^{\iota(mz+pt)}=-2\pi as.$$

Hence

$$\phi=-\frac{m}{pKC}I_0\epsilon^{\iota(mz+pt)}.$$

When na is very large, $p/m=v$ the velocity of propagation of electromagnetic disturbances through the dielectric, and if the dielectric is non-magnetic and we use the electromagnetic system of units $K=1/v^2$, thus the preceding equation becomes

$$\phi=\frac{v}{C}I_0\epsilon^{\iota(mz+pt)}.$$

We can apply this equation to find the reflected and transmitted currents when the circumstances suddenly change along the wire.

§ 28. *Wave reflected at the Junction of two Dielectrics.*—Suppose the plane $z=0$ separates two dielectrics, in the first of which the velocity of propagation of electromagnetic action is v, and in the second v'. Let $I_0\epsilon^{\iota(mz+pt)}$ be the incident current coming along the wire from the first medium to the second, $I'_0\epsilon^{\iota(-mz+pt)}$ the reflected current, and $I_1\epsilon^{\iota(mz+pt)}$ the current in the second medium, then

$$I_1=I_0+I'_0 \quad . \quad . \quad . \quad . \quad (1).$$

The potential at $z=0$ in the first medium is $(v/C)(I_0-I'_0)\epsilon^{\iota pt}$, and in the second $v'/CI_1\epsilon^{\iota pt}$. As the potential is continuous we have

$$v'I_1=v(I_0-I'_0) \quad . \quad . \quad . \quad . \quad (2).$$

From (1) and (2) we get

$$I'_0=-\frac{v'-v}{v'+v}I_0$$

$$I_1=\frac{2v}{v'+v}I_0$$

formulæ, which, as we might have expected, since the energy is entirely in the dielectric, are of the same type as those giving the reflected and transmitted waves when electromagnetic waves are incident on a reflecting surface and there are no wires in the field.

§ 29. *Reflexion from a Condenser at the End of the Wire.*—Let us suppose that a condenser whose capacity is C_1 is joined to the end of the wire at $z=0$; let the incident current be $I_0\epsilon^{\iota(mz+pt)}$ and the reflected current $I'_0\epsilon^{\iota(-mz+pt)}$, then at $z=0$ the rate at which electricity is running into the condenser is $(I_0+I'_0)\epsilon^{\iota pt}$. If ϕ is the potential of the plate of the condenser connected with the wire, the other plate being to earth, the change in the condenser is $C_1\phi$, and the rate at which it is increasing $C_1(d\phi/dt)$. Now

$$\phi=\frac{v}{C}(I_0-I'_1)\epsilon^{\iota pt},$$

hence

$$I_0+I'_0=\frac{vC_1}{C}\iota p(I_0-I'_0)$$

or

$$I'_0=\frac{\frac{vC_1}{C}\iota p-1}{\frac{vC_1}{C}\iota p+1}I_0$$

$$=-\epsilon^{-2\iota\theta}I_0$$

$$\text{if}\tan\theta=\frac{vC_1p}{C};$$

thus if the incident current is represented by $\cos(mz+pt)$ the reflected current will be $-\cos\left(pt-m\left(z+\frac{2\theta}{m}\right)\right)$. Thus the magnitude of the reflected current is equal to that of the incident; this we could have seen as there is no loss of energy; there is, however, a change of phase. If there is no capacity at the end the current is reversed in direction; when there is a small capacity the change of phase is such as would be produced if the wire were prolonged to a distance $2v^2C_1/C=2C_1/KC=2$ capacity at the end divided by capacity per unit length of the wire.

§ 30. *Time of Oscillations of a System consisting of a Wire connecting two equal Condensers.*—Suppose that we have a system where a wire of length $2l$ connects two equal condensers, each having a capacity C_1, the other plates of the condenser being at zero potential. Let the current in the wire be regarded as the sum of two currents, one represented by $I_0\cos(mz+pt)$ and the other by $I'_0\cos(-mz+pt)$, and let the origin from which z is measured be the middle of the wire; then when $z=-l$, the current flowing into the condenser, is $I_0\cos(-ml+pt)+I'_0\cos(ml+pt)$, and the charge in the condenser is $C_1\phi=\frac{C_1v}{C}\{I_0\cos(-ml+pt)-I'_0\cos(ml+pt)\}$.

Hence

$$I_0\cos(-ml+pt)+I'_0\cos(ml+pt)$$
$$=\frac{C_1v}{C}\cdot\frac{d}{dt}\{I_0\cos(-ml+pt)-I'_0\cos(ml+pt)\}.$$

Equating coefficients of $\cos pt$ and $\sin pt$ we get

$$\text{(1)}\qquad I_0=I'_0;\ \frac{\cot ml}{ml}=\frac{C_1v^2}{Cl}$$

or

$$\text{(2)}\qquad I_0=-I'_0;\ \frac{\tan ml}{ml}=-\frac{C_1v^2}{Cl};$$

these give the values of m, and hence the periods of the vibration. Let us consider the first equation. Taking first the solution when the wave length is long compared with the length of the wire, ml is very small and equation (1) becomes

$$1=m^2\frac{v^2C_1l}{C},$$

or since $mv=p$

$$p^2\frac{C_1l}{C}=1.$$

If the ends of the wire are connected one to one plate of a condenser and the other to the other, instead of to the plates of separate condensers, the second plates of which are kept at potential zero, we can prove in a similar way that when ml is small the equation for p is

$$p^2\frac{2C_1l}{C}=1\quad.\quad.\quad.\quad.\quad(3).$$

Now when the currents are varying so rapidly that na is large, $1/C=L$ where L is the coefficient of self-induction of the wire per unit length. For if I is the current in the wire the electromagnetic energy is equal to

$$\frac{1}{2}\int LI^2dz$$

where dz is an element of the wire. The electrostatic energy is equal to

$$\frac{1}{2}\int KC\phi^2dz,$$

where ϕ is the electrostatic potential, but in this case

$$\phi=\frac{r}{C}I$$

so that the electrostatic energy is equal to

$$\frac{1}{2}\int\frac{Kv^2}{C}I^2dz,$$

or since $Kv^2=1$ to

$$\frac{1}{2}\int\frac{I^2}{C}dz.$$

Since the mean electrostatic energy is equal to the mean electromagnetic, we have $L=1/C$. Thus equation (3) becomes

$$p^22Cl'L=1,$$

or if $L'=2lL$, *i.e.*, if L′ is the coefficient of self-induction of the circuit

$$p=\frac{1}{\sqrt{L'C_1}}.$$

This is the value given by Lord Kelvin in 1853 in his paper on the oscillatory discharge of a condenser.[77]

Let us now consider the value of m given by (1) when C_1v^2/Cl is small. In this case we see from the equation that $ml=(2n+1)\frac{\pi}{2}+x$ where x is small and n is an integer. Substituting this value of ml in (1) we find

$$x=-\{2n+1\}\frac{\pi}{2}\frac{C_1v^2}{Cl},$$

or, if λ is the wave length $=2\pi/m$

$$\lambda=\frac{4l}{2n+1}\left\{1+\frac{C_1v^2}{C}\right\}.$$

Thus when C_1v^2/C is small the effect of the condenser at the end on the wave length is the same as if the condenser were removed, and the length of the wire increased by $C_1v^2/2C$. If we know the wave length of the electrical vibrations emitted by the system and also C_1, we can from this equation determine C_1 the capacity of the condenser at the end. If we fill the space between the plates of the condenser with different substances, and determine the corresponding value of the capacities, we can compare the specific inductive capacities of the substances when exposed to alternating electric forces of the frequency corresponding to the wave length. This method has been employed by Drude.[78]

§ 31. *Reflexion from a Wire without Self-induction.*—If the end of the wire is connected with a place of zero potential by a resistance R without self-induction, then if ϕ is the potential at the end of the wire, the current through the resistance R is equal to ϕ/R. Hence if I_1 and I_2 are respectively the recedent and reflected currents

$$I_1+I_2=\frac{1}{R}\phi.$$

But $\phi=\frac{v}{C}(I_1-I_2)$. Substituting these values we find

$$I_2=\frac{\frac{v}{RC}-1}{\frac{v}{RC}+1}I_1.$$

This equation was first obtained by Heaviside.[79] The reflected current is smaller than the incident current, and so there is loss of energy by the reflexion. In the special case where $RC=v$ the reflected wave vanishes and all the energy is absorbed by the resistance.

§ 32. *Reflexion from a leaky Condenser.*—If the material separating the plates of the condenser is not a perfect insulator, but has a finite resistance R, there will be a conduction current through it equal to ϕ/R. The rate at which the charge accumulates on the plate is $\frac{C_1d\phi}{dt}$; hence at the end of the wire the condition is, if I_1 and I_2 are respectively the incident and reflected currents,

$$I_1+I_2=C_1\frac{d}{dt}\phi+\frac{\phi}{R}$$

where

$$\phi=\frac{v}{C}I_1-\frac{v}{C}I_2.$$

Substituting these values we find

$$I_2=\rho\epsilon^{-\iota\theta}I_1$$

where

$$\rho^2=\frac{(\xi-1)^2+\eta^2p^2}{(\xi+1)^2+\eta^2p^2}$$

$$\tan\theta=\frac{2\eta p}{1-\xi^2-\eta^2p^2},$$

where

$$\xi = v/\mathrm{RC}. \quad \eta = v\mathrm{C}_1/\mathrm{C};$$

ρ is the coefficient of damping, and θ the change in phase at reflexion. We can measure θ if we determine λ, the length of the wave with which the circuit is in resonance; in order, however, that the resonance should be appreciable the damping must be small. To find λ let A, B be the ends of the wire, and suppose a disturbance starts from B, travels to A, is reflected there back to B, and is again reflected. If after the second reflexion the phase differs by 2π, or by a multiple thereof, from the phase of the disturbance at starting, the resonance will be greatest. Now in travelling from B to A the loss of phase is $2\pi(2l/\lambda)$ if $2l = \mathrm{AB}$; at reflexion from A there is the loss of phase θ, and there are equal losses of phase from the backward journey and reflexion at B. Hence for resonance we have

$$\frac{8\pi l}{\lambda} + 2\theta = 2n\pi,$$

when n is an integer, or

$$\frac{4\pi l}{\lambda} = n\pi - \theta,$$

or

$$\tan\frac{4\pi l}{\lambda} = \tan(n\pi - \theta) = -\tan\theta = -\frac{2\eta p}{1 - \xi^2 - \eta^2 p^2}.$$

Hence if we determine ρ and λ, we have from the equations in this section the means of calculating R and C_1, and therefore the specific resistance and specific inductive capacity of the medium separating the plates of the condenser. This method has been used by Drude, § 37.

§ 33. *Self-induction and effective Resistance of a Wire carrying an alternating Current.*—Returning to § 27 we see that without any limitation as to $n\mathrm{a}$ being large, we have

$$\phi = -\frac{mv^2}{p\mathrm{C}}\mathrm{I}_0\epsilon^{\iota(mz+pt)} \quad . \quad . \quad (1),$$

where C is the capacity of unit length of the wire. If the wire is surrounded by a cylindrical conductor of internal radius b, $\mathrm{C} = 1/2 \log b/\mathrm{a}$. Differentiating equation (1) with respect to z, and writing E for $-d\phi/dz$, we have

$$\mathrm{E} = 2\iota p\frac{m^2v^2}{p^2}\log(b/\mathrm{a})\,\mathrm{I}_0\epsilon^{\iota(mz+pt)}.$$

By equation (7), § 25, when the conductivity of the outer conductor is sufficiently large to make $n'b$ very large

$$\kappa^2 = m^2 - \frac{p^2}{v^2} = -\frac{\iota p^2}{v^2}\left\{\frac{\mu}{n\mathrm{a}}\frac{\mathrm{J}_0(\iota n\mathrm{a})}{\mathrm{J}'_0(\iota n\mathrm{a})}\right\}\frac{1}{\log(b/\mathrm{a})}$$

or since we have very approximately

$$n^2 = \frac{4\pi\mu\iota p}{\sigma}$$

$$m^2 = \frac{p^2}{v^2}\left(1 - \frac{1}{4\pi p}\frac{n\sigma}{\mathrm{a}}\frac{\mathrm{J}_0(\iota n\mathrm{a})}{\mathrm{J}'_0(\iota n\mathrm{a})}\frac{1}{\log(b/\mathrm{a})}\right);$$

hence

$$\mathrm{E} = 2\iota p\left\{\log b/\mathrm{a} - \frac{1}{4\pi p}\frac{n\sigma}{\mathrm{a}}\frac{\mathrm{J}_0(\iota n\mathrm{a})}{\mathrm{J}'_0(\iota n\mathrm{a})}\right\}\mathrm{I};$$

I is the total current and is equal to $\mathrm{I}_0\epsilon^{\iota(mz+pt)}$.

Now (J. J. Thomson, *Recent Researches*, p. 275)

$$\iota n\mathrm{a}\frac{\mathrm{J}_0(\iota n\mathrm{a})}{\mathrm{J}'_0(\iota n\mathrm{a})} = -2 - \frac{n^2\mathrm{a}^2}{4} + \frac{n^4\mathrm{a}^4}{96} - \frac{n^6\mathrm{a}^6}{1536} + \frac{n^8\mathrm{a}^8}{23040} - \frac{13n^{10}\mathrm{a}^{10}}{4423680} + \ldots$$

Substituting this value and writing for n^2 its approximate value $4\pi\mu\iota p/\sigma$ we find

$$\mathrm{E} = \mathrm{P}\iota p\mathrm{I} + \mathrm{QI} = \mathrm{P}\frac{d\mathrm{I}}{dt} + \mathrm{QI} \quad . \quad . \quad . \quad (2),$$

where

$$\mathrm{P} = 2\log b/\mathrm{a} + \frac{1}{2}\mu - \frac{1}{48}\frac{\pi^2\mu^3p^2\mathrm{a}^4}{\sigma^2} + \frac{13}{8640}\frac{\pi^4\mu^5p^4\mathrm{a}^8}{\sigma^4} - \ldots$$

$$\mathrm{Q} = \frac{\sigma}{\pi\mathrm{a}^2}\left\{1 + \frac{1}{12}\frac{\pi^2p^2\mu^2\mathrm{a}^2}{\sigma^2} - \frac{1}{180}\frac{\pi^4p^4\mu^4\mathrm{a}^8}{\sigma^4}\ \ldots\right\}$$

Now if L is the coefficient of self-induction of a circuit and R its resistance, the external electromotive force when the current I is flowing through the circuit $= \mathrm{L}\frac{d\mathrm{I}}{dt} + \mathrm{RI}$.

Comparing this equation with (2) we may call P the self-induction and Q the effective resistance per unit length of the wire, and we see that these depend on the frequency of the current flowing through the wire. The expressions for P and Q show that as the frequency increases the self-induction diminishes, and the effective resistance increases; both these effects arise from the fact that as the frequency increases the current gets more and more concentrated in the outer layers of the wire. The expressions for the self-induction and the effective resistance are the same as those given by Maxwell (*Electricity and Magnetism*, § 690), with the exception that in Maxwell a constant A is written for $\log b/\mathrm{a}$, and μ is put equal to unity. It was Heaviside, however, who first explicitly called attention to the great effect produced by the frequency on the self-induction and resistance of a wire. When $p = 0$, *i.e.*, when the currents are steady $\mathrm{P} = 2\log(b/\mathrm{a}) + \frac{1}{2}\mu$: thus the self-induction of a straight iron wire is very much greater than that of one made of a non-magnetic metal.

When $n\mathrm{a}$ is very large $\mathrm{J}'_0(\iota n\mathrm{a}) = -\iota\mathrm{J}_0(\iota n\mathrm{a})$ and we have

$$\mathrm{E} = 2\iota p\left\{\log(b/\mathrm{a}) + \left(\frac{\sigma\mu}{4\pi p\mathrm{a}^2}\right)^{\frac{1}{2}}\left(\frac{1}{\sqrt{2}} - \frac{\iota}{\sqrt{2}}\right)\right\}\mathrm{I};$$

in this case the self-induction $\mathrm{P} = 2\log(b/\mathrm{a}) + (\sigma\mu/2\pi p\mathrm{a}^2)^{\frac{1}{2}}$ and the effective resistance $\mathrm{Q} = (\sigma\mu p/2\pi\mathrm{a}^2)^{\frac{1}{2}}$.

When $n\mathrm{a}$ is so small that P and Q may be regarded as independent of p, or when the period is given, equation (2) may be transformed into a form which is often convenient. We have

$$-\frac{d\phi}{dz} = \mathrm{P}\frac{d\mathrm{I}}{dt} + \mathrm{QI} \quad . \quad . \quad . \quad (3).$$

Now if s is the surface density of the electricity on the wire $2\pi\mathrm{a}s = \mathrm{C}\phi$, where C is the capacity per unit length of the wire and we have

$$2\pi\mathrm{a}\frac{ds}{dt} = -\frac{d\mathrm{I}}{dz} \text{ or } \mathrm{C}\frac{d\phi}{dt} = -\frac{d\mathrm{I}}{dz};$$

hence (3) becomes

$$\mathrm{P}\frac{d^2\mathrm{I}}{dt^2} + \mathrm{Q}\frac{d\mathrm{I}}{dt} = \frac{1}{\mathrm{C}}\frac{d^2\mathrm{I}}{dz^2},$$

which is sometimes called the telegraphic equation, as representing the variation of the current along a telegraph wire. It has been discussed by Poincaré,[80] Picard,[81] Boussinesq,[82] and very exhaustively by Heaviside.[83] Putting $\mathrm{I}' = \epsilon^{-\frac{\mathrm{Q}t}{2\mathrm{P}}}\mathrm{I}$ it may be transformed to

$$\frac{d^2\mathrm{I}'}{dt^2} = \frac{1}{\mathrm{CP}}\frac{d^2\mathrm{I}'}{dz^2} + \frac{\mathrm{Q}^2}{4\mathrm{P}^2}\mathrm{I}' \quad . \quad . \quad . \quad (4).$$

If $\mathrm{I}' = \mathrm{F}(x)$; $\frac{d\mathrm{I}'}{dt} = f(x)$ when $x = 0$ the solution of (4)[84] is

$$\mathrm{I}' = \frac{1}{2}\frac{d}{dt}\int_0^\pi t\mathrm{F}\left(x + \frac{t}{\sqrt{\mathrm{CP}}}\cos\alpha\right)\mathrm{J}_0\left(\frac{\iota\mathrm{Q}}{2\mathrm{P}}t\sin\alpha\right)\sin\alpha d\alpha.$$

$$+\frac{1}{2}\int_0^\pi tf\left(x + \frac{t}{\sqrt{\mathrm{CP}}}\cos\alpha\right)\mathrm{J}_0\left(\frac{\iota\mathrm{Q}}{2\mathrm{P}}t\sin\alpha\right)\sin\alpha d\alpha$$

§ 34. *Passage of an Electric Wave through a Medium containing Ions; anomalous Dispersion of Electric Waves.*—To take a simple case, let us consider a plane wave travelling parallel to the axis of z, the electric force in the wave being parallel to x and the magnetic force to y. In the medium through which the wave is travelling let there be a number of charged ions, and let the x co-ordinates of these be ξ_1, ξ_2, . . . The ions will be moved by the electric field and will produce a convective current equal to $\Sigma ed\xi/dt$, where the summation refers to the ions in unit volume round the point where the current is measured. The charges on the ions will produce an electric field, and in considering the dielectric currents in the field we must remember that the part due to the variation of the electric field due to the charged ions has already been included in the convection current $\Sigma ed\xi/dt$. Hence if X_0 is the part of the field not arising from the charged atoms the dielectric current will be $\mathrm{K}_0 d\mathrm{X}_0/dt$ where K_0 is the specific inductive capacity of the space when free from atoms. Thus equations B and A (§ 10) become

$$\mathrm{K}_0\frac{d\mathrm{X}_0}{dt} + 4\pi\Sigma e\frac{d\xi}{dt} = -\frac{d\beta}{dz}$$

$$\frac{d\mathrm{X}_0}{dz} = -\frac{d\beta}{dt} \text{ (if the medium is non-magnetic),}$$

so that

$$\frac{d^2\mathrm{X}_0}{dt^2} + \frac{4\pi}{\mathrm{K}_0}\Sigma e\frac{d^2\xi}{dt^2} = \frac{1}{\mathrm{K}_0}\frac{d^2\mathrm{X}_0}{dz^2} \quad . \quad . \quad (1).$$

Now if m be the mass of an ion, $\alpha_1\xi_1$ the force tending to bring the ion back to $\xi = 0$, and $\mathrm{R}_1\frac{d\xi_1}{dt}$ is the frictional resistance acting on the ion,

$$m_1\frac{d^2\xi_1}{dt^2} + \mathrm{R}_1\frac{d\xi_1}{dt} + \alpha_1\xi_1 = (\mathrm{X}_0 + \mathrm{X})e \quad . \quad . \quad (2),$$

where X is the force arising from the charges on the ion. To find X we notice that the system is electrically neutral when all the ξ's vanish, and that when an ion is displaced through ξ, the electrical effect is the same as that of an electric doublet whose axis is parallel to x, and whose moment is $e\xi$. The electric field is that due to a system of electric doublets the sum of whose moments per unit volume is $\Sigma e\xi$. To find the electric force due to these at a point, describe with that point as centre a sphere whose radius is large compared with the range of molecular action, but small compared with the length of the wave passing through the medium, so that inside this sphere the conditions may be taken as uniform. X will be the electric force due to the doublets in this sphere, and this will be the same as the magnetic force due to a system of little magnets provided the electrical moment of the doublet is equal to the magnetic moments of the magnets. The force due to the magnets is $4\pi I/3$, when I is the intensity of magnetization, *i.e.*, the sum of the moments of the magnets per unit volume; hence $X=\frac{4\pi}{3}\frac{e\xi}{K_0}$; where the factor K_0 is put equal to unity when e is measured in electrostatic units, and to $1/V_0^2$ when e is measured in electromagnetic units, V_0 being the velocity of light through the ether.

Let us suppose that all the quantities are proportionate to $\epsilon^{\iota pt}$; then from equation (2) we have

$$\xi=\frac{\left(X_0+\frac{4\pi}{3K_0}\Sigma e\xi\right)e}{a+R\iota p-mp^2}$$

hence if

$$\Theta=\Sigma\frac{e^2}{a+R\iota p-mp^2}$$

$$\Sigma e\xi=\frac{X_0\Theta}{1-\frac{4\pi\Theta}{3K^0}}$$

hence equation (1) becomes if X_0 varies as $\epsilon^{\iota(pt-mz)}$

$$-p^2X_0-\frac{p^2 4\pi\Theta}{1-\frac{4\pi\Theta}{3K_0}}\frac{X_0}{K_0}=-\frac{m^2}{K_0}X_0 \quad . \quad . \quad . \quad (3).$$

If V is the velocity of propagation through this medium filled with ions, V_0 the velocity through empty space, then $V=p/m$, $V_0^2=1/K_0$, and if ν is the refractive index of the medium, since $\nu^2=V_0^2/V^2=m^2/p^2K_0$, we have by equation (3)

$$1+\frac{4\pi\Theta/K_0}{1-4\pi\Theta/3K_0}=\nu^2,$$

or

$$\frac{4\pi}{3}\frac{\Theta}{K_0}=\frac{\nu^2-1}{\nu^2+2}.$$

This equation is given by Lorentz.[85] If p_1 is the free period of the ion when there are no frictional terms, $a_1=mp_1^2$; hence if there are N_1 molecules having periods p_1, N_2 having p_2, and so on.

$$\Theta=\frac{N_1e^2}{m_1(p_1^2-p^2)+R_1\iota p}+\frac{N_2e^2}{m_2(p_2^2-p^2)+R_2\iota p}+\ldots$$

This equation gives the refractive index in terms of the frequency, and is therefore the dispersion formula. To find the general character of the results to which it leads, let us take the simple case where all the ions are equal, and there is only one period, and no frictional resistance. Then

$$\frac{\nu^2-1}{\nu^2+2}=\frac{4\pi}{3}\frac{Ne^2V_0^2}{m(p_0^2-p^2)}.$$

The curve whose abscissæ are p^2 and ordinates ν^2 is shown in Fig. 49; we see that when p^2 is less than $p_0^2-\frac{4\pi}{3}\frac{Ne^2V_0^2}{m}$, ν^2 increases with p, and the dispersion is said to be normal as the refractive index for short waves is greater than that for long. Since ν^2 must be positive, the curve must be discontinuous between L when $p^2=p_0^2-\frac{4\pi}{3}\frac{Ne^2V_0^2}{m}$, and M where $p^2=p_0^2+\frac{8\pi}{3}\frac{Ne^2V_0^2}{m}$, and there can be no corresponding real values of ν^2:—that is, waves with frequencies between these values cannot be propagated through the medium, but are totally reflected from it. At the point L on the curve the velocity of propagation of waves through the medium is infinitely small, at the point M it is infinitely great, and after passing M ν becomes real again, but is always less than unity, and approaches unity as the limit when the frequency is infinitely rapid. In this region beyond M the refractive index is less, though the wave lengths are smaller, than for the region before L; the dispersion is said to be anomalous. A mechanical model showing these peculiarities of wave propagation has been described by Vincent.[86] If we include frictional terms, *i.e.*, the term ιRp in our expression for Θ, then though ν is complex, there is always a real part. In the curve which now represents the relation between the real part of ν^2 and p^2 (Fig. 50), there is no break, but throughout the range of values of p^2 in which there is no propagation of the waves without friction, there is very intense absorption, indicated by the dot and dash line. The long waves on one side of the absorption band have a greater index of refraction than the short waves on the other side. If p_1 and p_2 are the values corresponding to the points l, k, between which the absorption is most intense, ν is infinite for the frequency p_1 and zero for the frequency p_2. Hence, neglecting the frictional terms, we have

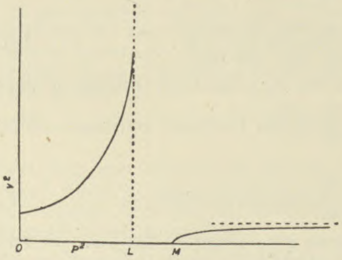


Fig. 49.

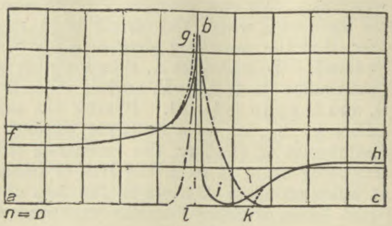


Fig. 50.

$$p_1^2=p_0^2-\frac{4\pi}{3}\frac{Ne^2V_0^2}{m},\ p_2^2=p_0^2+\frac{4\pi}{3}\frac{2Ne^2V_0^2}{m}.$$

The specific inductive capacity K of the medium under steady electric force is the value of ν^2 when $p=0$, hence

$$\frac{K-1}{K+2}=\frac{4\pi}{3}\frac{Ne^2V_0{}^2}{mp_0^2} \quad . \quad . \quad . \quad . \quad (1).$$

Substituting for $Ne^2V_0^2/m$ in the preceding equations we get

$$p_1^2=p_0^2\frac{3}{K+2},\ p_2^2=p_0^2\frac{3K}{K+2},\ \text{or}\ p_2^2=Kp_1^2.$$

Thus if the specific inductive capacity is large there will be a long range of frequencies for which there is very intense absorption. Anomalous dispersion of electric waves has been observed in many dielectrics. In liquids it was observed by Cole[87] for ethyl-alcohol. Drude[88] has made very extensive researches on this subject in a large number of liquids, the most conspicuous being glycerine, amyl-alcohol, acetic and formic acids; he found that the existence of anomalous dispersion was closely related with the chemical composition, the liquids showing it in a marked degree containing the hydrosyl radicle OH. If we assume the truth of the theory of dispersion just given, it follows that the anomalous dispersion of the electric waves must be due to a small number of molecules or aggregates of molecules being mixed with the fluid, and not to a property possessed by each individual molecule of the fluid. As an example, glycerine has been shown to exhibit anomalous dispersion for waves over a range which includes $p=2\pi\times2{\cdot}5\times10^7$, $p=2\pi\times1{\cdot}5\times10^8$, $p=2\pi\times4\times10^8$, numbers from which we conclude that p_0 is of the order of magnitude $2\pi\times10^8$. Now from equation (1) we must have $4\pi Ne^2V_0^2/3mp_0^2$ less than 1. Putting in this expression the smallest admissible value of e, viz., the charge on the hydrogen ion in electrolysis, and for m the largest admissible value, which if the effect were due to the individual molecules is the mass of the molecule of glycerine, we find that $Ne^2V_0^2/mp^2$ would be of the order 10^7. As this quantity must be less than unity we see that our supposition is inadmissible, and we conclude that the anomalous dispersion of glycerine and other fluids, and the high value of their specific inductive capacity in steady electric fields, is due to the presence of a small number of bodies in an exceptional state. The remarkable experiments of Dewar and Fleming[89] on the specific inductive capacities of liquids at very low temperatures, such as that of boiling liquid air, seem in harmony with this result, for they have shown that the abnormally high values for the specific inductive capacity which are characteristic of many liquids at ordinary temperatures disappear, and are replaced by values which are approximately the squares of the refractive indices of the substances at ordinary temperatures—a result which indicates that at very low temperatures the dissociation, or whatever action produced the bodies, which when mixed with the glycerine caused the high specific inductive capacity, no longer exists. Dewar and Fleming have examined a very large number of solutions, and find marked differences in the temperatures at which the great drop in the specific inductive capacity takes places. The nature of these differences is shown by the following curve (Fig. 51), the ordinates of which represent the specific inductive capacity and the abscissæ the temperatures.

Some solids exhibit anomalous dispersion. Thus the experiments made by Blondlot[90] and the writer[91] on the specific inductive capacity of glass show that it is higher for steady electric forces than for those which accompany electric waves. Lowe[92] found that while the specific inductive capacity of glass for electrical waves was smaller than in a steady electric field, the difference was not so large as that observed by Blondlot and the writer. Anomalous dispersion for electric waves has been observed in beryl by Fomm and Graetz.[93] Further experiments in electrical dispersion will be found described in papers by Marx,[94] Löwe,[95] Cole[96] and Thwing.[97]

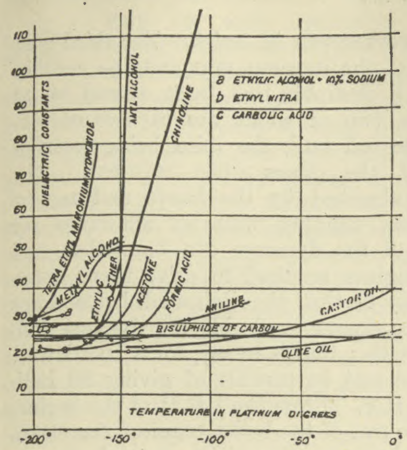


Fig. 51.

§ 35. We have seen that, on the theory of anomalous dispersion sketched above, the anomalous dispersion of electric waves a few centimetres long involves the existence of systems other than the ordinary molecules of the dielectric; we can press this result further, and show that on this theory the luminous vibrations given out by gases, or at any rate by some gases, cannot proceed from all the molecules; but that only a comparatively small number, which are probably in a special state, are luminous. For we see that if K is the specific inductive capacity of the gas under steady electric force, *i.e.*, when $p=o$,

$$\frac{K-1}{K+2}=\Sigma\frac{4\pi Ne^2}{3K_0 mp_1^2}$$

where p_1 is the frequency of one of the free periods of the molecule. Since $K_0p_1^2=4\pi^2/\lambda_1^2$ when λ_1 is the wave length of this vibration, we have

$$\frac{K-1}{K+2}=\Sigma\frac{Ne^2}{3\pi m}\lambda_1^2.$$

Let us take the case of hydrogen and confine our attention to the vibration corresponding to the red line for which $\lambda_1=6\cdot5\times10^{-5}$ cm. For hydrogen at atmospheric pressure $K-1=2\cdot7\times10^{-4}$. Thus

$$Ne=\frac{6\pi\times10^4}{(c/m)}$$

We have reason to think that e/m is about 10^7, in which case $Ne=1\cdot9\times10^{-2}$. If N^1 is the number of hydrogen molecules in unit volume, then by the laws of electrolysis $N^1e=\cdot4$, and hence $N/N^1=1/20$ nearly. Thus the number of systems vibrating with the period p_1 is small compared with the number of molecules. We have only considered the effect of one line in the spectrum of hydrogen. If we took into account the other lines the discrepancy between N and N^1 would be still further increased. Hence we conclude that if this theory of anomalous dispersion is true the source of the hydrogen lines is a comparatively small number of systems in a special state.

§ 36. *Scattering of Electric Waves by the refracting Medium. Opacity of the Medium.*—If ξ is the displacement of an ion under the external electric force X_0, then by § 34

$$e\xi=\frac{X_0c^2}{1-\dfrac{4\pi\Theta}{3K_0}}\,\frac{1}{m(p_1^2-p^2)+Rip}.$$

The effect of the displaced ion is the same as that of an electric doublet whose moment is $e\xi$; this doublet has a frequency p, and gives rise to a system of electric waves expressed by the equations in § 12. The radiation of these waves involves an expenditure of energy per unit time for each doublet equal to

$$\frac{2}{3}(c\xi)^2\frac{p^4}{V_0}.$$

If between two planes of unit area at right angles to z, separated by the distance dz, there are Ndz doublets, then the energy radiated from this region in unit time is

$$\frac{1}{3}\frac{NdzX_0^2}{V_0}\,\frac{c^4}{\left(1-\dfrac{4\pi\Theta}{3K_0}\right)^2}\,\frac{p^4}{(m(p_1^2-p^2)+Rip)^2}.$$

To supply this energy, the energy transmitted in unit time by the incident wave across the further plane must be less than that transmitted across the nearer plane by this amount. But by Poynting's theorem this difference is equal to

$$-\frac{d}{dz}\left(\frac{X_0^2}{4\pi V_0}\right)dz;$$

hence $$\frac{d}{dz}\left(\frac{X_0^2}{4\pi V_0}\right)=-\frac{2NX_0^2}{3V_0}\,\frac{c^4}{\left(1-\dfrac{\pi\Theta}{3K_0}\right)^2}\,\frac{p^4}{(m(p_1^2-p^2)+Rip)^2}.$$

Solving this equation we have

$$X_0^2=C\epsilon^{-hz},$$

where $$h=\frac{8\pi}{3}\,\frac{Ne^4}{\left(1-\dfrac{4\pi\Theta}{3K_0}\right)^2}\,\frac{p^4}{(m(p_1^2-p^2)+Rip)^2};$$

this may be written

$$h=\frac{8\pi^3(\mu^2-1)^2}{3N\lambda^4},$$

where μ is the refractive index, λ the wave length. Thus, even when there is no conductivity, there is opacity due to the scattering of the waves by the ions. This effect has been investigated by Lord Rayleigh[98] in connexion with the blue colour of the sky. For waves whose frequency is very great compared with the free vibrations of the system, $h=4\pi Ne^4/3m^2$; in this case the opacity becomes in the limit independent of the frequency.

[1] *Phil. Mag.* [4] 5, p. 393. [2] *Pogg. Ann.* 103, p. 69; 108, p. 497; 112, p. 452; 113, p. 437; 116, p. 132. [3] *Wied. Ann.* 34, pp. 155, 551, 609; *Ausbreitung der Elektrischen Kraft*, Leipzig, 1892. [4] *Wied. Ann.* 44, p. 74. [5] *Nature*, 41, p. 368. [6] *Wied. Ann.* 49, p. 593. [7] *Nature*, 39, p. 391. [8] *Wied. Ann.* 34, p. 609. [9] *Comptes rendus*, 115, p. 439. [10] *Nature*, 39, p. 548. [11] *Wied. Ann.* 41, p. 850. [12] *Ibid.* 45, p. 553. [13] *Ibid.* 47, p. 77. [14] *Ibid.* 37, p. 529. [15] *Ibid.* 40, p. 55. [16] *Ibid.* 42, p. 416; 45, p. 62. [17] *Ibid.* 40, p. 399. [18] *Ibid.* 40, p. 53. [19] *Phil. Mag.* 33, p. 299. [20] *Wied. Ann.* 44, p. 74. [21] *Ibid.* 44, p. 713. [22] *Trans. Roy. Soc.* A. 1897, 189, p. 1. [23] *Comptes rendus*, 111, p. 785; 112, p. 90. [24] *The Work of Hertz and some of his Successors.* London, 1894. [25] *Phil. Mag.* 43, p. 55. [26] *Lumière électrique*, 40, p. 511. [27] *Wied. Ann.* 66, p. 284. [28] *Proc. Roy. Soc.* 65, p. 166. [29] *Wied. Ann.* 64, p. 611. [30] *Phil. Mag.* 43, p. 55. [31] *Mem. della R. Acc. de Bologna*, [v.] iv. p. 487. [32] *Atti de Torino*, 30, p. 442, 1895. [33] *Wied. Ann.* 54, p. 342; 56, p. 717. [34] *Proc. Roy. Soc.* 63, p. 146. [35] *Wied. Ann.* 41, p. 850. [36] *Comptes rendus*, 114, p. 628. [37] *Wied. Ann.* 60, p. 1. [38] *Ibid.* 55, p. 633. [39] *Proc. Roy. Soc.* 46, p. 1. [40] *Journ. de phys.* x. p. 549. [41] *Comptes rendus*, 117, pp. 543, 893. [42] *Proc. Camb. Phil. Soc.* (Stokes jubilee volume). [43] *Sitzungsber. Wien. Akad.* 89, p. 298. [44] *Wied. Ann.* 33, p. 1; 35, p. 126. [45] *Phil. Mag.* 28, p. 304. [46] *Ibid.* 28, p. 315. [47] *Phil. Trans.* 181, A. p. 583. [48] *British Association Report*, 1891, p. 580. [49] *Comptes rendus*, 112, p. 783. [50] *Journ. de phys.* [3] 1, p. 361. [51] *Comptes rendus*, 121, p. 815. [52] *Wied. Ann.* 35, p. 136. [53] *Phil. Trans.* 189, A. p. 1. [54] The properties of Poisson's equation and its application to physical problems are fully discussed in Lord Rayleigh's *Theory of Sound*, vol. ii. chap. 14, and v. Helmholtz's *Vorlesungen über die Elektromagnetische Theorie des Lichts*, p. 131 *et seq.* [55] *Wied. Ann.* 36, p. 1. [56] *Phil. Trans.* 193, A, p. 159. [57] *Phil. Trans.* 1884, pt. 2, p. 343. [58] J. J. Thomson. *Proc. Math. Soc.* xv. p. 197. [59] J. J. Thomson, *Phil. Mag.* 11, p. 229, 1881. [60] *Pogg. Ann.* 158, p. 487. [61] J. J. Thomson. *Proc. Math. Soc.* xv. p. 197. [62] *Phil. Mag.* 12, p. 81. [63] *Phil. Mag.* 47, p. 375. [64] J. J. Thomson. *Recent Researches in Electricity and Magnetism*, p. 437. [65] *Nature*, 39, p. 391. [66] *Nature*, 40, p. 398. [67] J. J. Thomson, *Proc. Roy. Soc.* 45, p. 269. [68] *Proc. Roy. Soc.* 45, p. 269. [69] *Wied. Ann.* 62, p. 454, 1887. [70] *Communications from Physical Laboratory at Leiden*, No. 22. [71] *Wied. Ann.* 35, p. 49. See also Lodge, *Phil. Mag.* 47, p. 385. [72] *Recent Researches*, p. 425. [73] *Proc. Lond. Math. Soc.* 29, Pt. 2, p. 523. [74] *Ibid.* 17, p. 310; *Recent Researches*, p. 262 *et seq.* [75] *Phil. Mag.* 22, pp. 118, 273, 332; 23, pp. 10, 173. [76] *Wied. Ann.* 67, p. 233; *Drude Ann.* 2, p. 201. [77] *Phil. Mag.* [4] 5, p. 393. [78] *Wied. Ann.* 60, p. 1. [79] *Electromagnetic Theory*, p. 387. [80] *Comptes rendus*, 117, p. 1027. [81] *Ibid.* 118, p. 16. [82] *Ibid.* 118, p. 162. [83] *Electromagnetic Theory*, chap. vi. [84] Webster's *Electricity and Magnetism*, p. 545. [85] *Konink. Akad. van Wetenschappen*, Amsterdam, Ap. 6, 1888. For another method of treating this question, see v. Helmholtz, *Collected Papers*, vol. iii. p. 505. [86] *Phil. Mag.* 46, p. 557. [87] *Wied. Ann.* 57, p. 290. [88] *Ibid.* 58, p. 1; 59, p. 17; *Zeitschrift für Physikalische Chemie*, 23, p. 267. [89] *Proc. Roy. Soc.* 61, pp. 299, 358. [90] *Comptes rendus*, 112, p. 1058. [91] *Proc. Roy. Soc.* 46, p. 292. [92] *Wied. Ann.* 66, pp. 390, 582. [93] Fomm and Graetz, *Wied. Ann.* 54, p. 626. [94] Marx, *Wied. Ann.* 66, pp. 411, 597. [95] *Loc. cit.* [96] *Wied. Ann.* 57, p. 290. [97] *Zeitschrift für Physikalische Chemie*, 14, p. 286. [98] *Phil. Mag.* 47, p. 375.

(J. J. T.)

ELECTRICITY SUPPLY.

I. General Principles.

THE improvements made in the dynamo and electric motor between 1870 and 1880, and also in the details of the arc and incandescent electric lamp towards the close of that decade, induced engineers to turn their attention to the question of the private and public supply of electric current for the purpose of lighting and power. T. A. Edison [1] and St G. Lane Fox [2] were among the first to see the possibilities and advantages of public electric supply, and to devise plans for its practical establishment. In the case of private plants, provision has to be made for a source of electric current. In spite of a great amount of ingenuity devoted to the development of the primary battery and the thermopile, no means of generation of large currents is so economical and convenient as the dynamo (see Dynamo).

Private plants. Hence a private electric generating plant involves the erection of a dynamo, which may be driven either by a steam, gas, or oil engine, or by power obtained by means of a turbine from a low or high fall of water. It may be either directly coupled to the motor, or driven by a belt; and it may either be a continuous-current machine or an alternator; and, if the latter, either single-phase or polyphase. The convenience of being able to employ storage batteries in connexion with a private-supply system is so great that, unless power has to be transmitted long distances, the invariable rule is to employ a continuous-current dynamo. Where space is valuable, this is always coupled direct to the motor; and if a steam engine is employed, an enclosed engine is most cleanly and compact. Where coal or heating gas is available, a gas engine is exceedingly convenient, since it requires little attention. Where coal gas is not available, as in country houses, a Dowson gas-producer can be employed, or an oil engine. In connexion with the generator, it is almost the invariable custom to put down a secondary battery (see Accumulators), to enable the supply to be given after the engine has stopped. If the building to be lighted is at some distance from the engine-house, the battery should be placed in the basement of the building, and underground or overhead conductors, to convey the charging current, brought to it from the dynamo. It is usual, in the case of electric lighting installations, to reckon all lamps in their equivalent number of 8 candle-power (c.p.) incandescent lamps. In lighting a private house or building, the first thing to be done is to settle the total number of incandescent lamps and their size, whether 32 c.p., 16 c.p., or 8 c.p. Five c.p. lamps can be used with advantage in small bedrooms and passages. Each candle-power can be taken as equivalent to 3½ watts, or the 8 c.p. lamp as equal to 30 watts, the 16 c.p. lamp to 60 watts, and so on. Hence if the equivalent of 100 8 c.p. lamps is required in a building, the maximum electric power supply available must be 3000 watts, or 3 kilowatts. It is of course prudent to make allowance for extensions. The next matter to consider is the pressure of supply. If the battery can be in a position near the building to be lighted, it is best to use 100-volt incandescent lamps and enclosed arc lamps, which can be worked singly off the 100-volt circuit. If, however, the lamps are scattered over a wide area, or in separate buildings somewhat far apart, as in a public school, college, asylum, or hospital, it may be better to select 200 volts as the supply pressure. Arc lamps can then be worked two in series. The third step is to select the size of the dynamo unit and the amount of spare plant. It is desirable that there should be at least three dynamos, two of which are capable of taking the whole of the full load, the third being reserved to replace either of the others when required. The total power to be absorbed by the lamps and motors (if any) being given, together with an allowance for extensions, the size of the dynamos can be settled, and the power of the engines required to drive them determined. A good rule is that the indicated horse-power (I.H.P.) of the engine should be double the dynamo full-load output in kilowatts; that is to say, for a 10-kilowatt dynamo an engine should be capable of giving 20 indicated (not nominal) H.P. From the I.H.P. of the engine, if a steam engine, the size of the boiler required for steam production becomes known. For small plants it is safe to reckon that, including waste, boiler capacity should be provided equal to evaporating 40 pounds of water per hour for every I.H.P. of the engine. The locomotive boiler is a convenient form; but where large amounts of steam are required, some modification of the Lancashire boiler or the water-tube boiler is generally adopted. In settling the electromotive force of the dynamo to be employed, attention must be paid to the question of charging secondary cells, if any. If a secondary battery is employed in connexion with 100-volt lamps, it is usual to put in 53 or 54 cells. The electromotive force of these cells varies between 2·2 and 1·8 volts as they discharge; hence the above number of cells is sufficient for maintaining the necessary electromotive force. For charging, however, it is necessary to provide 2½ volts per cell, and the dynamo must therefore have an electromotive force of 135 volts, *plus* any voltage required to overcome the fall of potential in the cable connecting the dynamo with the secondary battery. Supposing this to be 10 volts, it is safe to install dynamos having an electromotive force of 150 volts, since by means of resistance in the field circuits this electromotive force can be lowered to 110 or 115 if it is required at any time to dispense with the battery. The size of the secondary cell to be selected will be determined by the nature of the supply to be given after the dynamos have been stopped It is usual to provide sufficient storage capacity to run all the lamps for three or four hours without assistance from the dynamo.

As an example taken from actual practice, the following figures give the capacity of the plant put down to supply 500 8 c.p. lamps in a hospital. The dynamos were 15-unit machines, having a full-load capacity of 100 amperes at 150 volts, each coupled direct to an engine of 25 I.H.P.; and a double plant of this description was supplied from two steel locomotive boilers, each capable of evaporating 800 pounds of water per hour. One dynamo during the day was used for charging the storage battery of 54 cells; and at night the discharge from the cells, together with the current from one of the dynamos, supplied the lamps until the heaviest part of the load had been taken; after that the current was drawn from the batteries alone. In working such a plant it is necessary to have the means of varying the electromotive force of the dynamo as the charging of the cells proceeds. When they are nearly exhausted, their electromotive force is less than 2 volts; but as the charging proceeds, a counter electromotive force is gradually built up, and the engineer in charge has to raise the voltage of the dynamo in order to maintain a constant charging current. This is effected by having the dynamos designed to give normally the highest E.M.F. required, and then inserting resistance in their field circuits to reduce it as may be necessary.

Turning next to the consideration of public electric supply, we may divide the methods at present in successful operation into two broad divisions, namely, (1) continuous-current systems and (2) alternating-current systems.

[1] British Patent Specifications, No. 5306 of 1878, and No. 602 of 1880.
[2] *Ibid.*, No. 3988 of 1878.

Leaving out of consideration a discussion of the conditions under which continuous-current or alternating-current systems are most applicable, we may describe briefly the general outlines of the methods adopted under each heading. *Continuous-current* systems are either low- or high-pressure. In the former the current is generated by dynamos at some pressure less than 500 volts, generally about 460 volts, and is supplied to users at half this pressure by means of a three-wire system of distribution, with or without the addition of storage batteries. The general arrangements of a *low-pressure* continuous-current supply station are as follow:—If steam is the motive power selected, it is generated under all the best conditions of economy by a battery of boilers, and supplied to engines which are now almost invariably coupled direct, each to its own dynamo, on one common bed-plate; a multipolar dynamo is very frequently employed, coupled direct to an enclosed engine. In choosing the size of unit to be adopted, the engineer has need of considerable experience and discretion, and also a full knowledge of the nature of the public demand for electric current. The over-all efficiency of a steam dynamo—that is, the ratio between the electrical power output, reckoned say in kilowatts, and the I.H.P. of the engine, reckoned in the same units—is a number which falls rapidly as the load decreases; but at full load may reach some such value as 80 or 85 per cent. It is common to specify the efficiency, as above defined, which must be attained by the plant at full load, and also the efficiencies at quarter- and half-load which must be reached or exceeded. Hence in the selection of the size of the units the engineer is guided by the consideration that whatever units are in use shall be as nearly as possible fully loaded. If the demand on the station is chiefly for electric lighting, it varies during the hours of the day and night with tolerable regularity. If the output of the station, either in amperes or watts, is represented by the ordinates of a curve, the abscissæ of which represent the hours of the day, this load-diagram is a curve as shown in Fig. 1, having a

Public supply.

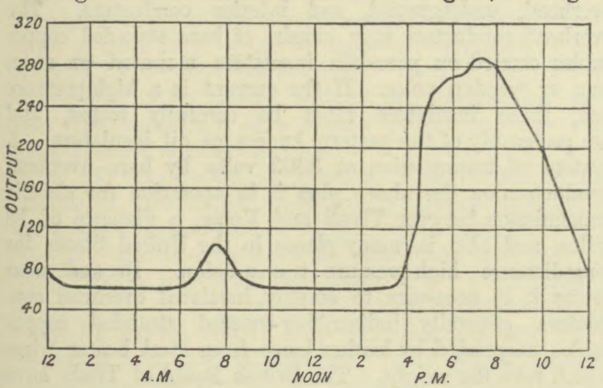


Fig. 1.

high peak somewhere between 6 and 8 p.m. The area enclosed by this load-diagram compared with the area of the circumscribing rectangle is called the *load-factor* of the station. This varies from day to day during the year, but on the average is not generally above 10 or 12 per cent., and it may be lower. Thus the total output from the station is only some 10 per cent. on an average of that which it would be if the supply were at all times equal to the maximum demand. Roughly speaking, it generally amounts to this, that the total output of an electric supply station furnishing current chiefly for electric lighting is at best equal to about two hours' supply during the day at full load. Hence during the greater part of the twenty-four hours a large part of the plant is lying idle. It is usual to provide certain small sets of steam dynamos, which are called the daylight machines, for supplying the demand during the day and later part of the evening, the remainder of the machines being called into requisition only for a short time. Provision must be made for sufficient reserve of plant, so that the breakdown of one or more sets will not cripple the output of the station. Assuming current to be supplied at about 460 volts by different and separate steam dynamos, the machines are connected through proper amperemeters and voltmeters with two bars on a main switchboard, called *omnibus bars*, so that any one can be put in connexion or removed. From this switchboard proceed a number of insulated conductors, called the positive and negative feeders. The switchboard is generally divided into three parts—one panel for the connexion of the positive feeders with the positive terminals of the generators, one for the negative feeders and negative generator terminals, while from the third (or middle-wire panel) proceed an equal number of middle-wire feeders. These sets of middle conductors are led out into the district to be supplied with current, and are there connected into a distributing system, consisting of three separate insulated conductors, respectively called the positive, middle, and negative distributing mains. The lamps in the houses are connected between the middle and negative and middle and positive mains by smaller triple supply and service wires. As far as possible the number of lamps installed on the two sides of the system are kept equal; but since it is not possible to control the consumption of current, it becomes necessary to provide at the station two small dynamos, called the *balancing machines*, connected respectively between the middle and positive and the middle and negative omnibus bars. These machines may have their shafts connected together, or they may be separate steam dynamos; their function is to supply the difference in the total current circulating through the whole of the lamps respectively on the two opposite sides of the middle wire. If storage batteries are employed in the station, it is usual to install two complete batteries, which are placed in a separate battery room and connected between the middle omnibus bars and the two outer omnibus bars. The extra electromotive force required to charge these batteries is supplied by two small dynamos, called *boosters*. It is not unusual to join together the two balancing dynamos and the two boosters on one common bed-plate, the shafts being coupled and in line, and to employ the balancing machines as electromotors to drive the boosters as required. The use of the boosters is to supply the extra half-volt per cell over and above the switchboard pressure which is required to drive the charging current through the battery towards the end of the charging operation.

In the *high-pressure* continuous-current system of supply the current is generated at a pressure of 1000 or 2000 volts, and transmitted from the generating station by conductors, called high-pressure feeders, to certain sub-centres or transformer centres, which are either buildings above ground, or cellars, or excavations under the road. In these transformer centres are placed machines, called *continuous-current transformers* (see TRANSFORMERS), which transform the electric energy and create a secondary electric current at a lower pressure, perhaps 100 or 150 volts, to be supplied by distributing mains to users. From these sub-centres insulated conductors are run back to the generating station, by which the engineer can start or stop the continuous-current rotatory transformers, and at the same time inform himself as to their proper action, and the electromotive force at the secondary terminals. This system was first put in practice in Oxford, England, and hence has been sometimes called by British engineers "the Oxford System." It is now in operation in a number of places in England, such as Wolverhampton, Walsall, and Shoreditch in London. It has the advantage that in connexion with the low-pressure distributing system, secondary batteries can be employed, so that a storage of electric energy is effected. Further, continuous-current arc lamps can be worked in series off the high-pressure mains, that is to say, sets of 20 to 40 arc lamps can be operated for the purpose of street lighting by means of the high-pressure continuous current.

The *alternating-current* systems in operation at the present time are the single-phase system, with distributing transformers or transformer sub-centres, and the polyphase systems, in which the alternating current is transformed down into an alternating current of low pressure, or, by means of rotatory transformers, into a continuous current. The general arrangement of a *single-phase* alternating-current system is as follows:—The generating station contains a number of alternators producing single-phase alternating current, either at 1000, 2000, or sometimes, as at Deptford and other places, 10,000 volts. These machines are sometimes worked in parallel, that is to say, all furnish their current to two common omnibus bars on a high-pressure switchboard, and each is switched into circuit at the moment when it is brought into step with the other machines, as shown by some form of *phase-indicator*. A number of high-pressure feeders are carried from the main switchboard to various transformer sub-centres, or else run throughout the district to which current is to be furnished. In some cases, instead of the high-pressure feeders starting from omnibus bars, each alternator works independently, and the feeders are grouped together on the various alternators as required. If the system laid down is the transformer sub-centre system, then at each of these sub-centres is placed a battery of alternating-current transformers, having their primary circuits all joined in parallel to the terminals of the high-pressure feeder, and their secondary circuits all joined in parallel on a distributing main, suitable switches and cut-outs being interposed. The pressure of the current is then transformed down by these transformers to the required supply pressure. The secondary circuits of these transformers are generally provided with three terminals, so as to supply the low-pressure side on a three-wire system. It is not advisable to connect together directly the secondary circuits of all the different sub-centres, because then a fault or short circuit on one secondary system affects all the others. In banking together transformers in this manner in a sub-station it is necessary to take care that the transformation ratio and secondary drop (see TRANSFORMERS) are exactly the same, otherwise one transformer will take more than its full share of the load, and will become overheated. The transformer sub-station system can only be adopted where the area of supply is tolerably compact. Where the consumers lie scattered over a large area, it is necessary to carry the high-pressure mains throughout the area, and to place a separate transformer or transformers in each building. From a financial point of view, this *house-to-house system* of alternating-current supply, generally speaking, is less satisfactory in results than the transformer sub-centre system. In the latter the transformers can be switched off, either by hand or by automatic apparatus, during the time when the load is light, and then no power is expended in magnetizing their cores. But with the house-to-house system the whole of the transformers continually remain connected with the high-pressure circuits; hence in the case of supply stations which have only an ordinary electric lighting load, and therefore a load-factor not above 10 per cent., the efficiency of distribution is considerably diminished.

The single-phase alternating-current system is defective in that it cannot be readily combined with secondary batteries for the storage of electric energy. Hence in many places preference is now given to the *polyphase system*. In such a system a polyphase alternating current, either two or three phase, is transmitted from the generating station at a pressure of 5000 to 10,000 volts, or sometimes higher, and at various sub-stations is transformed down, first by static transformers into an alternating current of lower pressure, say 500 volts, and then by means of rotatory transformers into a continuous current of 500 volts or lower, for use for lighting or traction. A remarkable system of this kind has been established at Niagara. A portion of the water at the Falls is employed to drive 5000 h.p. turbines, placed at the bottom of a deep chase; these drive 5000 h.p. two-phase alternators, fixed on the ground surface 150 feet above the turbines, and the two-phase current thus generated at 5000 volts is transmitted to various sub-centres, where it is transformed as already described. Large systems of distribution by polyphase currents transformed into continuous current are now in operation in New York, and similar systems have been established in London. When stations supply current not only for lighting but for traction, the current for the latter purpose must be generated at a pressure of 500 volts, and it is an economical arrangement to employ continuous-current machines which are wound to generate 500 to 550 volts, but can have their electromotive force reduced by resistance in the fields to between 400 and 460 volts. Such machines can be used either to operate a three-wire 230-volt lamp system of electric lighting or an electric traction system of 500 volts, being used chiefly in the day-time for traction and in the evenings for lighting.

Distribution.

The distribution of electric energy involves the arrangement of a system of insulated conductors, the conducting material being invariably copper having a conductivity of not less than 98 per cent. according to Matthiessen's standard (see ELECTRICITY, I.). These conductors may be divided into three classes—overhead, underground, and interior conductors. The overhead conductors may consist of bare stranded copper cables carried on porcelain insulators mounted on stout iron or wooden poles. If the current is a high-pressure one, these insulators must be carefully tested, and are preferably of the pattern known as oil insulators. A system of transmission at 5000 volts by bare overhead conductors on the above plan is in operation for electric transmission between Tivoli and Rome, a distance of 18 miles, and also in many places in the United States for long-distance high-pressure transmission. In and near towns it is necessary to employ insulated overhead conductors, generally indiarubber-covered stranded copper cables, suspended by leather loops from steel bearer wires which take the weight. The British Board of Trade have elaborated rules for the construction of overhead lines to transmit large electric currents. Where telephone and telegraph wires pass over such overhead electric lighting wires, they have to be protected from falling on the latter by means of guard wires. By far the largest part, however, of electric distribution is now carried out by *underground conductors*, which are either bare or insulated. Bare copper conductors may be carried underground in culverts or chases, air being in this case the insulating material, as in the overhead system. A culvert and covered chase is constructed under the road or side-walk, and properly shaped oak crossbars are placed in it carrying glass or porcelain insulators, on which stranded copper cables, or, preferably, copper strips placed edgeways, are stretched and supported. The advantages of this method of construction are cheapness and the ease with which connexions can be made with service lines for house supply; the disadvantages are the somewhat large space in which coal gas leaking out of case pipes can accumulate, and the difficulty of keeping the culverts at all times free from rain-water. Moisture has a tendency to collect on the negative insulators, and hence to make a dead earth on the negative side of the main; while unless the culverts are well ventilated, explosions from mixtures of coal gas and air are liable to occur. Insulated cables are insulated with a material which is in itself waterproof, or with one which is only waterproof in so far as it is enclosed in a waterproof tube, *e.g.*, of lead. Gutta-percha and indiarubber are examples of materials of the former kind. Gutta-percha, although practically everlasting when in darkness and laid under water, as in the case of submarine cables, has not been found satisfactory for use with large systems of electric distribution, although much employed for telephone and telegraph work. Insulated cables are of three classes:—(*a*) *Insulated cables drawn into pipes.* In this system of distribution cast-iron or stoneware pipes, or special stoneware conduits, or conduits made of a material called bitumen concrete, are first laid underground in the street. These contain a number of holes or "ways," and at intervals drawing-in boxes are placed which consist of a brick or cast-iron box having a water-tight lid, by means of which access is gained to a certain section of the conduit. Wires are used to draw in the cables, which are either indiarubber or lead-covered, the copper being insulated by means of paper, impregnated jute, or other similar material. The advantages of a drawing-in system are that spare ways can be left when the conduits are put in, so that at a future time fresh cables can be added without breaking up the roadway. (*b*) *Armoured cables.* A very extensively used system of distribution is by means of armoured cables. In this case the copper conductors, two, three, or more in number, may be twisted together or arranged concentrically, and are insulated by means of specially prepared jute or paper insulation, overlaid with a continuous tube of lead. Over the lead, but separated by a hemp covering, is put a steel armour consisting of two layers of steel strip, wound in opposite directions and kept in place by an external covering. Such a cable can be laid directly in the ground without any preparation other than the excavation of a simple trench, junction-boxes being inserted at intervals to allow of branch cables being taken off. (*c*) *Cables in bitumen.* One of the earliest systems of distribution employed by Edison consisted in fixing two segment-shaped copper conductors in a steel tube, the interspace between the conductors and the tube being filled in with a bitumen compound. A later plan is to lay down an iron trough, in which the cables are supported by wooden bearers at proper distances, and fill in the whole with natural bitumen. This system has been carried out extensively by the Callendar Cable Company. Occasionally concentric lead-covered and armoured cables are laid in this way, and then form an expensive but highly efficient form of insulated conductor. In selecting a system of distribution regard must be paid to the nature of the soil in which the cables are laid. Lead is easily attacked by soft water, although under some conditions it is apparently exceedingly durable, and an atmosphere containing coal gas is injurious to indiarubber.

The third large class of conductors comprises those placed in the interior of houses and buildings. These generally consist of indiarubber covered cables, laid in wood casing. The copper wire must be tinned and then covered, first with a layer of unvulcanized pure indiarubber, then with a layer of vulcanized rubber, and lastly one or more layers of protective cotton, twist or tape. No conductor of this character employed for interior house-wiring should have a less insulation resistance than 300 megohms per mile when tested with a pressure of 600 volts after soaking 24 hours in water. The wood casing should, if placed in damp positions or under plaster, be well varnished with waterproof varnish. As far as possible all joints in the run of the cable should be avoided, and after the wiring is complete, careful tests for insulation should be made. The Institution of Electrical Engineers of Great Britain have drawn up rules to be followed in interior house-wiring, and the principal fire offices, following the lead of the Phœnix Fire Office, of London, have made regulations which, if followed, are a safeguard against bad workmanship and resulting possibility of damage by fire. Where fires having an electric origin have taken place, it has invariably been traced to some breach of these rules. Opinions differ, however, as to the value and security of this method of laying interior conductors in buildings, and two or three alternative systems have been much employed. In one of these, called the *interior conduit* system, highly insulating waterproof and practically fireproof tubes or conduits replace the wooden casing; these being either of plain insulating material, or covered with brass or steel armour, may be placed under plaster or against walls. They are connected by bends or joint-boxes. The insulated wires being drawn into them, any short circuit or heating of the wire cannot give rise to a fire, as it can only take place in the interior of a non-inflammable tube. A third system of electric light wiring is the safety concentric system, in which concentric conductors are used. The inner one, which is well-insulated, consists of a copper-stranded cable. The outer may be a galvanized iron strand, a copper tape or braid, or a brass tube, and is therefore necessarily connected with the earth. A fourth system consists in the employment of twin insulated wires twisted together and sheathed with a lead tube; the conductor thus formed can be fastened by staples against walls or laid under plaster or floors. The general arrangement for distributing current to the different portions of a building for the purpose of electric lighting is to run up one or more rising mains, from which branches are taken off to distributing boxes on each floor, and from these boxes to carry various branch circuits to the lamps. At the distributing boxes are collected the cut-outs and switches controlling the various circuits. When alternating currents are employed, it is usual to select as a type of conductor either twin-twisted conductor or concentric; and the employment of these types of cable, rather than two separate cables, is essential in any case where there are telephone or telegraph wires in proximity, for otherwise the alternating current would create inductive disturbances in the telephone circuit. A concentric cable, however, possesses considerable electrostatic capacity, and when employed in connexion with high-pressure alternators or transformers gives rise to certain peculiar effects, called resonance effects. The general nature of these is best understood by considering the action of a condenser connected to the terminals of an alternator.

Interior conductors.

Let an alternator have its terminals closed by a condenser of capacity C; let the connexion be through a conductor having resistance R and inductance L; let $p=2\pi n$ where n is the frequency; and let V_0 be the maximum value of the alternating potential difference of the alternator terminals, and V_1 be that at the condenser terminals. Then assuming the potentials vary harmonically, it is easy to show that

$$V_0^2/V_1^2/=(1-CLp^2)^2+C^2R^2p^2.$$

(See J. Hopkinson, *Proc. Inst. Elec. Eng.*, 1884, p. 513; Fleming, *Ibid.*, 1891, p. 362.) The ratio V_1/V_0 can therefore be greater than unity, and the ratio is a maximum when $C=L/(R^2+p^2L^2)$. Hence if an alternator is run at a constant speed and excitation, and a conductor, such as a long length of concentric cable, is attached to its terminals, the actual potential difference between the concentric conductors may be many times greater than that of the open circuited alternator. This rise of pressure is called a *resonance effect*, and the engineer must be on his guard against it when testing long lengths of concentric cable, because if the length should be such as to give the critical capacity corresponding to the other conditions present in the circuit, the actual enhanced electric pressure on the cable may be sufficient to break it down. With high frequency these effects are more marked, and it is possible to have a progressive rise in potential all along a conductor connecting a condenser to an alternator as we proceed away from the alternator terminals. Thus Tesla (*Electrician*, March 6, 1891) has observed that when a condenser was connected by wires 20 feet long to an alternator whose frequency was 20,000 per second, there was a progressive rise in the difference of potential between the wires as points were taken nearer and nearer to the condenser. These condenser or resonance effects were observed on a large scale and investigated during the laying-out of the scheme of electric supply by alternating currents from Deptford to London carried out by Ferranti (see Fleming, *Journ. Inst. Elec. Eng.* vol. xx. p. 383). In that system there are several large concentric conductors having a length of 6 miles, and it was found that if the mains were switched into connexion with the alternators when kept running at constant speed and excitation, the potential difference between the mains, measured anywhere, was greater than that between the alternator terminals when the mains were not connected. If the cable is open-circuited at the far end, a current will still be found flowing through the armature of an alternator connected to it. This is called the condenser current or *capacity current* of the cable. If C is the total capacity of the cable in microfarads and $p=2\pi n$, where n is half the number of alternations per second, then, the maximum or R.M.S. (effective) value of the condenser current being called I and the potential difference between the conductors V, then on the assumption that V varies harmonically, but not otherwise, we have

$$I=CpV/10^6.$$

Thus, if the capacity of a concentric main is, say, 0·3 microfarad per mile, and the length 10 miles, the capacity current which would flow through an alternator connected with it, having an effective electromotive force of 10,000 volts and a frequency of 100, would be $10 \times 0{\cdot}3 \times 2 \times 100 \times 10{,}000/18 = 132/7 = 19$ amperes nearly. It might happen, however, if the right resonance condition were established, that the impressed electromotive force, and therefore the capacity current, would be grearly augmented on connecting the cable to the alternator. The capacity in microfarads (C) of a concentric main of length L centimetres, insulated with a dielectric having an inductive capacity K, is easily calculated from the formula

$$C=\frac{1}{9\times10^5}\times\frac{KL}{2\log_\epsilon D/d},$$

and hence since one mile = 160,933 cms., the capacity per mile is given by

$$C=\frac{160{,}933}{4{,}145{,}400}\quad\frac{K}{\log_{10}D/d}$$

where D is the inner diameter of the outer tube or conductor, d the outer diameter of the inner tube or conductor, and K the dielectric constant of the insulator. This is very nearly equal to

$$\frac{K}{25\log_{10}\frac{D}{d}}.$$

Thus if $D=2d$, the logarithm is nearly 0·3, and if the dielectric is indiarubber, K would be nearly equal to 4, hence the capacity per mile would be nearly one-half of a microfarad. It has been shown, however, that the capacity of a condenser, as measured by alternating electric currents, depends to a small extent upon the wave form of the alternating electromotive force.

In addition to these steady resonance effects, there are peculiar initial conditions which arise when long concentric cables are switched into connexion with alternating-current generators. In this case violent oscillations of potential may take place, giving rise to excessive electric strains, if the cables, when feeding alternating-current transformers, are suddenly switched into or out of connexion with the generators. Long concentric cables should therefore never be so connected, but always be brought into or out of connexion with the generators through a resistance or impedance, which can be gradually removed or put in. It is necessary to avoid making sudden changes in the capacity or self-induction of an alternating-current system of supply, especially when the electromotive force is large, or else oscillations of potential of excessive amplitude are set up which break down the insulation of the conductors at some point.

A subject which has attracted much attention is the amount and measurement of the true power-absorption in the dielectric of cables. All ordinary dielectrics, such as indiarubber, paper, gutta-percha, or bitumen, absorb and dissipate energy when electric strain through them is reversed. This is usually called dielectric hysteresis loss. The ratio of the true power absorbed by an alternating-current cable to the product of the impressed voltage and condenser current is called the power-factor, and may amount to about 2 to 3 per cent. For further information the reader may consult the record of a useful discussion following on a paper by Mr W. M. Mordey. (See *Proc. Inst. Elec. Eng. Lond.*, February 1901.)

(J. A. F.)

II. Electric Lighting.

The utilization of electric energy for the purpose of Electric Lighting is effected by devices called Electric Lamps, of which there are two varieties: (1) *Arc Lamps* and (2) *Incandescent Lamps*. Under these headings we may briefly consider the history, physical principles, and present practice of the Art of Electric Lighting. If a voltaic battery of a large number of cells has its terminal wires provided with rods of electrically-conducting carbon, and these are brought in contact and then slightly separated, a form of electric discharge takes place between them called *the electric arc*. It is not quite certain who first observed this effect of the electric current. The usually expressed opinion that Sir Humphry Davy, in 1801, first produced and studied the phenomenon is probably correct. In 1808, however, Davy had provided for him at the Royal Institution a battery of 2000 cells, with which he exhibited the electric arc on a large scale.

Arc Lamps.

The electric arc as a form of discharge may be produced between any conducting materials maintained at different potentials, provided that the source of electric supply is able to furnish a sufficiently large current; but for illuminating purposes pieces of hard graphitic carbon are most convenient. If some source of continuous electric current, such as a battery or dynamo, is connected to rods of such carbon, first brought into contact and then slightly separated, the following facts may be noticed:—With a low electromotive force of about 50 or 60 volts no discharge takes place until the carbons are in actual contact, unless the insulation of the air is broken down by the passage of a small electric spark. When this occurs, the space between the carbons is filled at once with a flame or luminous vapour, and the carbons themselves become highly incandescent at their extremities. If they are horizontal the flame takes the form of an arch springing between their tips; hence the name *arc*. This varies somewhat in appearance according to the nature of the current, whether continuous or alternating, and according as it is formed in the open air or in an enclosed space to which free access of oxygen is prevented. Electric arcs between metal surfaces differ greatly in colour according to the nature of the metal. When formed by an alternating current of high electromotive force they resemble a lambent flame, flickering about and producing a somewhat shrill humming sound.

Electric arcs may be classified into *continuous-* or *alternating-current arcs*, and *open* or *enclosed arcs*. Observing a carbon arc, we notice that if the current is continuous the positive carbon becomes much hotter at the end than the negative, and that in the open air it is worn away, partly by combustion, becoming hollowed out at the extremity into a *crater*. At the same time the negative carbon gradually becomes pointed, and also wears away, though much less quickly than the positive. In the continuous-current open arc the greater part of the light proceeds from the highly incandescent positive crater. When the arc is examined through dark glasses, or by the optical projection of its image upon a screen, a violet band or stream of vapour is seen to extend between the two carbons, surrounded by a nebulous golden flame or aureole. If the carbons are maintained at the right distance apart the arc remains steady and silent, but if the carbons are impure, or the distance between them too great, the true electric arc rapidly changes its place, flickering about and frequently becoming extinguished; when this happens it can only be restored by bringing the carbons once more into contact. If the current is alternating, then the arc is symmetrical, and both carbons possess nearly the same appearance. If it is enclosed in a vessel nearly air-tight, so as to prevent the access of free oxygen, the rate at which the carbons are burnt away is greatly reduced, and if the current is continuous the positive carbon is no longer cratered out and the negative no longer so much pointed as in the case of the open arc.

Carbons.

Davy used for his first experiments rods of wood charcoal which had been heated and plunged into mercury to make them better conductors. Not until much later (1843) was it proposed by Foucault to employ pencils cut from the hard graphitic carbon deposited in the interior of gas retorts. In 1846 Greener and Staite patented a process for manufacturing carbons for this purpose, but it was not until after the invention of the Gramme dynamo in 1870 that any great demand existed for them. Carré in France in 1876 began to manufacture arc lamp carbons of high quality from coke, lampblack, and syrup. Now they are made by taking some specially refined form of finely divided carbon, such as the soot or lampblack formed by cooling the smoke of burning paraffin or tar, or by the carbonization of organic matter, and making it into a paste with gum or syrup. This carbon paste is forced through dies of appropriate size and shape by means of a hydraulic press, the rods thus formed being subsequently baked with such precautions as to preserve them perfectly straight. In some cases they are *cored*, that is to say, have a longitudinal hole down them, filled in with a softer carbon. Sometimes, too, they are covered with a thin layer of copper by electro-deposition. They are supplied for the market in sizes varying from 4 or 5 to 30 or 40 millimetres in diameter, and from 8 to 16 inches in length. The value of carbons for arc lighting purposes greatly depends on their purity and freedom from ash in burning, and on perfect uniformity of structure. For ordinary purposes they are generally round in section, but for certain special uses, such as lighthouse work, they are made fluted or with a star-shaped section. The positive carbon is usually of larger section than the negative. For continuous-current arcs a cored carbon is generally used as a positive, and a smaller solid carbon as a negative. Countless researches have been made on the subject of carbon manufacture, and the art has been brought to great perfection. Special manuals must be consulted for further information.

Physical phenomena.

The physical phenomena of the electric arc are best examined by forming a carbon arc between two carbon rods of the above description, held in line in a special apparatus, and arranged so as to be capable of being moved to or from each other with a slow and easily regulated motion. An arrangement of this kind is called *a hand-regulated arc lamp* (see Fig. 2). If such an arc lamp is connected to a source of electric supply having an electromotive force preferably of 100 volts, and if some resistance is included in the circuit, say about 5 ohms, a steady and continuous arc is formed when the carbons are brought together and then slightly separated. Its appearance may be most conveniently examined by projecting its image upon a screen of white paper by means of an achromatic lens. A very little examination of the distribution of light from the arc shows that the illuminating or candle-power is not the same in different directions. If the carbons are vertical and the positive carbon is the upper of the two, the illuminating power is greatest in a direction at an angle inclined about 40 or 50 degrees below the horizon, and at other directions has different values, which may be represented by the lengths of radial lines drawn from a centre, the extremities of which define a curve called the *illuminating curve* of the arc lamp (see Fig. 3). Considerable differences exist between the forms of the illuminating-power curves of the continuous and alternating current and the open or enclosed arcs. The chief portion of the emitted light proceeds from the incandescent crater; hence the form of the illuminating-power curve, as shown by Trotter in 1892, is due to the apparent area of the crater surface which is visible to an eye regarding the arc in that direction.

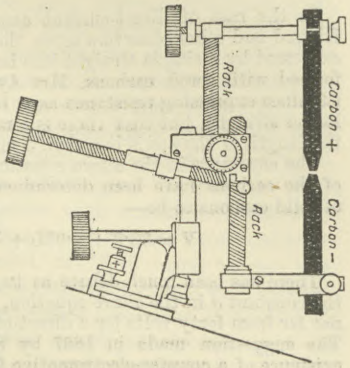


Fig 2.

The form of the illuminating-power curve varies with the length of the arc and relative size of the carbons. Leaving out of account for the moment the properties of the arc as an illuminating agent, the variable factors with which we are concerned are (i.) the current through the arc; (ii.) the potential difference of the carbons; (iii.) the length of the arc; and (iv.) the size of the carbons. Taking in the first place the typical direct-current arc between solid carbons, and forming arcs of different lengths and with carbons of different sizes, it will be found that, beginning at the lowest current capable of forming a true arc, the potential difference of the carbons (the arc P.D.) decreases as the current increases. Up to a certain current strength the arc is silent, but at a particular critical value P.D. suddenly drops about 10 volts, the current at the same time rising 2 or 3 amperes. At that moment the arc begins to *hiss*, and in this hissing condition, if the current is still further increased, P.D. remains constant over wide limits. This drop in voltage on hissing was first noticed by Niaudet (*La Lumière Electrique*, vol. iii. p. 287). It has been shown by Mrs Ayrton (*Journ. Inst. Elec. Eng.* vol. xxviii. p. 200) that the hissing is mainly due to the oxygen which gains access from the air to the crater, when the latter becomes so large by reason of the increase of the current as to overspread the end of the positive carbon. According to A. Blondel and Luggin, hissing takes place whenever the current density becomes greater than about 0·3 or 0·5 ampere per square millimetre of crater area.

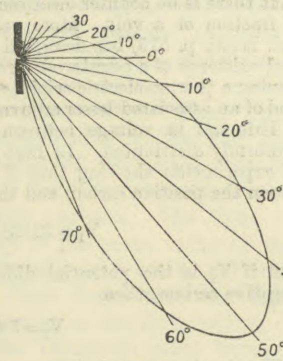


Fig. 3.

The relation between the current, the carbon P.D., and the length of arc in the case of the direct-current arc has been investigated by many observers with the object of giving it mathematical expression.

Let V stand for the potential difference of the carbons in volts, A for the current through the arc in amperes, L for the length of the arc in millimetres, R for the resistance of the arc; and let a, b, c, d, &c., be constants. Edlund in 1867, and other workers after him, considered that their experiments showed that the relation between V and L could be expressed by a simple linear equation,

$$V = a + bL.$$

Later researches by Mrs Ayrton (*Electrician*, vol. xli. p. 720) have, however, shown that for a direct-current arc of given size with solid carbons, the observed values of V can be better represented as a function both of A and of L of the form

$$V = a + bL + \frac{c + dL}{A}.$$

In the case of direct-current arcs formed with solid carbons, Edlund and other observers agree that the arc resistance R may be expressed by a simple straight line law, $R = e + fL$. If the arc is formed with cored carbons, Mrs Ayrton has demonstrated that the lines expressing resistance as a function of arc length are no longer straight, but that there is a rather sudden dip down when the length of the arc is less than 3 mm.

The constants in the above equation for the potential difference of the carbons have been determined by Mrs Ayrton in the case of solid carbons to be—

$$V = 38{\cdot}9 + 2{\cdot}07L + \frac{11{\cdot}7 + 10{\cdot}5L}{A}.$$

There has been much debate as to the meaning to be given to the constant a in the above equation, which has a value apparently not far from forty volts for a direct-current arc with solid carbons. The suggestion made in 1867 by Edlund,[1] that it implied the existence of a counter-electromotive force in the arc, was opposed by Luggin in 1889,[2] Lecher in 1888,[3] and by Stenger in 1892;[4] whereas von Lang and Arons, in 1896,[5] concluded that experiment indicated the presence of a counter-electromotive force of 20 volts. A. Blondel concludes, from experiments made by him in 1897,[6] that there is no counter-electromotive force in the arc greater than a fraction of a volt. More recently Duddell (*Proc. Roy. Soc.* vol. lxviii. p. 518) has described experiments tending to prove the real existence of a counter-electromotive force in the arc, probably having a thermo-electric origin, residing near the positive electrode, and of an associated lesser adjuvant *e.m.f.* near the negative carbon.

This fall in voltage between the carbons and the arc is not uniformly distributed. In 1898 Mrs Ayrton described the results of experiments showing that if V_1 is the potential difference between the positive carbon and the arc, then

$$V_1 = 31{\cdot}28 + \frac{9 + 3{\cdot}1L}{A};$$

and if V_2 is the potential difference between the arc and the negative carbon, then

$$V_2 = 7{\cdot}6 + \frac{13{\cdot}6}{A}.$$

The total potential difference between the carbons, minus the fall in potential down the arc, is therefore equal to the sum of $V_1 + V_2 = V_3$.

$$\text{Hence } V_3 = 38{\cdot}88 + \frac{2^2{\cdot}6 + 3{\cdot}1L}{A}.$$

The difference between this value and the value of V, the total potential difference between the carbons, gives the loss in potential due to the true arc. These laws are simple consequences of straight-line laws connecting the work spent in the arc at the two electrodes with the other quantities. If W be the work spent in the arc on either carbon, measured by the product of the current and the potential drop in passing from the carbon to the arc, or *vice versâ*, then for the positive carbon $W = a + bA$, if the length of arc is constant, $W = c + dL$, if the current through the arc is constant, and for the negative carbon $W = e + fA$.

In the above experiments the potential difference between the carbons and the arc was measured by using a third exploring carbon as an electrode immersed in the arc. This method, adopted by Lecher, Uppenborn, S. P. Thompson, and Fleming, is open to the objection that the introduction of the third carbon may to a considerable extent disturb the distribution of potential.

The total work spent in the continuous-current arc with solid carbons may, according to Mrs Ayrton, be expressed by the equation

$$W = 11{\cdot}7 + 10{\cdot}5L + (38{\cdot}9 + 2{\cdot}07L)A.$$

It will thus be seen that the arc, considered as a conductor, has the property that if the current through it is increased, the difference of potential between the carbons is decreased, and in one sense, therefore, the arc may be said to act as if it were a *negative resistance.* Messrs Frith and Rodgers (*Electrician*, vol. xxxviii. p. 75) have suggested that the resistance of the arc should be measured by the ratio between a small increment of carbon potential difference and the resulting small increment of current; in other words, by the equation dV/dA, and not by the ratio simply of V : A. Considerable discussion has taken place whether an electrical resistance can have a negative value, belonging as it does to the class of scalar mathematical quantities. Simply considered as an electrical conductor, the arc resembles an intensely heated rod of magnesia or other refractory oxide, the true resistance of which is decreased by rise of temperature. Hence an increase of current through such a rod of refractory oxide is accompanied by a decrease in the potential difference of the ends. This, however, does not imply a negative resistance, but merely the presence of a resistance with a negative temperature coefficient.

Other physical investigations have been concerned with the intrinsic brightness of the crater. It has been asserted by many observers, such as Blondel, Abney, S. P. Thompson, Trotter, Violle, and others, that this is practically independent of the current passing, but great differences of opinion exist as to its value. Abney's values lie between 39 and 116, Trotter's between 80 and 170 candles per square millimetre. Blondel in 1893 made careful determinations of the brightness of the arc crater, and came to the conclusion that it was 160 candles per square millimetre. More recently J. E. Petavel has found a value of 147 candles per square millimetre for current densities varying from ·06 to ·26 amperes per square millimetre (*Proc. Roy. Soc.* vol. lxv. p. 475). Violle also, in 1893, supported the opinion that the brightness of the crater per square millimetre was independent of the current density, and from certain experiments and assumptions as to the specific heat of carbon, he asserted the temperature of the crater was about 3500° C. It has been concluded that this constancy of temperature, and therefore of brightness, is due to the fact that the crater is at the temperature of the boiling-point of carbon, and in that case its temperature should be raised by increasing the pressure under which the arc works. W. E. Wilson in 1895 attempted to measure the brightness of the crater under various pressures, and found that under five atmospheres the resistance of the arc appeared to increase and the temperature of the crater to fall, until at a pressure of 20 atmospheres the brightness of the crater had fallen to a dull red. In a later paper W. E. Wilson and G. Fitzgerald stated that these preliminary experiments were not confirmed, and their later researches throw considerable doubt on the suggestion that it is the boiling-point of carbon which determines the temperature of the crater. (See *Electrician*, vol. xxxv. p. 260, and vol. xxxviii. p. 343.) On the whole, although valuable work has been done in exploring the physics of the electric arc, much knowledge yet remains to be gained before we can be said to understand the full meaning of this simple physical phenomenon, which is hardly likely to be fully interpreted before our information is greatly increased as to the process by which electric current is transmitted through gas or vapour.

Alternating-current arc.

The study of the alternating-current arc has proved to be fertile in suggesting a number of new experimental problems for investigators. In this case all the factors, namely, current, carbon P.D., resistance, and illuminating power, are periodically varying; and as the electromotive force reverses itself periodically, at certain instants the current through the arc is zero. Owing to the fact that the current can be interrupted for a moment without extinguishing the arc, it is possible to work the electric arc from an alternating current generator without apparent intermission in the light, provided that the frequency is not much below 50. During the moment that the current is zero the carbon continues to glow. Each carbon in turn becomes, so to speak, the crater carbon, and the illuminating power is therefore symmetrically distributed. The curve of illumination is as shown in Fig. 4. The nature of the variation of the current and arc P.D. can be examined by one of two methods, or their modifications, originally due to Joubert and A. Blondel. Joubert's method, which has been perfected by many observers, consists in attaching to the shaft of the alternator a contact which closes a circuit

[1] *Phil. Mag.*, series i., vol. xxxvi. p. 358.
[2] *Wien. Ber.* vol. 98, p. 1198.
[3] *Wied. Ann.* 33, p. 609.
[4] *Ibid.*, 45, p. 33.
[5] *Ibid.*, 30, p. 95.
[6] *Journal de Physique*, or *Electrician*, vol. xxxix. p. 615.

at an assigned instant during the phase. This contact is made to complete connexion either with a voltmeter or with a galvanometer placed as a shunt across the carbons or in series with the arc. By this arrangement these instruments do not read, as usual, the root-mean-square value of the arc P.D. or current, but give a constant indication determined by, and indicating, the instantaneous values of these quantities at some assigned instant during the phase. By progressive variation of the phase-instant at which the contact is made, the successive instantaneous values of the electric quantities can be measured and plotted out in the form of curves. This method has been much employed by Blondel, Fleming, Steinmetz, Tobey and Walbridge, Frith, Görges, and many others. The second method, due to Blondel, depends on the use of the *Oscillograph*, which is a galvanometer having a needle or coil of very small periodic time of vibration, say $\frac{1}{2000}$th part of a second or less, so that its deflections can follow the variations of current passing through the galvanometer. An improved form of oscillograph, devised by Duddell, consists of two fine wires, which are strained transversely to the lines of flux of a strong magnetic field (see MEASURING INSTRUMENTS, ELECTRIC). The current to be examined is made to pass up one wire and down the other, and these wires are then slightly displaced in opposite directions. A small mirror attached to the wires is thus deflected rapidly to and fro in synchronism with the variations of the current. From the mirror a ray of light is reflected which falls upon a photographic plate made to move across the field with a uniform motion. In this manner a photographic trace can be obtained of the wave form. By this method we are enabled to watch the variations of electric quantities in an alternating current arc. The variation of illuminating power can be followed by examining and measuring the light of the arc through slits in a revolving stroboscopic disc, which is driven by a motor synchronously with the variation of current through the arc.

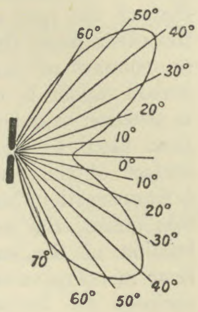


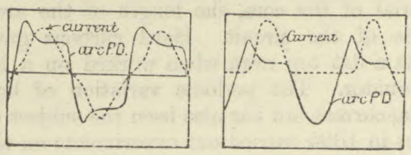
Fig. 4.

Without entering into an exact historical summary of discovery, it suffices to say that the general phenomena of the alternating-current arc are as follow:—If the arc is supplied by an alternator of low inductance, and soft or cored carbons are employed to produce a steady and silent arc, the potential difference of the carbons periodically varies in a manner not very different from that of the alternator on open circuit. If, however, hard carbons are used, the alternating-current arc deforms the shape of the alternator electromotive force curve; the carbon P.D. curve may then have a very different form, and becomes, in general, more rectangular in shape, usually having a high peak at the front. The arc also impresses the deformation on the current curve. Blondel in 1893 (*Electrician*, vol. xxxii. p. 161) gave a number of potential and current curves for alternating-current arcs, obtained by the Joubert contact method, using two movable coil galvanometers of high resistance to measure respectively potential difference and current. Blondel's deductions were that the shape of the current and volt curves is greatly affected by the nature of the carbons, and also by the amount of inductance and resistance in the circuit of the alternator. Blondel, Ayrton, Sumpner, and Steinmetz have all observed that the alternating-current arc, when hissing or when formed with uncored carbons, acts like an inductive resistance, and that there is a lag between the current curves and the potential difference curves. Hence the *power-factor*, or ratio between the true power and the product of the root-mean-square values of arc current and carbon potential difference, in this case is less than unity. For silent arcs Blondel found power-factors lying between 0·88 and 0·95, and for hissing ones, values such as 0·70. Ayrton and Sumpner stated that the power-factor may be as low as 0·5. Joubert, as far back as 1881, noticed the deformation which the alternating-current arc impresses upon the electromotive force curve of an alternator, giving an open circuit a simple harmonic variation of electromotive force. Tobey and Walbridge in 1890 gave the results of a number of observations taken with commercial forms of alternating-current arc lamps, in which the same deformation was apparent. Blondel in 1896 came to the conclusion that with the same alternator we can produce carbon P.D. curves of very varied character, according to the material of the core, the length of the arc, and the inductance of the circuit. Hard carbons gave a P.D. curve with a flat top even when worked on a low inductance alternator. The periodic variation of light in the alternating-current arc has also been the subject of inquiry. H. Görges in 1895 carried out experiments on this subject at Berlin, and applied a stroboscopic method to steady the variations of illuminating power. Fleming and Petavel also employed a similar arrangement, driving the stroboscopic disc by a synchronous motor (*Phil. Mag.*, April 1896). The light passing through slits of the disc was selected in one particular period of the phase, and by means of a lens could be taken from any desired portion of the arc or the incandescent carbons. The light so selected was measured relatively to the mean value of the horizontal light emitted by the arc, and accidental variations were thus eliminated. They found that the light from any part is periodic, but owing to the slow cooling of the carbons never quite zero, the minimum value happening a little later than the zero value of the current. The light emitted by a particular carbon when it is the negative, does not reach such a large maximum value as when it is the positive. The same observers brought forward experiments which seemed to show that for a given expenditure of power in the arc the alternating current arc in general gives less mean spherical candle-power than the continuous current one.

The effect of the wave form on the efficiency of the alternating-current arc has engaged the attention of many workers. Rössler and Wedding in 1894 gave an account of experiments with alternating-current arcs produced by alternators having electromotive force curves of very different wave forms, and they stated that the efficiency or mean spherical candle-power per watt expended in the arc was greatest for the flattest of the three wave forms by nearly 50 per cent. Burnie in 1897 gave the results of experiments of the same kind. His conclusion was, that since the light of the arc is a function of the temperature, that wave form of current is most efficient which maintains the temperature most uniformly throughout the half period. Hence, generally, if the current rises to a high value soon after its commencement, and is preserved at that value, or nearly at that value, during the phase, the efficiency of the arc will be greater when the current curve is more pointed or peaked. An important contribution to our knowledge concerning alternating-current arc phenomena was made in 1899 by Messrs W. Duddell and E. W. Marchant, in a paper containing valuable results obtained with their improved oscillograph.[1] They studied the behaviour of the alter-

[1] *Journ. Inst. Elec. Eng.* vol. xxviii. p. 1. The authors of this paper give numerous instructive curves taken with the oscillograph, showing the form of the arc P.D. and current curves for a great variety of alternating-current arcs.

nating-current arc when formed both with solid carbons, with cored carbons, and with carbon and metal rods. They found that with solid carbons the arc P.D. curve is always square-shouldered and begins with a peak, as shown in Fig. 5 (*a*), but with cored carbons it is more sinusoidal. Its shape depends on the total resistance in the circuit, but is almost independent of the type of alternator, whereas the current wave form is largely dependent on the machine used, and on the nature and amount of the impedance in the circuit; hence the importance of selecting a suitable alternator for operating alternating-current arcs. The same observers drew attention to the remarkable fact that if an arc is formed between a carbon and metal rod, say a zinc rod, there is a complete interruption of the current over half a period corresponding to that time during which the carbon is positive; this suggests that the rapid



(*a*) (*b*)

Fig. 5.

cooling of the metal facilitates the flow of the current from it, and resists the flow of current to it. The dotted curve in Fig. 5 (*b*) shows the current curve form in the case of a copper rod. By the use of the oscillograph Messrs Duddell and Marchant showed that the hissing continuous-current arc is intermittent, and that the current is oscillatory and may have a frequency of 1000 per second. They also showed that enclosing the arc increases the arc reaction, the front peak of the potential curve becoming more marked and the power-factor of the arc reduced.

If a continuous-current electric arc is formed in the open air with a positive carbon having a diameter of about 15 millimetres, and a negative carbon having a diameter of about 9 millimetres, and if a current of 10 amperes is employed, the potential difference between the carbons is generally from 40 to 50 volts. Such a lamp is therefore called a 500 watt arc. Under these conditions the carbons each burn away at the rate of about one inch per hour, actual combustion taking place in the air which gains access to the highly-heated crater and negative tip; hence the most obvious means of preventing this disappearance is to enclose the arc in an air-tight glass vessel. Such a device was tried very early in the history of arc lighting. The result of using a completely air-tight globe, however, is that the contained oxygen is removed by combustion with the carbon, and carbon vapour or hydrocarbon compounds diffuse through the enclosed space and deposit themselves on the cool sides of the glass, which is thereby obscured. It was, however, shown by L. B. Marks (*Electrician*, vol. xxxi. p. 502, and vol. xxxviii. p. 646) in 1893, that if the vessel is not completely closed, and if the arc is an arc formed with a small current and relatively high voltage, namely, 80 to 85 volts, it is possible to admit air in such small amount that though the rate of combustion of the carbons is reduced, yet the air destroys by oxidation the carbon vapour escaping from the arc, and so prevents the obscuration of the glass containing-vessel. An arc lamp operated in this way is called an enclosed arc lamp (see Fig. 6). The top of the enclosing bulb is closed by a gas check plug which admits through a small hole a limited supply of air. The peculiarity of an enclosed arc lamp operated with a continuous current is that the carbons do not burn to a crater on the positive, and a sharp tip or mushroom on the negative, but preserve nearly flat surfaces. This feature

Enclosed arc lamps.

affects the distribution of the light. The illuminating curve of the enclosed arc, therefore, has not such a strongly marked maximum value as that of the open arc, but on the other hand the true arc or column of incandescent carbon vapour is less steady in position, wandering round from place to place on the surface of the carbons. As a compensation, however, for this defect, the actual combustion of the carbons per hour in commercial forms of enclosed arc lamp is about one-twentieth part of that of an open arc lamp taking the same current.

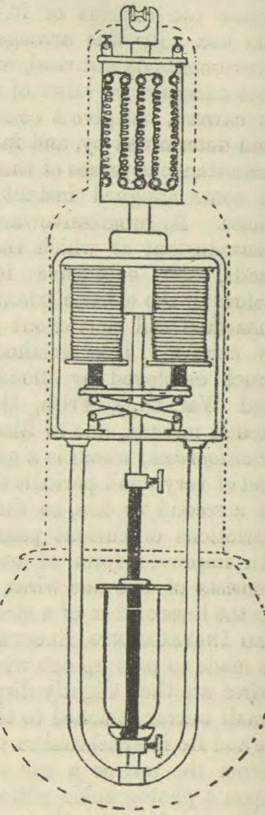


Fig. 6.

Before leaving the discussion of the physical phenomena of the electric arc, one or two other facts in connexion with it may be mentioned. It was shown by Fleming in 1890 that the column of incandescent carbon vapour constituting the true arc possesses a unilateral conductivity (*Proc. Roy. Inst.* vol. xiii. p. 47). If a third carbon is dipped into the arc so as to constitute a third pole, and if a small voltaic battery of a few cells, with a galvanometer in circuit, is connected in between the middle pole and the negative carbon, it is found that when the negative pole of the battery is in connexion with the negative carbon the galvanometer indicates a current, but does not when the positive pole of the battery is in connexion with the negative carbon of the arc.

The arc as an illuminant.

Turning next to the consideration of the electric arc as a source of light, we have already noticed that the illuminating power in different directions is not the same. If we imagine an electric arc, formed between a pair of vertical carbons, to be placed in the centre of a hollow sphere painted white on the interior, then it would be found that the various zones of this sphere are unequally illuminated. If the points in which the carbons when prolonged would intercept the sphere are called the poles, and the line where the horizontal plane through the arc would intercept the sphere is called the equator, we might consider the sphere divided up by lines of latitude into zones, each of which would be differently illuminated. The total quantity of light or the total illumination of each zone is the product of the area of the zone and the intensity of the light falling on the zone measured in candle-power. We might regard the sphere as uniformly illuminated with an intensity of light such that the product of this intensity and the total surface of the sphere was numerically equal to the surface integral obtained by summing up the products of the areas of all the elementary zones and the intensity of the light falling on each. This mean intensity is called the *mean spherical candle-power* of the arc. If the distribution of the illuminating power is known and given by an illumination curve, the mean spherical candle-power can be at once deduced by a construction due to M. Rousseau (*La Lumière Electrique*, vol. xxxvii. p. 415).

Let BMC (see Fig. 7) be a semicircle which by revolution round the diameter BC sweeps out a sphere. Let an arc be situated at A, and let the element of the circumference PQ = ds sweep out a zone of the sphere. Let the intensity of light falling on this zone be I. Then if θ = the angle MAP and $d\theta$ the incremental angle PAQ, and if R is the radius of the sphere, we have

$$ds = Rd\theta\ ;$$

also, if we project the element PQ on the line DE we have

$$ab = ds \cos\theta,$$
$$\therefore\ ab = R\cos\theta d\theta$$

and $$Iab = IR\cos\theta d\theta.$$

Let r denote the radius PT of the zone of the sphere, then

$$r = R\cos\theta.$$

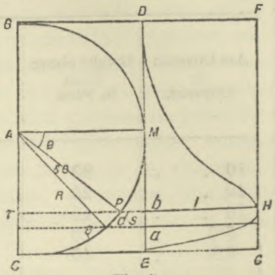


Fig. 7.

Hence the area of the zone swept out by PQ is equal to

$$2\pi R\cos\theta\ ds = 2\pi R^2\cos\theta d\theta$$

in the limit, and the total quantity of light falling on the zone is equal to the product of the mean intensity or candle-power I in the direction AP and the area of the zone, and therefore to

$$2\pi IR^2\cos\theta d\theta.$$

Let I_0 stand for the mean spherical candle-power, that is, let I_0 be defined by the equation

$$4\pi R^2 I_0 = 2\pi R\Sigma(Iab)$$

where $\Sigma(Iab)$ is the sum of all the light actually falling on the sphere surface, then

$$I_0 = \frac{1}{2R}\Sigma(Iab)$$
$$= \frac{\Sigma(Iab}{2RI max}\ I max$$

where $I max$ stands for the maximum candle-power of the arc. If, then, we set off at b a line bH perpendicular to DE and in length proportional to the candle-power of the arc in the direction AP, and carry out the same construction for a number of different observed candle-power readings at known angles above and below the horizon, the summits of all ordinates such as bH will define a curve DHE. The mean spherical candle-power of the arc is equal to the product of the maximum candle-power ($I max$), and a fraction equal to the ratio of the area included by the curve DHE to its circumscribing rectangle DFGE. The area of the curve DHE multiplied by $2\pi/R$ gives us the *total flux of light* from the arc.

Owing to the inequality in the distribution of light from an electric arc, it is impossible to define the illuminating power by a single number in any other way than by stating the mean spherical candle-power. All such commonly used expressions as "an arc lamp of 2000 candle-power" are, therefore, perfectly meaningless.

Photometry of arc. The photometry of arc lamps presents particular difficulties, owing to the great difference in quality between the light radiated by the arc and that given by any of the ordinarily used light standards. (For standards of light and photometers, see LIGHT.) All photometry depends on the principle that if we illuminate two white surfaces respectively and exclusively by two separate sources of light, we can by moving the lights bring the two surfaces into such a condition that their *illumination* or *brightness* is the same without regard to any small colour difference. The quantitative measurement depends on the fact that the illumination or brightness produced upon a surface by a source of light is inversely as the square of the distance of the source. The trained eye is capable of making a comparison between two surfaces illuminated by different sources of light, and pronouncing upon their equality or otherwise in respect of brightness, apart altogether from a certain colour difference; but in order that this should be capable of being done with accuracy, it is essential that the two illuminated surfaces, the brightness of which is to be compared, shall be absolutely contiguous and not separated by any harsh line. The process of comparing the light from the arc directly with that of a candle or other similar flame standard is exceedingly difficult, owing to the much greater proportion and intensity of the violet rays in the arc. The most convenient practical working standard is an incandescent lamp run at a high temperature, that is, at an efficiency of about $2\frac{1}{2}$ watts per candle. If it has a sufficiently large bulb, and has been *aged* by being worked for some time previously, it will at a constant voltage preserve a constancy in illuminating power sufficiently long to make the necessary photometric comparisons, and it can itself be compared at intervals with another standard incandescent lamp, or with a flame standard such as a Harcourt pentane lamp.

In measuring the candle-power of arc lamps it is necessary to have some arrangement by which the brightness of the rays proceeding from the arc in different directions can be measured. For this purpose the lamp may be suspended from a support, and a radial arm arranged to carry three mirrors, so that in whatever position the arm may be placed, it gathers light proceeding at one particular angle above or below the horizon from the arc, and this light is reflected out finally in a constant horizontal direction. An easily-arranged experiment enables us to determine the constant loss of light by reflection at all the mirrors, since that reflection always takes place at 45 degrees. The ray thrown out horizontally can then be compared with that from any standard source of light by means of a fixed photometer, and by sweeping round the radial arm the photometric or illuminating curve of the arc lamp can be obtained. From this we can at once determine the nature of the illumination which would be produced on a horizontal surface if the arc lamp were suspended at a given distance above it. Let A (see Fig. 8) be an arc lamp placed at a height h(=AB) above a horizontal plane. Let ACD be the illuminating power curve of the arc, and hence AC the candle-power in a direction AP.

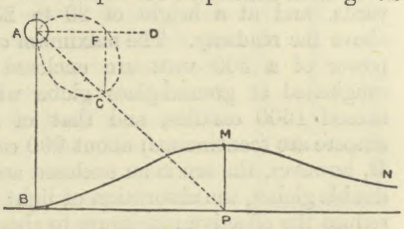


Fig. 8.

The illumination (I) or brightness on the horizontal plane at P is equal to $\frac{AC}{(AP)^2}$ $\cos APM = \frac{FC}{h^2+x^2} = I$ where BP = x. Hence if the candle-power curve of the arc and its height above the surface are known, we can describe a curve BMN, whose ordinate PM will denote the brightness on the horizontal surface at any point P. It is easily seen that this ordinate must have a maximum value at some point. This brightness is best expressed in *candle-feet*, taking the unit of illumination to be that given by a standard candle on a white surface at a distance of one foot. If any number of arc lamps are placed above a horizontal plane, the brightness at any point can be calculated by adding together the illuminations due to each respectively.

Street arc lighting. In the practical use of arc lamps for street and public lighting, the question of the distribution of light on the horizontal surface is all-important. The aim should be to produce as far as possible a uniform illumination sufficient for visual purposes. We form an opinion on the success of such lighting by observing the mean, maximum, and minimum illumination. In order that street surfaces may be well lighted, the minimum illumination should not fall below 0·1 candle-foot, and in general, in well-lighted streets, the maximum illumination will be 1 candle-foot and upwards. By means of an illumination photometer, such as that of Preece and Trotter, it is easy to measure the illumination in candle-feet at any point in a street surface, and to plot out a number of contour lines of equal illumination. Experience has shown that to obtain satisfactory results the lamps must be placed on a high mast 20 or 25 feet above the roadway surface. These posts are now generally made of cast-iron in various ornamental forms (see Fig. 9), the necessary conductors for conveying the current up to the lamp being taken inside the iron mast. (The pair of incandescent lamps half-way down the standard are for use in the middle of the night, when the arc lamp would give more light than is required; they are lighted by an automatic switch whenever the arc is extinguished.) The lamp itself is generally enclosed in an opalescent spherical globe, which is woven over with wire-netting so that in case of fracture the pieces may not cause damage. The necessary trimming, that is, the replacement of carbons, is effected either by lowering the lamp or, preferably, by carrying round a portable ladder enabling the trimmer to reach it. For the purpose of public illumination it is very usual to employ a lamp taking 10 amperes, and therefore absorbing about 500 watts. Such a lamp is called a 500 watt arc lamp, and it is found that a satisfactory illumination is given for most street purposes by placing 500 watt arc lamps at distances varying from 40 to 100 yards, and at a height of 20 to 25 feet above the roadway. The maximum candle-power of a 500 watt arc enclosed in a roughened or ground-glass globe will not exceed 1500 candles, and that of a 6·8 ampere arc (continuous) about 900 candles. If, however, the arc is an enclosed arc with double globes, the absorption of light would reduce the effective maximum to about 200 c.p. and 120 c.p. respectively. When arc lamps are placed in public thoroughfares not less than 40 yards apart, the illumination anywhere on the street surface is practically determined by the two nearest ones. Hence the total illumination at any point may be obtained by adding together the illuminations due to each arc separately. Given the photometric polar curves or illuminating-power curves of each arc taken outside the shade or globe, we can therefore draw a curve representing the resultant illumination on the horizontal surface. It is obvious that the higher the lamps are placed, the more uniform is the street surface illumination, but the less its average value; thus two 10 ampere arcs placed on masts 20 feet above the road surface and 100 feet apart will give a maximum illumination of about 1·1 and a minimum of about 0·15 candle-feet in the interspace (see Fig. 10). If the lamps are raised on 40-feet posts the maximum illumination will fall to 0·3, and the minimum will rise to 0·2. For this reason some engineers have advocated very high masts, and masts have been employed as high as 90 feet. In docks and railway yards high masts (50 feet) are an advantage, because the strong contrasts due to shadows of trucks, carts, &c., then become less marked, but for street illumination they should not exceed 30 to 35 feet in height. Taking the case of 10 ampere and 6·8 ampere arc lamps in ordinary opal shades, the following figures have been given by Trotter as indicating the nature of the resultant horizontal illumination:—

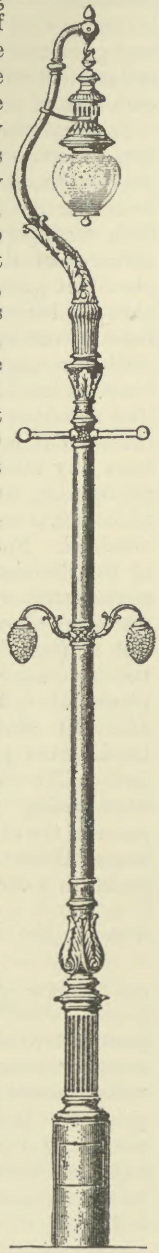


Fig. 9.

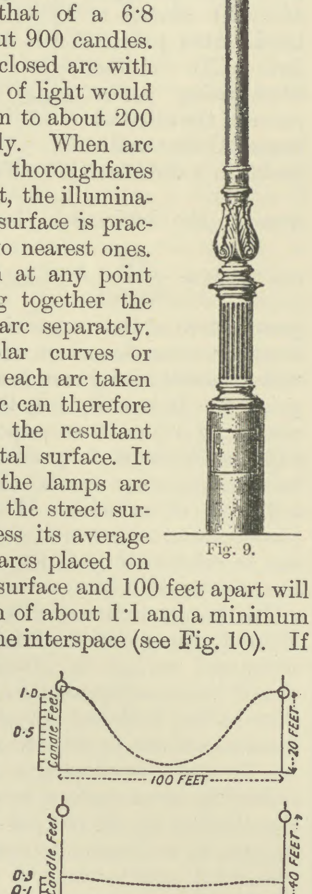


Fig. 10.

Arc Current in Amperes.	Height above Road in Feet.	Distance apart in Feet.	Horizontal Illumination in Candle-Feet.	
			Maximum.	Minimum.
10 . .	20	120	1·85	0·12
10 . .	25	120	1·17	0·15
10 . .	40	120	·5	0·28
6·8 .	20	90	1·1	0·21
6·8 .	40	120	0·3	0·17

As regards distance apart, a very usual practice is to place the lamps at spaces equal to six to ten times their height above the road surface. Blondel (*Electrician*, vol. xxxv. p. 846) gives the following rule for the height (h) of the arc to afford the maximum illumination at a distance (d) from the foot of the lamp-post, the continuous current arc being employed:—

For naked arc	$h=0·95\ d.$
,, arc in rough glass globe . .	$h=0·85\ d.$
,, ,, opaline globe . . .	$h=$,,
,, ,, opal globe . . .	$h=0·5\ d.$
,, ,, holophane globe . .	$h=0·5\ d.$

These figures show that the distribution of light on the horizontal surface is greatly affected by the nature of the enclosing globe. For street illumination naked arcs, although sometimes employed in works and factory yards, are entirely unsuitable, since the result produced on the eye by the bright point of light is to paralyse a part of the retina and contract the pupil, hence rendering the eye less sensitive when directed on feebly illuminated surfaces. Accordingly, diffusing globes have to be employed. It is usual to place the arc in the interior of a globe of from 12 to 18 inches in diameter. This may be made of ground glass, opal glass, or be a dioptric globe such as the holophane. The two former are strongly absorptive, as may be seen from the results of experiments by Messrs Guthrie and Redhead. The following table shows the astonishing loss of light due to the use of opal globes:—

	Naked Arc.	Arc in Clear Globe.	Arc in Rough Glass Globe.	Arc in Opal Globe.
Mean spherical c.p. .	319	235	160	144
Mean hemispherical c.p. .	450	326	215	138
Percentage value of transmitted light . . .	100	53	23	19
Percentage absorption .	0	47	77	81

By using Trotter's, Fredureau's, or the holophane globe, the light may be so diffused that the whole globe appears uniformly luminous, and yet not more than 20 per cent. of the light is absorbed. Taking the absorption of an ordinary opal globe into account, it is not usual to find that a 500 watt arc gives more than 500 c.p. as a maximum candle-power. Even with a naked 500 watt arc the mean spherical candle-power is not generally more than 500 c.p., or at the rate of 1 c.p. per watt. The maximum candle-power for a given electrical power is, however, greatly dependent on the current density in the carbon, and to obtain the highest current density the carbons must be as thin as possible. (See T. Hesketh, "Notes on the Electric Arc," *Electrician*, vol. xxxix. p. 707.)

The practical employment of the electric arc as a means of illumination is dependent upon mechanism for automatically keeping two suitable carbon rods in the proper position, and moving them so as to enable a steady arc to be maintained. Means must be provided for holding the carbons in line, and when the lamp is not in operation they must fall together, or come together when the current is switched on, so as to start the arc. As soon as the current passes, they must be moved slightly apart, and gripped in position immediately the current reaches its right value, being moved farther apart if the current increases in strength, and brought together if it decreases. Moreover, it must be possible for a considerable length of carbon to be fed through the lamp as required.

Arc lamp mechanism.

Once early devised form of arc-lamp mechanism was a system of clock-work driven by a spring or weight, which was started and stopped by the action of an electromagnet; in modern lighthouse lamps a similar mechanism is still employed. There is no need to occupy space by reference to the early arc-lamp mechanism of Staite (1847), Foucault (1849), Serrin (1857), and Duboscq (1858). These, and a host of later inventors, devised numerous forms of mechanical and clock-work lamps. The modern self-regulating type may be said to have been initiated in 1878 by the differential lamp of von Hefner-Alteneck, and the clutch lamp of C. F. Brush. The general principle of the former may be explained as follows:—There are two solenoids, placed one above the other. The lower one, of thick wire, is in series with the two carbon rods forming the arc, and is hence called the *series coil*. Above this there is placed another solenoid of fine wire, which is called the *shunt coil*. Suppose an iron rod to be placed so as to be partly in one coil and partly in another; then when the coils are traversed by currents, the iron core will be acted upon by forces tending to pull it into these solenoids. If the iron core be attached to one end of a lever, the other end of which carries the upper carbon, it will easily be seen that if the carbons are in contact and the current is switched on, the series coil alone will be traversed by the current, and its magnetic action will draw down the iron core, and therefore pull the carbons apart and strike the arc. The moment the carbons separate, there will be a difference of potential between them, and the shunt coil will then come into action, and will act on the core so as to draw the carbons together. Hence the two solenoids act in opposition to each other, one increasing and the other diminishing the length of the arc, and maintaining the carbons in the proper position. In the actual lamp of this type the upper carbon is in reality attached to a rod having a side-rack gearing, with a train of wheels governed by a pendulum. The action of the series coil on the mechanism is to first lock or stop the train, and then lift it as a whole slightly. This strikes the arc. When the arc is too long, the series coil lowers the gear and finally releases the upper carbon, so that it can run down by its own weight. The principle of a shunt and series coil operating on an iron core in opposition is the basis of the mechanism of a number of arc lamps. Thus the lamp invented by Krizik and Piette, called the Pilsen Lamp, comprises an iron core made in the shape of a double cone or spindle (see Fig. 11), which is so arranged in a brass tube that it can move into or out of a shunt and series coil, wound the one with fine and the other with thick insulated wire, and hence regulate the position of the carbon attached to it. The movement of this core is made to feed the carbons directly without the intervention of any clock-work, as in the case of the Hefner-Alteneck lamp.

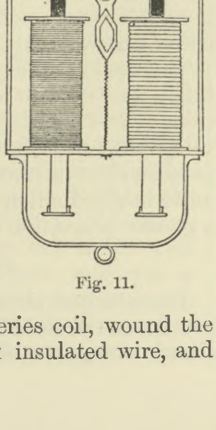


Fig. 11.

In the clutch-lamp mechanism the lower carbon is fixed, and the upper carbon rests upon it by its own weight and that of its holder. The latter consists of a long rod passing through guides, and is embraced somewhere by a ring capable of being tilted or lifted by a finger attached to the armature of an electromagnet, the coils of which are in series with the arc. When the current passes through the magnet it attracts the armature, and by tilting the ring lifts the upper carbon-holder, and hence strikes the arc. If the current diminishes in value, the upper carbon drops a little by its own weight, and the feed of the lamp is thus effected by a series of small lifts and drops of the upper carbon (see Fig. 12) Another element sometimes employed in arc-lamp mechanism is the brake-wheel regulator. This is a feature of one form of the Brockie and of the Crompton-Pochin lamps. In these the movement of the carbons is effected by a cord or chain which passes over a wheel, or by a rack geared with the brake wheel. When the current is passing through the lamp, the wheel is free to move, and the carbons fall together; but when the current is switched on, the chain or cord passing over the brake wheel, or the brake wheel itself, is gripped in some way, and at the same time the brake wheel is lifted so that the arc is struck.

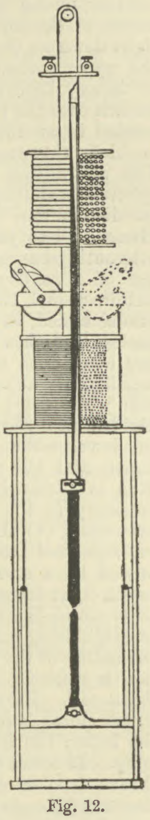


Fig. 12.

Although countless forms of self-regulating device have been invented for arc lamps, nothing has survived the test of time so well as the typical mechanisms which work with carbon rods in one line, one or both rods being moved by a controlling apparatus as required. The early forms of semi-incandescent arc lamp, such as those of Werdermann and others, have dropped out of existence. These were not really true arc lamps, the light being produced by the incandescence of the extremity of a thin carbon rod pressed against a larger rod or block. The once famous Jablochkoff candle has also disappeared from practice. This was invented in 1876, and consisted of two carbon rods about 4 mm. in diameter, placed parallel to each other and separated by a partition of kaolin, steatite, or other refractory non-conductor. Alternating currents were employed, and the candle was set in operation by a match or starter of high-resistance carbon paste which connected the tips of the rods. When this burned off, a true arc was formed between the parallel carbons, the separator volatilizing as the carbons burned away. Although much ingenuity and capital were expended on this system of lighting between 1877 and 1881, it no longer exists. One cause of its disappearance was its relative inefficiency in light-giving power when compared with other forms of carbon arc taking the same amount of power, and a second equally important reason was the waste in carbons. If the arc of the electric candle was accidentally blown out, no means of relighting existed; hence the great waste in half-burnt candles. Wilde, Jamin, Rapieff, and others endeavoured to provide a remedy, but without success. Of late years great advantages have attended the introduction of the *enclosed arc lamp*, in consequence of the economy effected in carbon consumption and in the labour-cost of trimming.

It is impossible to give here detailed descriptions of a fraction of the arc-lamp mechanisms devised, and it must suffice to indicate the broad distinctions between various types. (1) Arc lamps may be either *continuous-current* or *alternating-current* lamps. For outdoor public illumination the former are greatly preferable, as owing to the form of the illuminating power-curve they send the light down on the road surface where it is most required, provided the upper carbon is the positive one. For indoor, public room, or factory lighting, *inverted arc* lamps are sometimes employed. In this case the positive carbon is the lower one, and the lamp is carried in an inverted metallic reflector shield, so that the light is chiefly thrown up on the ceiling, whence it is diffused all round. The alternating current arc is not only less efficient in mean spherical candle-power per watt of electric power absorbed, but its distribution of light is disadvantageous for street purposes. Hence of late years, when arc lamps have to be worked off an alternating-current circuit for public lighting it is usual to make use of a *rectifier*, which rectifies the alternating current into a unidirectional though pulsating current. (2) Arc lamps may be also classified, as above described, into *open* or *enclosed arcs*. The enclosed arc has the advantage that it can be made to burn for 200 hours with one pair of carbons, whereas open arc lamps are usually only able to work 8, 16, or 32 hours without recarboning, even when fitted with double carbons. (3) Arc lamps are further divided into *focussing* and *non-focussing* lamps. In the former the lower carbon is made to move up as the upper carbon moves down, and the arc is therefore maintained at the same level. This is advisable for arcs included in a globe, and absolutely necessary in the case of lighthouse lamps and lamps for optical purposes. (4) Another subdivision is into *hand-regulated* and *self-regulated* lamps. In the hand-regulated arcs the carbons are moved by a screw attachment as required, as in some forms of search-light lamp and lamps for optical lanterns. The carbons in large search-light lamps are usually placed horizontally. (5) The self-regulating lamps may be classified into groups depending upon the nature of the regulating appliances. In some cases the regulation is controlled only by a *series coil*, and in others only by a *shunt coil*. Examples of the former are the original Gülcher and Brush clutch lamp, and some modern enclosed arc lamps; and of the latter, the Siemens "band" lamp, and the Jackson-Mensing lamp. In series coil lamps the variation of the current in the coil throws into or out of action the carbon-moving mechanism; in shunt coil lamps the variation in voltage between the carbons is caused to effect the same changes. Other types of lamp involve the use both of shunt and series coils acting against each other. A further classification of the self-regulating lamps may be found in the nature of the carbon-moving mechanism. This may be some modification of the Brush ring clutch, hence called *clutch* lamps; or some variety of *brake wheel*, as employed in Brockie and Crompton lamps; or else some form of *electric motor* is thrown into or out of action and effects the necessary changes. In many cases the arc-lamp mechanism is provided with a *dash-pot*, or contrivance in which a piston moving nearly air-tight in a cylinder prevents sudden jerks in the motion of the mechanism, and thus does away with the "hunting" or rapid up-and-down movements to which some varieties of clutch mechanism are liable. As with the dynamo, the struggle for existence has gradually eliminated the less efficient forms of mechanism, and a few particular types survive which combine the maximum of efficiency in action with least cost of manufacture. One very efficient form is illustrated in the Thomson lamp and Brush-Vienna lamp. In this mechanism a shunt and series coil are placed side by side, and have iron cores suspended to the ends of a rocking arm held partly within them. Hence, according as the magnetic action of the shunt or series coil prevails, the rocking arm is tilted backwards or forwards. When the series coil is not in action the *motion* is free, and the upper carbon-holder slides down, or the lower one slides up, and starts the arc. The series coil comes into action to withdraw the carbons, and at the same time locks the mechanism. The shunt coil then operates against the series coil, and between them the carbon is fed forwards as required. The control to be obtained is such that the arc shall never become so long as to flicker and become extinguished, when the carbons would come together again with a rush, but the feed should be smooth and steady, the position of the carbons responding quickly to each change in the current.

Arrangement. Arc lamps may be arranged either (i.) in series, (ii.) in parallel, or (iii.) in series parallel. In the first case a number, say 20, may be traversed by the same current, in that case supplied at a pressure of 1000 volts. Each must have a magnetic cut-out, so that if the carbons stick together or remain apart the current to the other lamps is not interrupted, the function of such a cut-out being to close the main circuit immediately any one lamp ceases to pass current. Arc lamps worked in series are generally supplied with a current from a constant current dynamo, which maintains an invariable current of, say 10 amperes, independently of the number of lamps on the external circuit. If the lamps, however, are worked in series off a constant potential circuit, such as one supplying at the same time incandescent lamps, provision must be made by which a resistance coil can be substituted for any one lamp that is removed or short-circuited. In the case when lamps are worked in parallel, each lamp is independent, but it is then necessary to add a resistance in series with the lamp. By special devices three lamps can be worked in series of 100 volt circuits. Alternating-current arc lamps can be worked off a high-tension circuit in parallel by providing each lamp with a small transformer. In some cases the alternating high-tension current is *rectified* and supplied as a unidirectional current to lamps in series. If single alternating-current lamps have to be worked off a 100 volt alternating-circuit, each lamp must have in series with it a choking coil or economy coil, to reduce the circuit pressure to that required for one lamp. Alternating-current lamps take a larger *effective* current, and work with a less effective or virtual carbon P.D., than continuous current arcs of the same wattage.

Cost. The cost of working public arc lamps is made up of several items. There is first the cost of supplying the necessary electric energy, then the cost of carbons and the labour of recarboning, and, lastly, an item due to depreciation and repairs of the lamps. An ordinary open type 10 ampere arc lamp, burning carbons 15 and 9 mm. in diameter for the positive and negative, and working every night of the year from dusk to dawn, uses about 600 feet of carbons per annum. If the positive carbon is 18 mm. and the negative 12 mm., the consumption of each size of carbon is about 70 feet per 1000 hours of burning. It may be roughly stated that at the present prices of arc-lamp carbons the cost is about 15s. per 1000 hours of burning; hence if such a lamp is burnt every night from dusk to midnight the annual cost in that respect is about £1, 10s. The annual cost of labour per lamp for trimming is in Great Britain from £2 to £3 per annum; hence, approximately speaking, the cost per annum of maintenance of a public arc lamp burning every night from dusk to midnight is about £4 to £5, or perhaps £6, per annum, depreciation and repairs included. Since such a 10 ampere lamp uses half a Board of Trade unit of electric energy every hour, it will take 1000 Board of Trade units per annum, burning every night from dusk to midnight; and if this energy is supplied, say at 3d. per unit, the annual cost of energy will be about £12, and the upkeep of the lamp, including carbons, labour for trimming and repairs, will be about £16 to £18 per annum. The cost for labour and carbons is considerably reduced by the employment of the enclosed arc lamp, but owing to the absorption of light produced by the inner enclosing globe, and the necessity for generally employing a second outer globe, there is a lower resultant candle-power per watt expended in the arc. Enclosed arc lamps as now made (1899), burn without attention for 200 hours, singly on 100 volt circuits, or two in series on 200 volt circuits, and in addition to the cost of carbons per hour being only about one-twentieth of that of the open arc, have another advantage in the fact that there is a more uniform distribution of light on the road surface, because a greater proportion of light is thrown out horizontally.

Incandescent Lamps.

Incandescent electric lighting, although not the first, is yet in one sense the most obvious method of utilizing electric energy for illumination. It was evolved from the early observed fact that a conductor is heated when traversed by an electric current, and that if it has a high resistance and a high melting-point it may be rendered incandescent, and therefore become a source of light. Naturally every inventor turned his attention to the employment of wires of refractory metals, such as platinum or alloys of platinum-iridium, &c., for the purpose of making an incandescent lamp, and in the middle and latter half of the 19th century many attempts of this kind were made. No reference need be made to the experiments of De Moleyns in 1841, King and Starr in 1845, Watson in 1853, and Staite in 1848, for in spite of their ingenuity these inventors achieved no satisfactory result. Part, however, of their want of success is attributable to the fact that in their day the problem of the economical production of electric current by the dynamo machine had not been solved. In 1878 Edison directed his attention to the same subject, and devised lamps in which a platinum wire was employed as the light-giving agent, carbon being made to adhere round it by pressure. Abandoning this, he next directed his attention to the construction of an "electric candle," consisting of a thin cylinder or rod formed of finely-divided metals, platinum, iridium, &c., mixed with refractory oxides, such as magnesia, or zirconia, lime, &c. This refractory body was placed in a closed vessel and heated by being traversed by an electric current. In a further improvement he proposed to use a block of refractory oxide, round which a bobbin of fine platinum or platinum-iridium wire was coiled. Every other inventor who worked at the problem of incandescent lighting seems to have followed nearly the same path of invention. Long before this date, however, the notion of employing carbon as a substance to be heated by the current had entered the minds of inventors; even in 1845 King had employed a small rod of plumbago as the substance to be heated. It was obvious, however, that carbon could only be so heated when in a space destitute of oxygen, and accordingly King placed his plumbago rod in a barometric vacuum. Konn in 1872, and Kosloff in 1875, followed in the same direction.

Carbon filament lamp.

Without entering into a detailed history of the development of incandescent electric lighting, we may say that no real success attended the efforts of inventors until it was finally recognized, as the outcome of the work by J. W. Swan, T. A. Edison, and, in a lesser degree, Lane Fox and Sawyer and Mann, that the conditions of success were as follow:—First, the substance to be heated must be carbon in the form of a thin wire rod or thread, technically termed a *filament*; second, this must be supported and enclosed in a vessel formed entirely of glass; third, the vessel must be exhausted as perfectly as possible; and fourth, the current must be conveyed into and out of the carbon filament by means of platinum wires hermetically sealed through the glass. By successive stages inventors were led to perfect all the details of the process of manufacturing an incandescent electric lamp in its present form. One great difficulty was the production of the carbon filament. Early inventors, such as King, Sawyer, and Mann, and others, had attempted to cut out a suitably shaped piece of carbon from a solid block; but Edison and Swan were the first to show that the proper solution of the difficulty was to carbonize an organic substance to which the necessary form had been previously given. For this purpose cardboard, paper, and ordinary thread were originally employed, and even, according to Edison, a mixture of lampblack and tar rolled out into a fine wire and bent into a spiral. At one time Edison employed a filament of bamboo, carbonized after being bent into a horse-shoe shape. Swan used a material formed by treating ordinary crochet cotton-thread with dilute sulphuric acid, the "parchmentized thread," thus produced being afterwards carbonized. In the modern incandescent lamp the filament is generally constructed by preparing first of all a form of soluble cellulose. Carefully purified cotton-wool is dissolved in some solvent, such as a solution of zinc chloride, and the viscous material so formed is forced by hydraulic pressure through a die. The long thread thus obtained, when hardened, is a semi-transparent substance resembling cat-gut, and when carefully carbonized at a high temperature gives a very dense and elastic form of carbon filament. It is cut into appropriate lengths, which after being bent into horse-shoes, double-loops, or any other shape desired, are tied or folded round carbon formers and immersed in plumbago crucibles, packed in with finely divided plumbago. The crucibles are then heated to a high temperature in an ordinary combustion or electric furnace, whereby the organic matter is destroyed, and a skeleton of carbon remains. The higher the temperature at which this carbonization is conducted, the denser is the resulting product. The filaments so prepared are sorted and measured, and short leading-in wires of platinum are attached to their ends by a carbon cement or by a carbon depositing process, carried out by heating electrically the junction of the carbon and platinum under the surface of a hydrocarbon liquid. They are then mounted in bulbs of lead glass having the same coefficient of expansion as platinum, through the walls of which, therefore, the platinum wires can be hermetically sealed. The bulbs pass into the exhausting-room, where they are exhausted by some form of mechanical or mercury pump. During this process an electric current is sent through the filament to heat it, in order to disengage the gases occluded in the carbon, and exhaustion must be so perfect that no luminous glow appears within the bulb when held in the hand and touched against one terminal of an induction coil in operation. Finally, the lamp is provided with a collar having two sole plates on it, to which the terminal wires are attached, or else the terminal wires are simply bent into two loops; in a third form, the Edison screw

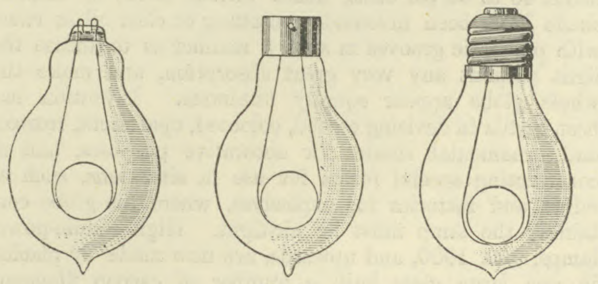


Fig. 13.

terminal, it is provided with a central metal plate, to which one end of the filament is connected, the other end being joined to a screw collar. The collars and screws are formed of thin brass embedded in plaster of Paris, or in some material like vitrite or black glass (cp. Fig. 13).

In order to put the lamp into connexion with the circuit supplying the current, it has to be fitted into a socket or holder. Three of the principal types of holder in use are the bottom contact (B.C.) or Dornfeld socket, the Edison screw-collar socket, and the Swan or loop socket. In the Dornfeld socket (Fig. 14, *a* and *a'*) two spring pistons, in contact with the two sides of the circuit, are fitted into the bottom of a short metallic tube having bayonet joint slots cut in the top. The brass collar on the lamp has two pins, by means of which a bayonet connexion is made between it and the socket; and when this is done, the spring pins are pressed against the sole plates on the lamp. In the Edison socket (Fig. 14, *b*) a short metal tube with an insulating lining has on its interior a screw sleeve, which is in connexion with one wire of the circuit; at the bottom of the tube, and insulated from the screw sleeve, is a central metal button, which is in connexion with the other side of the circuit. On screwing the lamp into the socket, the screw collar of the lamp and the boss or plate at the base of the lamp make contact with the corresponding parts of the socket, and complete the connexion. In some cases a form of switch is included in the socket, which is then termed the key-holder. For loop lamps the socket consists of an insulated block, having on it two little hooks, which engage with the eyes of the lamp. This insulating block also carries some form of spiral spring or pair of spring loops, by means of which the lamp is pressed away from the socket, and the eyes kept tight by the hooks. This spring or Swan socket (Fig. 14, *c*) is found useful in places where the lamps are subject to vibration, for in such cases the Edison screw collar cannot well be used, because the vibration loosens the contact of the lamp in the socket. The sockets may be fitted with appliances for holding ornamental shades or conical reflectors. The incandescent filament being a sharp and very brilliant line of light, makes a disagreeable impression upon the eye if looked at directly; hence various devices are adopted for moderating its brilliancy and distributing the light. A simple method is to sand-blast the exterior of the bulb, whereby it acquires an appearance similar to that of ground glass, or the bare lamp may be enclosed in a suitable glass shade. Such shades, however, if made of opalescent or semi-opaque glass, absorb a large proportion of the light, about 40 to 60 per cent.; hence various forms of dioptric shade have been invented, consisting of clear glass ruled with prismatic grooves in such a manner as to diffuse the light without any very great absorption, and make the whole globe appear equally luminous. Invention has been fertile in devising etched, coloured, opalescent, frosted, and ornamental shades for decorative purposes, and in constructing special forms for use in situations, such as mines and factories for explosives, where the globe containing the lamp must be air-tight. High candle-power lamps, 500, 1000, and upwards, are now made by placing in one large glass bulb a number of carbon filaments arranged in parallel between two rings, which are connected with the main leading-in wires. When incandescent lamps are used for optical purposes it is necessary to compress the filament into a small space, so as to bring it into the focus of a lens or mirror. The filament is then coiled or crumpled up into a spiral or zigzag form. Such lamps are called *focus lamps.* Incandescent lamps are technically divided into several broad divisions, called respectively high and low voltage lamps, high and low efficiency lamps, standard and fancy lamps. The difference between high and low efficiency lamps is based upon the relation of the power absorbed by the lamp to the candle-power emitted. Every lamp when manufactured is marked with a certain figure, called the *marked volts.* This is understood to be the electromotive force in volts which must be applied to the lamp terminals to produce through the filament a current of such magnitude that the lamp will have a practically satisfactory life, and give in a horizontal direction a certain candle-power, which is also

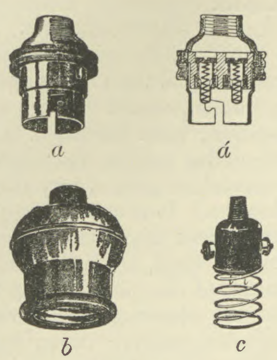


Fig. 14.

marked upon the glass. The numerical product of the current in amperes passing through the lamp, and the difference in potential of the terminals measured in volts, gives the total power taken up by the lamp in watts; and this number divided by the candle-power of the lamp (taking generally a horizontal direction) gives the *watts per candle-power.* This is an important figure, because it is determined by the temperature; it therefore determines the quality of the light emitted by the lamp, and also fixes the average duration of the filament when rendered incandescent by a current. Even in a good vacuum the filament is not permanent. Apart altogether from accidental defects, which may sooner or later cause it to break, the carbon is slowly volatilized, and carbon molecules are also projected in straight lines from different portions of the filament. This process not only causes a change in the nature of the surface of the filament, but also a deposit of carbon on the interior of the bulb, whereby the glass is blackened and the candle-power of the lamp reduced. The volatilization increases very rapidly as the temperature rises. Hence at points of high resistance in the filament, more heat being generated, a higher temperature is attained, and the scattering of the carbon becomes very rapid; in such cases the filament is sooner or later cut through at the point of high resistance. In order that incandescent lighting may be practically possible, it is essential that the lamps shall have a certain *average life*, that is, duration; and this useful duration is fixed not merely by the possibility of passing a current through the lamp at all, but by the rate at which the candle-power diminishes. The decay of candle-power is called the *ageing* of the lamp, and the useful life of the lamp may be said to be that period of its existence before it has deteriorated to a point when it gives only 75 per cent. of its original candle-power. It is found that in practice carbon filament lamps, as at present made, cannot be worked at a higher efficiency than 2½ watts per candle-power without a too rapid duration and a too short life. Hence lamp manufacturers classify lamps into various classes, marked for use say at 2½, 3, 3½, and 4 watts per candle. A 2½ watt per candle lamp would be called a *high-efficiency lamp*, and a 4 watt per candle lamp would be called a *low-efficiency* lamp. Under ordinary circumstances the low-efficiency lamp would probably have a longer life, but its light would be less suitable for many purposes of illumination in which colour discrimination is required. The possibility of employing high-efficiency lamps depends greatly on the uniformity of the electric pressure of the supply. If the voltage is exceedingly uniform, then high-efficiency lamps can be satisfactorily employed; but they are not adapted for standing the variations in pressure which are liable to occur with public supply-stations, since, other things being equal, their filaments are less substantial. The classification of lamps into high and low voltage lamps is based upon the watts per candle-power corresponding to the marked volts. When incandescent lamps were first introduced, the ordinary working voltage was 50 or 100, but at the present time a large number of public supply-stations furnish current to consumers at a pressure of 200 or 250 volts. This increase was necessitated by the enlarging area of supply in towns, and therefore the necessity for conveying through the same subterranean copper cables a large supply of electric energy without increasing the maximum current value and the size of the cables. This can only be done by employing a higher working electromotive force; hence arose a demand for incandescent lamps having marked volts of 200 and upwards, technically termed high-voltage lamps. The employment of higher pressures in public supply-stations has necessitated greater care in the selection of the lamp fittings, and in the manner of carrying out the wiring work. Switches, sockets, fuses, ceiling roses, &c., which are adequate for use with 100 volts become unsuitable when employed with higher pressures, because of the greater risk of starting an electric arc between adjacent metallic parts. The advantages, however, of higher supply pressures, from the point of view of supply-stations, are undoubted. At the same time the consumer desires a lamp of a higher efficiency than the ordinary carbon filament lamp. The demand for this has resulted in inventors turning their attention to substances other than carbon which can be rendered incandescent by the electric current.

Recent improvements.

The luminous efficiency of any source of light, that is to say, the percentage of rays emitted which affect the eye as light compared with the total radiation, is dependent upon its temperature. In an ordinary oil lamp the luminous rays do not form much more than 3 per cent. of the total radiation. In the carbon-filament incandescent lamp, when worked at about 3 watts per candle, the luminous efficiency is about 5 per cent.; and in the case of the arc lamp the radiation from the crater contains about 10 to 15 per cent. of eye-affecting radiation. Hence any improvement in the incandescent lamp must involve the use of a substance which is capable, without destruction, of enduring a higher temperature than the carbon filament. The temperature of a carbon filament working at about 3 watts per candle is not far from the melting-point of platinum, that is to say, is nearly 1775° C. If it is worked at a higher efficiency, say 2·5 watts per candle-power, the temperature rises rapidly, and at the same time the volatilization and molecular scattering of the carbon is rapidly increased, so that the average duration of the lamp is very much shortened. An improvement, therefore, in the efficiency of the incandescent lamp can only be obtained by finding some substance which will endure heating to a higher temperature than the carbon filament. Inventors turned their attention many years ago, with this aim, to the refractory oxides and similar substances. Jablochkoff in 1877 described and made a lamp consisting of a piece of kaolin, which was brought to a state of incandescence first by passing over it an electric spark, and afterwards maintained in a state of incandescence by a current of lower electromotive force. Lane Fox and Edison, in 1878, proposed to employ platinum wires covered with films of lime, magnesia, steatite, or with the rarer oxides, zirconia, thoria, &c.; and Lane Fox, in 1879, suggested as an incandescent substance a mixture of particles of carbon with the earthy oxides. These earthy oxides—magnesia, lime, and the oxides of the rare earths, such as thoria, zirconia, erbia, yttria, &c. —possess the peculiarity that at ordinary temperatures they are practically non-conductors, but if heated to very high temperatures, their resistance at a certain point rapidly falls, and they become fairly good conductors. Hence if they can once be brought into a state of incandescence a current can pass through them and maintain them in that state. On the other hand, at this temperature they give up oxygen to carbon; hence no mixtures of earthy oxides with carbon are permanent when heated.

Nernst lamp.

Nernst in 1897, however, patented an incandescent lamp in which the incandescent body consists entirely of a slender rod or filament of magnesia. If such a rod is heated by the oxyhydrogen blowpipe to a high temperature it becomes conductive, and can then be maintained in an intensely luminous condition by passing a current through it after the flame is withdrawn. Nernst found that by mixing together, in suitable proportions, magnesia with oxides of the rare earths, he was able to prepare a material which can be formed into slender rods and threads, and which is rendered sufficiently conductive to pass a current with an electromotive force as low as 100 volts, merely by being heated for a few moments with a spirit lamp, or even by the radiation from a neighbouring platinum spiral brought to a state of incandescence. The Nernst lamp, therefore, consists of a slender rod of the mixed oxides attached to platinum wires by an oxide paste. The rod is surrounded by, or brought into proximity with, a coil of platinum wire which can be heated to incandescence, and the radiation from which suffices to heat the oxide rod to a point at which it is able to pass sufficient current to maintain itself in a state of incandescence. When this condition is reached, the current is automatically cut off from the platinum coil. Oxide filaments of this description need not be enclosed in an exhausted glass vessel, and they can be brought, without risk of destruction, to a temperature considerably higher than a carbon filament; hence the lamp has a higher luminous efficiency. Many attempts have been made to cover over the carbon filament in a glow lamp with such substances, as thoria, zirconia, and the rare oxides, generally under the conception that at the same temperature such a surface would radiate a larger proportion of luminous rays than carbon; but all such attempts have been a failure, from the fact that these oxides are rapidly reduced by contact with carbon at any temperature near the melting-point of platinum.

In the manufacture of carbon-filament lamps a process is very generally applied to the carbon which is technically termed "treating." The carbon filament, when formed, is placed in a vessel surrounded by an atmosphere of hydrocarbon, such as coal gas or vapour of benzol. If current is then passed through the filament the hydrocarbon vapour is decomposed, and carbon is thrown down upon the filament in the form of a lustrous and dense deposit having an appearance like steel when seen under the miscroscope. This deposited carbon is not only much more dense than ordinary carbonized organic material, but it has a much lower specific electric resistance. An untreated carbon filament is generally termed the primary carbon, and a deposited carbon the secondary carbon. In the process of treating, the greatest amount of deposit is at any places of high resistance in the primary carbon, and hence it tends to cover up or remedy the defects which may exist. The bright steely surface of a well-treated filament is a worse radiator than the rougher black surface of an untreated one, hence it does not require the expenditure of so much electric power to bring it to the same temperature, and probably on account of its greater density it deteriorates or ages much less rapidly.

Photometry and testing.

The arrangement most suitable for the photometry and testing of incandescent lamps is a gallery or room large enough to be occupied by several workers, the walls being painted dead black. The photometer, preferably one of the Lummer-Brodhun form, is set up on a gallery or bench. On one side of it must be fixed a working standard, which may be an incandescent lamp; if this has a glass bulb much larger than the ordinary lamp, it will not so easily become blackened by a deposit of carbon. Its candle-power can be compared, at regular intervals and known voltages, with that of some accepted flame standard, such as that of Vernon Harcourt; in a lamp factory or electrical laboratory it is convenient to have a number of such large bulb standard lamps. This working standard should be maintained at a fixed distance on one side of the photometer, such that when worked at a standard voltage it creates an illumination of one candle-foot on one side of the photometer disc. The incandescent lamp to be examined is then placed on the other side of the photometer disc on a travelling carriage, so that it can be moved to and fro. Arrangements must be made to measure the current and the voltage of this lamp under test, and this is most accurately accomplished by employing a potentiometer. (see MEASURING INSTRUMENTS, ELECTRIC). The holder which carries the lamp should be of such a description that the lamp can be held with its axis in any required position; in making normal measurements the position of the lamp should be with its axis vertical, the filament being so situated that none of the turns or loops overlie one another as seen from the photometer disc. Observations can then be made of the candle-power corresponding to different currents and voltages.

The candle-power of the lamp varies with the other variables in accordance with exponential laws of the following kind:—

If A is the current in amperes through the lamp, V the voltage or terminal potential difference, W the power absorbed in watts, *c.p.* the maximum candle-power, and *a*, *b*, *c*, &c., constants, it has been found that A and *c.p.* are connected by an exponential law such that,

$$c.p. = aA^x$$

where x is a number lying between 5 and 6, generally equal to 5·5 or 5·6. Also it has been found that $c.p. = bW^3$ very nearly, and that

$$c.p. = cV^y \text{ nearly}$$

where c is some other constant, and y is a number nearly equal to 6. It is obvious that if the candle-power of the lamp varies very nearly as the 6th power of the current and of the voltage, the candle-power must vary as the cube of the wattage.

Abney and Festing have also given a formula connecting candle-power and watts equivalent to $c.p. = (W-d)^2$ where d is a constant.

Curves delineating the relation of these variables for any incandescent lamp are called its *characteristic-curves.* The life or average duration is a function of $W/c.p.$, or of the *watts per candle-power,* and therefore of the voltage at which the lamp is worked. It follows from the above relation that the watts per candle-power vary inversely as the fourth power of the voltage.

From limited observations it seems that the average life of a carbon-filament lamp varies as the fifth or sixth power of the watts per candle-power. If V is the voltage at which the lamp is worked and L is its average life, then L varies roughly as the twenty-fifth power of the reciprocal of the voltage, or

$$L = a V^{-25}.$$

A closer approximation to experience is given by the formula

$$\log_{10} L = 13{\cdot}5 - \frac{V}{10} - \frac{V^2}{20{,}000}.$$

(See J. A. Fleming, "Characteristic Curves of Incandescent Lamps," *Phil. Mag.*, May 1885.)

Allusion has already been made to the fact that carbon-filament glow lamps by use deteriorate in light-giving power. This is due to two causes. As already explained, carbon is scattered from the filament and deposited upon the glass, and also changes take place in the filament which cause it to become reduced in temperature, even when subjected to the same terminal voltage. In many lamps it is found that the first effect of running the lamp is to slightly increase its candle-power, even although the voltage be kept constant; this is the result of a small decrease in the resistance of the filament. The heating to which it is subjected slightly increases the density of the carbon at the outset; this has the effect of making the filament lower in resistance, and therefore it takes more current at a constant voltage. The greater part, however, of the subsequent decay in candle-power is due to the deposit of carbon upon the bulb, as shown by the fact that if the filament is taken out of the bulb and put into a new clean bulb the candle-power in the majority of cases returns to its original value. Since the lamp ceases to be as useful, considered as a transforming device, when the candle-power falls below a certain percentage of the original value, it has been suggested that for every lamp there is a certain point in its career which may be called the "smashing-point," when it is advantageous to replace it by a new one.

Ageing of lamps.

Variations of pressure in the electric supply exercise a very prejudicial effect upon the light-giving qualities of incandescent lamps. If for instance glow lamps, nominally of 100 volts, are supplied from a public electric lighting-station, in the mains of which the pressure varies between 90 and 110 volts, their life will be greatly abbreviated, and they will become blackened much sooner than would be the case if the pressure were perfectly constant. Since the candle-power of the lamp varies very nearly as the fifth or sixth power of the voltage, it follows that a variation of 10 per cent. in the electromotive force creates a variation of nearly 50 per cent. in the candle-power. Thus a 16 candle-power glow lamp, marked for use at 100 volts, was found on test to give the following candle-powers at voltages varying between 90 and 105:—At 105 volts it gave 22·8 c.p.; at 100 volts, 16·7 c.p.; at 95 volts, 12·2 c.p.; and at 90 volts, 8·7 c.p. Thus a variation of 25 per cent. in the candle-power was caused by a variation in voltage of only 5 per cent. The same kind of variation in working voltage exercises also a marked effect upon the average duration of the lamp. The following figures show the results of some tests on typical 3·1 watt lamps run at voltages above the normal, taking the average life when worked at the marked volts (namely, 100) as 1000 hours:—

At 101	volts	the life was	818	hours.
,, 102	,,	,,	681	,,
,, 103	,,	,,	662	,,
,, 104	,,	,,	452	,,
,, 105	,,	,,	374	,,
,, 106	,,	,,	310	,,

To remedy these effects, self-acting regulators have been devised by which the voltage at the points of consumption is kept constant, even although it varies at the point of generation. If, however, such a device is to be effective, it must operate very quickly, as even the momentary effect of increased pressure is felt by the lamp. It is only therefore in those cases where the working pressure can be kept exceedingly constant that high-efficiency lamps can be advantageously employed, otherwise the cost of lamp renewals more than counterbalances the economy in the cost of power. The slow changes that occur in the resistance of the filament make themselves evident by an increase in the per watts candle-power. The following table shows some typical figures indicating the results of ageing in a 16 candle-power carbon-filament glow lamp:—

Voltage regulators.

Hours Run.	Candle-Power.	Watts per Candle-Power.
0 . .	16·0	3·16
100 . .	15·8	3·26
200 . .	15·86	3·13
300 . .	15·68	3·37
400 . .	15·41	3·53
500 . .	15·17	3·51
600 . .	14·96	3·54
700 . .	14·74	3·74

The above table shows a gradual increase in watts per candle-power. This, however, does not imply necessarily an increase in the total power taken by the lamp, but is merely the consequence of the decay in candle-power produced by the blackening of the lamp. It is clear, therefore, that in estimating the value of an incandescent lamp for illuminating purposes the user must take into account not merely the price of the lamp and the initial watts per candle-power, but the rate of decay of the lamp.

The scattering of carbon from the filament to the glass bulb produces interesting physical effects, which have been studied by Edison, Preece, and Fleming. If into an ordinary carbon-filament glow lamp a platinum plate is sealed, not connected to the filament but attached to a third terminal, then it is found that when the lamp is worked with continuous current a galvanometer connected in between the middle plate and the positive terminal of the lamp indicates a current, but not when connected in between the negative terminal of the lamp and the middle plate. If the middle plate is placed between the legs of a horse-shoe-shaped filament, it becomes blackened most quickly on the side facing the negative leg. The above effect, commonly called the *Edison effect*, is connected with an electric discharge and convection of carbon which takes place between the two extreme ends of the filament, and, as experiment seems to show, consists in the conveyance of an electric charge, either by carbon molecules or something smaller than molecules. There is, however, an electric discharge between the ends of the filament, which rapidly increases with the temperature of the filament and the terminal voltage; hence one of the difficulties of manufacturing high-voltage glow lamps, that is to say, glow lamps for use on circuits having an electromotive force of 200 volts and upwards, is the discharge which thus takes place across from one leg of the filament to the other.

Edison effect.

A brief allusion may next be made to the mode of use of incandescent lamps for interior and private lighting. At the present time hardly any other method of distribution is adopted than that of an arrangement *in parallel*; that is to say, each lamp on the circuit has one terminal connected to a wire which finally terminates at one pole of the generator, and its other terminal connected to a wire leading to the other pole. The lamp filaments are thus arranged between the conductors like the rungs of a ladder. In series with each lamp is placed a switch and a fuse or cut-out. The lamps themselves are attached to some variety of ornamental fitting, or in many cases suspended by a simple pendant, consisting of an insulated double flexible wire attached at its upper end to a ceiling rose, and carrying at the lower end a shade and socket in which the lamp is placed. Lamps, however, hung in this manner, head downwards, are disadvantageously used because their *end-on candle-power* is not generally more than 60 per cent. of their maximum candle-power. For descriptions of the immense varieties of ornamental fittings employed, special manuals must be consulted. Suffice it to say here that in interior lighting one of the great objects to be attained is a uniformity of illumination and the avoidance of harsh shadows. This can be achieved by a proper distribution of the lamps. It is impossible to give any hard and fast rules as to what number must be employed in the illumination of any room, as a great deal depends upon the nature of the reflecting surfaces, such as the walls, ceilings, &c. A room papered with dark paper, or having dark oak panels, will require double as many lights to produce satisfactory interior illumination, as will be the case in a room whose walls are very light in colour, or which contains many mirrors. As a rough guide, it may be stated that for every 100 square feet of floor surface one 16 candle-power lamp placed about 8 feet above the floor will give a dull illumination, two will give a good illumination, and four will give a brilliant illumination. We generally judge of the nature of the illumination in a room by our ability to read comfortably in any position. In order that this may be done, the horizontal illumination on the book should not be less than one candle-foot. The following table shows approximately the illuminations in candle-feet, in various situations, derived from actual experiments:—

Domestic use.

In a well-lighted room on the floor or tables	1·0 to 3 c.f.
On a theatre stage	3 to 4 c.f.
On a railway platform	·05 to ·5 c.f.
In a picture gallery	·65 to 3·5 c.f.
The mean daylight in May in the interior of a room	30 to 40 c.f.
In full sunlight	7000 to 10,000 c.f.
In full moonlight	1/60th to 1/100th c.f.

From an artistic point of view, one of the worst methods of lighting a room is by pendant lamps, collected in single centres in large numbers. Properly speaking, the lights ought to be distributed in different portions of the room, and so shaded that the naked filament is nowhere visible to the eye, but the light is received only by reflection from surrounding objects. Ornamental effects are frequently produced by means of candle lamps in which a small incandescent lamp, imitating the flame of a candle, is placed upon a white porcelain tube as a holder, and these small units are distributed and arranged in electroliers and brackets. It conduces to economy in the consumption of electric energy if a sufficient number of switches is provided, so that only those lights which are actually required need be used. For details as to the various modes of placing conducting wires in houses, and the various precautions for safe usage, the reader is referred to the article I. GENERAL PRINCIPLES above.

We may conclude with a brief reference to the historical development of electric lighting in Great Britain. In the year 1879 the Government had its attention directed for the first time to electric lighting as a possible subject for legislation, and a consideration of the existing state of electric lighting was referred to a Select Committee of the House of Commons. No legislative action, however, was taken at that time—in fact, the invention of the incandescent lamp was incomplete. Edison's British master-patent was only filed in Great Britain in November 1879. In 1882 an important Electrical Exhibition was held at the Crystal Palace, and the perfected electric incandescent lamp was for the first time seen by the public in large numbers. Owing, however, to the legislative enactments of the first Electric Lighting Act, 1882, progress was at first retarded, and it was not until after 1888, when the Electric Lighting Amendment Act was passed, that much advance began to be made in the development of electric lighting. After an important inquiry held by the Board of Trade in May 1889, rapid progress began to be made, and from and after that date public and private electric lighting has extended at an enormous rate. At the end of 1893 there were rather over one million 8 candle-power lamps in use in Great Britain; at the end of 1895, about two millions; at the end of 1896, about three millions; at the end of 1898, five millions; and at the end of 1899, rather over seven millions.

Additional information on the subjects treated above may be found in the following books and original papers:—

Mrs AYRTON. *The Electric Arc.* London, 1900.—HOUSTON and KENNELLY. *Electric Arc Lighting. Electric Incandescent Lighting.*—S. P. THOMPSON. *The Arc Light*, Cantor Lectures, Society of Arts, 1895.—H. NAKANO. "The Efficiency of the Arc Lamp," *Proc. American Inst. Elec. Eng.*, 1889.—A. BLONDEL. "Public and Street Lighting by Arc Lamps," *Electrician*, vols. xxxv. and xxxvi., 1895.—T. HESKETT. "Notes on the Electric Arc," *Electrician*, vol. xxxix., 1897.—G. S. RAM. *The Incandescent Lamp and its Manufacture.* London, 1895.—J. A. FLEMING. *Electric Lamps and Electric Lighting.* London, 1899.—DREDGE. *Electric Illumination*, 2 vols. London, 1882, 1885.—A. P. TROTTER. 'The Distribution and Measurement of Illumination," *Proc. Inst. C.E.* vol. cx., 1892.—E. L. NICHOLS. "The Efficiency of Methods of Artificial Illumination," *Trans. American Inst. Elec. Eng.* vol. vi., 1889.—Sir W. DE W. ABNEY. *Photometry*, Cantor Lectures, Society of Arts, 1894.—A. BLONDEL. "Photometric Magnitudes and Units," *Electrician*, 1894.—J. E. PETAVEL. "An Experimental Research on some Standards of Light," *Proc. Roy. Soc.* vol. lxv. p. 469, 1899.—F. JEHL. *Carbon-Making for*

all Electrical Purposes. London, 1899.—Also the *Preliminary Report of the Sub-Committee of the American Institute of Electrical Engineers* on "Standards of Light."

(J. A. F.)

III. Electric Traction.

Electric traction, as treated in this article, will refer to the operation of vehicles for the transportation of passengers and goods upon tracks, as distinguished from what are known as telpherage systems on the one hand, and automobiles intended to run on common roads on the other.

History.

Possibly the first electric motor was that made by the Abbe Dal Negro, in Italy, in 1830. As early as 1835, Thomas Davenport, a blacksmith of Brandon, Vt., U.S.A., constructed and exhibited an automobile electric car, operated by batteries carried upon it. Robert Davidson, of Aberdeen, Scotland, began experimenting about 1838 with the electric motor as a means of traction, and constructed a very powerful engine, weighing five tons and carrying a battery of forty cells. This locomotive made several successful trips on Scottish railways, but was finally wrecked by jealous employees of the railway while it was lying in the car sheds at Perth. In 1840 a provisional patent was granted in England to Henry Pinkus, which described a method of supplying electric energy to a moving train from fixed conductors. A little later, in 1845, French and Austrian patents granted to Major Alexander Bessolo described practically what is to-day the third-rail system. In 1847 Professor Moses G. Farmer, of Maine, U.S.A., built a model locomotive operated by electricity, which he exhibited at Dover, New Hampshire, and later at other places in New England. Shortly afterwards Professor C. G. Page, of the Smithsonian Institution, in Washington, constructed an electric railway motor, which made a trip on April 29, 1851, from Washington, D.C., to Bladensburg, Md., over the Baltimore and Ohio Railway. This machine carried 100 Grove's cells, and attained speeds as high as 19 miles an hour. Perhaps the beginning of modern electric traction may be said to date from 1879, when the firm of Siemens & Halske put in operation the first electric railway at the Industrial Exposition in Berlin. In America it was not until a year later that real work began, and Mr T. A. Edison built an experimental line near his laboratory in Menlo Park, N.J. In 1880 a locomotive driven by accumulators was constructed and operated at a linen bleaching establishment at Breuil en Auge, in France; and in 1881 a similar car was worked upon the Vincennes tramway line. On May 12, 1881, the first commercial electric railway for regular service was opened for operation at Lichterfelde, in Germany. The first really noteworthy road was that constructed at the Giant's Causeway at Portrush, in the North of Ireland. This line was 6 miles long, and the power was obtained from turbine wheels actuated by a cascade on the river Rush. The method of supply was, curiously enough, the third-rail. In 1883 invention in electric railways seems to have taken a decided advance in America. It was in this year that the conflicting interests of Edison and S. D. Field were consolidated; and at the same time Van Depoele and Daft began their experimental work, which later resulted in numerous commercial railways. Next year Messrs Bentley & Knight opened to the public in Cleveland, Ohio, U.S.A., a railway operated by an open-slot conduit, and for the first time worked in competition with horse traction on regular street railway lines. For the next two years much experimental work was done, but it may be said with fairness that the first of the thoroughly modern systems, in which a large railway was equipped and operated under service conditions by electricity, was the line built in Richmond, Va., U.S.A., by Frank J. Sprague in 1887. This railway had 13 miles of track, and started with an equipment of forty cars. It has been in continuous and successful commercial operation ever since. The original Richmond system was in all its essential particulars the overhead trolley system now in use. Many improvements have been made in the construction of the motors, the controllers, the trolleys, and the various details of car equipment and overhead construction, but the broad principles have not been departed from. The success of the Richmond line called the attention of tramway managers to the advantages of electricity as a motive power, and its substitution for other systems has progressed with astonishing rapidity. In the United States practically all the horse and cable tram-lines have been or are being provided with one form or another of electric traction, and Europe also is at present actively engaged in changing from the older methods of tramway operation to electrical methods. In the United States the original city lines have been extended into the suburbs, and interurban lines have been built, so that there are continuous electric lines of several hundred miles in length. The interurban service has developed electric railways competing with steam railways in speed and in the size and comfort of the cars. Electric locomotives have been constructed for special purposes. In Baltimore, Md., U.S.A., the Baltimore and Ohio Railroad has a tunnel which, with its covered approaches, is over a mile and a half long, and in which is a grade of 42 feet to the mile. The steam locomotive gases, due especially to the very heavy freight trains that were hauled, made the operation of the tunnel impossible. Electric locomotives were built and put in operation in 1895. These machines weigh 96 tons, all of the weight being on the drivers, and they can haul trains of over 2000 tons up the grade. Other locomotives of various sizes and designs have also been built.

Advantages.

At the present time it may fairly be said that electricity has shown its superiority over its competitors—horses and moving cables—for tramway work. It is cheaper and more flexible. The relative cost of operation varies, of course, with the local conditions, but a fair average estimate would be that cable lines cost 25 per cent. more to operate than electric, and horse lines 100 per cent. more. The increased speed of the electric cars and the comfort rendered possible by larger vehicles always increase the receipts when horse traction is replaced by electric, while the latter, as compared with the cable, allows better and easier control of the car and a much greater possible speed variation. The installation of an overhead electric line costs less than a cable system, though the expense of a conduit electric line is about the same. By the extension of the urban tramway systems into the suburbs and the construction of interurban lines, electricity has come into competition with steam. Here the conditions are different. For ordinary suburban service the electric cars, running through the city streets and on the highways, cannot, in speed, compete with steam trains operated on private rights of way. The fact that they run more frequently and can be entered anywhere along the line gives them an advantage, and within limited distances they have taken a large proportion of suburban traffic from steam railways. For long-distance service, in order to compete with steam, a speed much greater than that used on ordinary tram lines must be used, while owing to the time spent on the car more attention must be paid to the comfort of the passenger. Speed and comfort being equal, the great advantage of electricity is that, when it is used, the most economical way of transporting a given number of passengers between two points is in a large number of small trains; with steam the converse is true. A frequent service is a great attraction to passengers. But when the freight question is considered, the tables are turned. The most favourable condition for freight haulage is with trains of maximum size. This is in accordance with the requirements of economy in steam transportation, but gives the maximum investment and minimum economy for an electric system. Moreover, the comparatively slow freight trains would make a high-speed service impossible at short intervals on the same tracks. We may conclude, then, that at the present time electricity does not compare favourably with steam either for heavy freight service or for through passenger service where frequent trains are not required. For smaller distances, where short train-intervals are of importance in attracting traffic, electricity has advantages over steam both for passenger and express service.

Systems of electric traction may be divided broadly into two classes, the one employing continuous, the other alternating currents to drive the motors. Both of these classes may be further divided with reference to the conducting system employed between the source of current and the motor. The system may also be divided according to operative units into three classes—the single car, the train pulled by one or more directly controlled locomotives or motor cars, and the train operated by two or more motor cars under a common secondary control. This last is called the "multiple unit system."

Continuous-Current Systems.—The applications of continuous current to electric traction comprise six principal varieties, with numerous modifications and combinations. In all of them the motors are operated under a constant, or approximately constant, potential difference. The system in which cars were connected in series by automatic switches, in limited use in the United States in 1888 and 1889, has now disappeared, and the parallel system of connexion, in which the cars are bridged across between the two sides of a conducting system maintained at a substantially constant voltage, has become practically universal.

Single trolley. The overhead conductor and track-return construction is the standard for street railway work in most of the cities where electric traction is employed, though there are some notable exceptions. In its present development the system may be said to have grown out of the work of Sprague in Richmond in 1887. Over the track is suspended a bare wire, generally of hard-drawn copper, known as the trolley wire. The normal practice is to use a wire not less than 0·325 of an inch in diameter to assure permanence, since smaller wires wear out rapidly from the friction of the trolley and the burning of the surfaces of contact. The wire is usually of circular cross section. Sometimes wires of other sections have been used, notably one having a cross section similar to the figure 8, but the advantage of these forms is problematical, while the difficulty attending their proper installation is considerable. In some cases the working conductor, or trolley wire, is suspended at one side of the track, connexion with it being made by a side-bearing trolley, but its usual place is directly over the track, as this arrangement leads to simpler and more efficient construction of trolleys, &c. For certain special cases, where very large currents are employed, the overhead conductor is made of bar metal or structural shapes. In the Boston (Mass.) subway, where the traffic is very heavy, a bar of rectangular section is used, supported at frequent intervals from the roof. In the Baltimore and Ohio Railroad's tunnel at Baltimore, Md., the steel working conductor originally consisted of two Z bars forming a trough, the current being collected by an iron shoe, but this form has been replaced by a sectional third rail. But whatever the nature of the conductor, it is usually insufficient to carry the current necessary for the operation of the system without excessive loss. Recourse is therefore had to feeders or reinforcing conductors. These may be of any form, but are most frequently copper wires or cables of large section, connected at intervals of a few hundred feet to the working conductor. They are sometimes carried on poles, but municipal ordinances frequently require their installation in underground conduits. In general, it is customary to divide the working conductor into sections of from 1000 to 5000 feet in length, insulated from one another and fed separately through manual or automatic cut-out switches, so that an accident causing a short-circuit or break in continuity on one section will not impair the operation of others.

In ordinary street railway construction there are two methods of suspending the trolley wire in vogue. The most usual construction is to hang it from insulators attached to transverse wires running between pairs of poles set on opposite sides of the track. Bracket arms attached to poles are often used, especially on suburban lines; they are frequently double, or T-shaped, and placed between the two tracks of a double-track line. In the standard construction for either variety of suspension, the insulators are bell-shaped, and composed of some hard moulded or vitreous material. The trolley wire is supported by a clamp about 9 inches long, which embraces about three-quarters of its circumference. This clamp is usually made of bronze, and is now generally fastened to the trolley wire by a screw, causing the two parts of the clamp to close upon the wire as would the jaws of a vice, or is automatic, clamping the wire the more tightly as the strain upon it increases. It was formerly considered expedient to solder the wire into the clamp, but this practice is now generally abandoned. The insulating bell is so designed that its material is subjected only to compression stresses by the weight of the wire. It is provided at its upper part with a single catch for attachment to the transverse wire, or to the bracket arm. If a span wire is used, it is fastened to the poles, there being turn buckles to tighten it, while a strain insulator on either side gives a double insulation between it and the poles. With a bracket construction it was formerly the custom to attach the insulator directly to the arm, but the blow of the trolley broke great numbers of insulators, and it has therefore become the practice to adopt some more flexible method of attachment, a number of different forms being in use. The poles between which the span wires are stretched, or to which the bracket arms are attached, are of wood or iron. They are firmly set in the ground, usually with concrete.

In order to provide a proper return path for the current, the track must be made electrically continuous. This is accomplished by bonding the individual lengths of rail together in some way, or by actually welding them together to form a continuous length. There are many types of rail-bonding. In most of them holes are drilled in the ends of adjacent rails, and a copper conductor inserted between them, its ends being in some way forced against the walls of the holes. In one type the bond is in the form of a hollow cylinder, the ends of which are inserted in the holes in the rails, and a tapered steel pin driven in so as to expand the cylinder out against the rail. In another form the end of the bond is a solid cylinder, which is upset by hydraulic pressure, forcing it against the rail. A semi-plastic amalgam of mercury has been used to give a contact between the adjacent rails and the tie-plate connecting them. The most usual practice is to use a short bond covered and protected by the tie-plates. Tracks used for a return circuit are cross-bonded at intervals. It very often happens that the track return has too great an electrical resistance. In this case it is reinforced by conductors connected to it at intervals, and extending back to the power-house. Neglect to provide a proper return circuit has caused a great loss of energy and excessive electrolytic action in many places. The lightning arresters provided on overhead lines are placed on the poles at intervals determined by the location of the line.

Double trolley. In a few places the municipal authorities, in order to avoid the disturbances on telephone lines due to the fluctuation of the trolley current, and the electrolysis of gas and water pipes which may arise from a grounded return, have required the erection of a double overhead system. In this each track has two trolley wires forming a complete metallic circuit. The largest system of this kind is in Cincinnati, Ohio, U.S.A., where in 1900 there were over 225 miles of tramlines. The system has the advantages to which it owes its existence, but the multiplicity of wires at crossings, right-angle turnouts, &c., is so complicated that automatic switching cannot be attempted. The man in charge of the car removes the double trolley from the wires at such points, and replaces it when they are passed. The construction adopted, except as regards the points mentioned, is practically similar to that already described for the track-return system.

Open-slot conduit. A very large number of patents have been granted in various countries for electric traction systems in which one or both of the fixed conductors are installed in a conduit underground, communication being had with them by means of an open slot, into which projects a current-taking device of some nature carried by the car as it moves along. A system of this character was installed many years ago at Blackpool, in England, and later one was very successfully operated in Budapest. The first large and important installation of this character to be made was in Washington, D.C., U.S.A., where a considerable system of street railways was changed from horse operation to this new method. The success of this system, and of experiments made on Lenox Avenue, in New York city, led to the construction of many miles of railways of the conduit type in the latter city. American practice in conduit construction has become fairly well standardized. The conduit is oval in shape, its major axis being vertical, and is formed of concrete. An excavation about 30 inches deep is first made, and in this are laid cast-iron yokes weighing 410 ℔ each, and spaced 5 feet apart, centre to centre. Every third yoke contains bearings for a hand-hole plate, and weighs about 600 ℔. These yokes surround the conduit proper, and are provided with extensions on each side, for the attachment of the rails. In the older construction the rails were laid directly upon the iron of the yokes, steel wedges and shims being used under them for the final alignment of the rails. In the more recent construction, on the Third Avenue Railroad in New York City, a wooden stringer, 6 by $6\frac{3}{4}$ inches in size, is laid along from yoke to yoke on the bearing surfaces, and the rail laid upon this. The rail is held down on the yoke by means of two bolts at each bearing-point, these bolts having turned-up heads which embrace the foot of the rail. The slot-rails, or Z bars forming the two jaws of the $\frac{5}{8}$ inch slot, are bolted to the upper part of the yokes. The weights of metal used per linear yard of construction of this type are: cast-iron, including both types of yokes, 500 ℔; track rails, 214 ℔; slot rails, 116 ℔; conductor rails, 42 ℔; conduit plate, 16 ℔—nearly 400 ℔ of rolled steel per yard. After the rails, which are of a high girder type, are fastened in place, thin plates of sheet steel are bent into the oval holes in the yokes, extending from yoke to yoke, and forming the inner surface of the completed conduit. Around this is carefully laid a shell, 4 inches thick, of Portland cement concrete. The yokes are furnished with lugs which serve to retain temporarily wooden boards forming a mould in which the concrete is rammed. Sectional wooden shapes serve to hold the thin steel lining in place while the concrete is hardening. Around this concrete tube, and on each side of it, to form a basis for the street pavement, is laid a mass of coarser concrete. In each side of the special yokes is placed an insulator of porcelain, protected by a cast-iron shell, and carrying a support for the conductor-rail, which is of T-shaped steel, weighing 21 ℔ per yard. It is in 30-foot lengths, and is supported every 15 feet by the insulators, the ends of separate rails being matched at and held by an insulator support. This rail is, of course, bonded with copper bonds. Two such conductor-rails are installed in the conduit 6 inches apart, the flat faces corresponding to the upper surface of the T being placed toward each other. Elaborate provisions for drainage and inspection are also provided, depending upon the situation of the tracks and nature of the street. The current is fed to the conductor-rails by heavy copper conductors of from 500,000 to 1,000,000 circular mils. cross-section, insulated and lead-covered, laid in ducts alongside of or between the two tracks of double-track systems. Connexion is made between the cars and the conductor-rails by means of a "plough," carried by a hard steel plate, which is channelled to receive the insulated wires leading up to the controller on the car. The plough carries two cast-iron rubbing-blocks, which are pressed outward into contact with the conductor-rails by springs, the two being, of course, very carefully insulated from each other and from the other metal-work of the plough. It has been found expedient in practice to reverse the polarity of the current used on these conduit roads from time to time, since electrolytic deposits, formed by small leakage currents in the vicinity of insulators, &c., are thus redissolved before they become a source of trouble. This system is much more expensive to install than the overhead trolley system, but experience has shown that it can be as economically operated. Most of the troubles that have occurred have been due to lack of experience, but on the whole they have not been more serious than those experienced with overhead systems.

Closed conduit. The great expense of the open conduit has led numerous inventors to bring out systems of operating electric railways by means of closed conduits, or sectional third rails, in which the working-conductor is laid on the surface of the ground between the rails, and is connected with the source of current only as the car passes over each section. In this way the immediate section or portion of the working-conductor under the car is electrically active, but other sections are not, and all danger to the passage of street traffic is removed. Up to 1900, nearly one thousand patents for this type of railway construction had been granted by the United States Patent Office alone. So far the system has been introduced in but few places, but its performance has been more than promising, and it is thought that it will be more extensively adopted in the future. Among the more important railways at present equipped with it may be mentioned one in Paris, using the Diatto system, and one at Monte Carlo, where the Westinghouse system is installed. In both these the current is supplied by means of "buttons" or metallic discs laid flush with the surface of the street between the tracks, and connected through switches to a working-conductor. Under the car is installed a current-taking device in the shape of a long runner or skate, which runs over the buttons and is appropriately connected with a storage battery on the car, so that when it touches one of the buttons current is sent from the battery through a system of electromagnets operating the switches which connect that particular button to the feeding system, and thus the runners are enabled to pick up current for the operation of the motors on the car. The various systems differ in the method of connecting the contact rail or button with the live conductors: in some a magnet on the car works a mechanism to make the desired contact, in others a current from batteries on the car actuates a switch located near the track, in others still compressed air is employed for the purpose, as in the new system being installed in the Baltimore and Ohio tunnel at Baltimore.

Third-rail system. The third-rail system, which is a development of the overhead trolley and track-return system, has been applied to several large and important railway installations, especially in the United States, and in the prolongation of the Orléans Railway in Paris from the Place Valhubert to the new station at the Quai d'Orsay. Its name almost sufficiently indicates its method of operation. A rail similar to the track-rails is laid upon insulators and forms the working-conductor. On the elevated railways in New York, Brooklyn, Boston, and Chicago a pressure of about 600 volts is used between this rail and the running-rails which form the return circuit. Contact is made with the third rail by means of a bronze or cast-iron shoe, either resting upon the rail by its own weight, or pressed down upon it by springs. This is generally attached to some part of the truck of the car in preference to any part of the body of the car, so as to avoid any vibration or swaying due to the movement of the body upon its springs. The third-rail system has been adopted in many instances where large and powerful trains are to be operated on private rights of way, but it is nowhere in use for electric traction upon highways or in streets where there is any passing of foot passengers or vehicles. An excellent example of such construction may be found in the Albany and Hudson Railroad, which connects the City of Albany with the town of Hudson, in New York State. Here the length of the road is about 32 miles, the track being of standard gauge and laid with a 60-pound T-rail. A T-rail of the same size, raised about 1 foot above the level of the running-rails, is used for the electrical conductor, and is installed on insulators situated 5 feet apart on the ends of the cross-ties. All these rails are well bonded with copper bonds at the joints, and at road crossings, which on this railroad are at grade, the third rail is omitted for a distance nearly equal to the length of a train. Appropriate cast-iron shoes, fixed to the trucks of the front and rear cars of a train, bridge the space, so that the forward shoes are running on the rail past the break before the rear shoes leave it. Upon this railroad motors of considerable size and power are used, and both passengers and freight in their original cars, as received from connecting steam railways, are transported. Other examples of third-rail construction occur in the underground systems of the City and South London Railway, the Waterloo and City Railway, and the Central London Railway in London, and the Versailles Division of the Western Railway of France. Experiments of great interest and value have been made by the New York, New Haven, and Hartford Railroad, upon a section of its track in the State of Connecticut, with a very simple system of third-rail construction, in which the conductor-rail is placed between the running-rails. This rail is of a curious, special section resembling the letter A, and is merely laid upon wooden blocks saturated with insulating materials, its form being such as to deflect rain and other moisture away from the insulators. Very high speeds have been attained on this section of track, upon which motor cars haul the standard equipment of freight, baggage, and passenger cars of the railway.

Accumulators. One of the oldest forms of electric traction is by accumulators. In brief, its principle is that storage batteries, or accumulators, are carried on the car, which becomes a veritable automobile. It has been the usual practice to install about eighty cells giving a pressure of 160 to 175 volts at the motors; these are recharged after the car has run about 25 miles. In general, the accumulators are not charged in place, but the car is supplied with a new set, fully charged, at the end of a run of about the length mentioned. The system has been installed in a very large number of places in Europe and America, but has never shown the gratifying commercial success which the direct-conduction systems exhibit, on account of the high cost and depreciation of storage batteries. In some places, notably in Hanover, Germany, where legislative ordinances have forbidden the overhead conducting system in city streets, a combination has been used whereby accumulator cars run in the city districts from the energy stored in their batteries, and in the suburbs operate directly as overhead trolley cars, the batteries being charged at the same time from the overhead system.

Alternating-Current Systems.—There has been much discussion on the subject of electric traction by means of alternating or polyphase currents, but little work has been done. The polyphase current is much used as a means of distributing energy from a central power-station over extended lines of railways, but is generally converted into direct current through the agency of rotary converters, and fed to the lines as such. There are, however, a few railways working directly with induction motors upon a three-phase system of supply. Prominent among these may be mentioned the Jungfrau Railway in Switzerland. Upon this line the rails are used as one of the three conductors, and two trolley wires are suspended above the track. The locomotive is provided with two trolleys, one running upon each wire, and consists simply of an induction motor coupled through appropriate gearing to the mechanism of the truck. For starting, a large resistance is introduced into the rotor, or secondary, circuit of the motors by means of collecting rings placed upon its shaft, upon which bear brushes. This resistance is cut out as the speed increases, until it is all withdrawn and the rotor is short-circuited, when full speed is attained. It has been found that potential differences of about 500 volts in each phase can safely be handled, and it is claimed that the one or two railways using alternating currents have shown gratifying results in practice. It is believed that the equipment of long lines of railway, having comparatively infrequent and heavy trains, will furnish an opportunity for the wider introduction of polyphase systems, and that the latter will be largely developed in connexion with the electrical operation of existing steam railways.

In the system elaborated by Messrs Ganz, of Budapest, and known as the "Cascade" system, an arrangement is introduced analogous to the "series-parallel" method used in direct current working. There are two motors, or a multiple of two, to each car or locomotive, just as there are two cylinders in a compound engine, and the two are in mechanical connexion with each other. One of them, which may be called the primary, is wound for a higher tension than the other (the secondary), and the maximum speed of the latter is only half that of the former. The three-phase current, which has a frequency of 15, is conveyed by means of two overhead trolley wires and the rails upon which the trains run. It enters the stator coils of the primary motor, and thereby sets up an induced current in the rotor of that motor, which, of course, begins to revolve. The frequency of this induced current is proportional to the "slip" between the rotor and the revolving field of the stator, and will therefore gradually decrease as the speed of the motor increases up to the speed of synchronism. This induced current generated in the primary rotor, supposing that the train is being started from rest, is led to the stator of the secondary motor, and the rotor of this in turn has a current generated in its coils of a frequency proportional to its "slip." This second current is taken through a variable resistance in circuit with the secondary rotor. Supposing now that the two motors, which are mechanically linked together, have attained half the full speed for which the machine is designed—that is, the full speed of which the secondary motor is capable—then the "slip" of the primary motor being 50 per cent., the frequency of the current induced in its rotor and passing through the stator of the secondary motor must be about 7½, and the secondary motor will be running about synchronously with the current it is receiving. Thus the energy from the main supply is all being taken by the primary stator, which hands on half to the secondary motor to be converted into motion, and itself transforms the other half into mechanical effort. At this stage of half-speed the secondary motor has done its share in accelerating the train and becomes useless, because as soon as it begins to be run faster than the speed for which it is constructed it ceases to act as a motor and becomes a generator, exerting a retarding influence on the speed of revolution instead of helping it. At this point, therefore, it is cut off from electrical connexion with the primary motor, and allowed to run idle, the variable resistance that was joined up with its rotor being transferred to that of the primary. Acceleration now proceeds by the aid of the primary motor alone, the resistance being automatically altered from its maximum to zero as the motor increases its speed from half to full and approximates to synchronous running. Under no circumstances is it possible to exceed the maximum designed speed, even when going down a hill, for as soon as the speed of the motor is forced beyond that for which it is intended it ceases to be a motor, and becoming a generator experiences a negative torque which checks its pace. When it is desired to stop the train the same property is utilized; the secondary motor is put in series with the primary, and, as its rotor is then being driven at double its normal speed, it also is subjected to a negative torque, which continues until the machine has been brought to half-speed. In this way the greater part of the kinetic energy of the moving train is absorbed by being reconverted into electrical energy, and the mechanical brakes are called upon to do comparatively little in effecting a stop. There is thus a saving in the wear of the tires and brake blocks and also of the rails, since it is not possible to skid the wheels. The current of 3000 volts being almost certainly fatal if taken through the body, very careful precautions are adopted to prevent accidents. Thus the driver does not actually touch any of the switches by which the train is controlled, but they are all operated by means of compressed air; the same agency is used to raise the trolley poles up to the trolley wires, and to work the variable resistance. This last is of a liquid form, but instead of the metal plates being lowered into the solution (which is of carbonate of soda) the liquid is forced up against the plates by the air pressure to the required height. Breakage of a trolley wire is also guarded against by an arrangement whereby its snapping, or even its undue sagging owing to elongation, closes a short circuit and by melting safety fuses instantly renders the line dead. This cascade system has been adopted in substitution for steam-power on the Lecco, Sondrio, and Chiavenna line in Italy, 66 miles long.

Generation of current. The question of the generation and the distribution of the current only belongs to this article in so far as electric traction has introduced peculiarities in the type of apparatus or the methods of its use. In a continuous-current station the current is generated at an approximately constant potential, varying from 500 volts to 700 volts on different systems. As the load is apt to fluctuate, except in large stations, within wide limits, the machinery must be built to stand the most severe usage. The engines are more massive than would be necessary for constant loads, and the dynamos must be built to stand sudden overloads without destructive sparking; usually, indeed, they are considerably over-compounded, not so much for the sake of raising the voltage, as to strengthen the field and prevent sparking on overload. When a number of machines are to be run in parallel—as is usually the case—they are provided with "equalizing" switches, which serve to throw the series fields in parallel. As a result, if one of the machines tends to increase its armature current beyond its proper amount, the current in the series fields does not increase with it, but retains its normal proportion. The armature reaction and resistance fall of potential in this machine would both tend to increase, and its armature potential, and therefore its current, would return to its proper value. From the dynamos the current from each machine goes through an ammeter and automatic circuit-breaker to the main "omnibus" bars, then through the station ammeter to the feeder "omnibus" bars, then through ammeters and circuit-breakers to the feed-cables. As a rule, watt-meters are provided to measure the output of the station, and if an overhead system is being supplied, lightning arresters are installed. Where continuous currents are used to operate cars at considerable distances from the generating stations, "boosters" are used. These are series-wound dynamos driven at a constant speed, through which the current that is to feed the distant section of the line is passed. Usually the characteristic of the booster is so calculated that the amount by which it raises the voltage for a given current just equals the fall of potential in the feeding-line for the same current. The result is that the potential at the end of the line will be the same as that at the station. The question of economy, as between putting in additional copper and wasting energy in the booster, is easily calculated; the advantage is more and more on the side of the latter as the distance increases and the service becomes more infrequent. It is necessary to the satisfactory operation of a system that the variations of voltage should not be too great, so boosters sometimes become a practical necessity, irrespective of the question of strict economy. As traction systems have been combined and extended, the area of operation of many of the companies has grown so that a number of direct-current stations are used for a single system. The limit of distance to which electric energy can be economically supplied at the comparatively low voltages employed is not great, and the advantage of having one or two large stations to supply a system, in place of a number of smaller ones, is evident. This fact has led to the use of high-potential alternating currents for the distribution of energy, the voltage being reduced at the points of consumption, and in most cases changed to a continuous current by rotary converters. At first difficulties, due to defects of the converters, were experienced, but these have been largely eliminated, and the system may be considered as satisfactory. If alternating currents are used for the car motors, the economical distribution of energy is greatly simplified, the rotaries being eliminated, and their first cost and losses and expense of operation saved. The expense of operating sub-stations containing rotary converters is necessarily large, and the capital outlay required for them is often greater than that for the generating station.

Cars. As a rule, the cars used for electric traction have varied but slightly from the type of tramway car prevalent in different localities. The tendency, however, has been to increase their size, and to make them more ornamental as well as more comfortable. For electric railway work, as distinguished from tramway work, the cars have followed the pattern that has become standard on steam lines. The trucks used for electric cars are made of steel, with heavy axles and heavy suspension bars for the electric motors. For smaller vehicles, a single four-wheel truck is used, the wheel base being limited by the curvature of the track, but not as a rule exceeding 7½ feet. For the longer and heavier cars, two four-wheel trucks are employed. If two motors are used on a double-truck car, and if the grades on the road are very heavy, the trucks are made on the maximum traction pattern, in which the greater part of the weight of the car is on the motor-driven wheels. For very large high-speed cars, trucks are used of practically the same type and weight as are employed on steam railways.

Motors. Electric motors for traction purposes have been highly elaborated and developed. At first they drove the car axles through belts or sprocket chains, the motor being sometimes attached to the car, sometimes to the truck. At Richmond, however, in 1887, the Sprague method of communicating the power from the motor axle to the car axle was put into practical operation, and this has with slight modifications been retained. It consisted of sleeving one end of the motor on the axle, suspending the other flexibly from the car body or truck, and driving from the armature through spur gearing. At first the motors were too small for the work demanded of them. Their high speed required a double reduction in gearing, their over-heating caused continual burn-outs, and the sparking at the commutators necessitated constant repairs. These defects were gradually eliminated. The motors were made larger, the quality of the iron and insulation was greatly improved, and finally a four-pole motor requiring only a single speed reduction by spur-gearing was produced. Since that time further improvements in material and design have been introduced, and the present motor has been evolved. Almost all the standard modern traction motors are of the same general design. The armature is built up of carefully tested iron discs, which are deeply slotted to make room for the coils. These are wound and insulated separately, and placed in the slots in the armature cove; sometimes they are held in place by binding wire, sometimes by wedges. The commutator is put in place and soldered, and the proper end-coverings put on. The magnet frame is made in two parts, of cast steel, enclosing the entire armature. A lid in the top casting gives access to the brushes, which are of carbon. The field coils are wound on forms and properly insulated. The machine is series-connected. When in operation it is practically water and dust proof, and with proper attention is a very durable piece of machinery. Although the standard design of motors is at present based on a single-reduction gearing, yet there are in operation traction-motors which are not geared. This is the case with those on the City and South London Railway, the Baltimore and Ohio tunnel locomotives, and in other special cases. In the City and South London machines the armature is directly on the axle; on the Baltimore and Ohio locomotives the motors are sleeved on the axles, there being a slight play between the sleeve and the axle, which allows a flexible support. The wheels are driven by arms projecting from the armature shaft.

There is no fixed method of rating the output of traction-motors. Most manufacturers, in giving a certain horse-power capacity, mean that at the given rating the motor will run an hour with a rise of a certain number of degrees, not that it can be run continuously at the power given. Another system of rating depends on the draw-bar pull which the motor can develop under normal conditions of voltage and speed. Uniformity is greatly needed.

Controllers. One of the most important parts of the equipment of an electric car or locomotive is the controlling device. In the early days of electric traction a number of different methods of regulating the speeds of the cars were used, but they have been reduced to practically one standard method. In the old Sprague system there were at first no resistances outside of the motors themselves, but the field coils of the motors were divided into sections, and by changing the relative connexions of these sections the total resistance of the circuit could be changed; at the same time, the strength of the field for a given total current was either increased or decreased. In other systems the fields and armatures of the motors were not changed in their relation to one another, but external resistances were cut out and in by the controller. It is evident that if we wish to change the speed of a car within wide limits, all the other factors remaining constant, there will be a very considerable loss by either of these methods of regulating, unless the relative connexions of the motor armatures can be changed. This can be done by putting the armatures in series where low speed is desired, and in parallel where the speed is to be increased. This method was tried in the early days of electric traction, at Richmond, and discarded, but it has been again taken up, and is now the standard method of regulation in ordinary tramway work. Roughly speaking, when the car is started the controller connects the two armatures in series with an external resistance, then cuts out the external resistance, then breaks the circuit, then throws the two armatures in parallel with an external resistance in series with them, and then cuts out this external resistance. By this method a considerable range of speed is attained at a fair efficiency. The controller consists of a cylinder having on it a number of copper segments so arranged that on rotating the cylinder different connexions are made between stationary fingers that bear on these segments. In the first types much difficulty was experienced from the burning of the segments and fingers, due to the sparking on breaking the circuit, but this has been to a large extent obviated by using magnetic blow-outs at the point of break. (A magnetic blow-out is simply a small magnet so arranged that the arc caused by breaking the circuit takes place in the magnetic field.) There is a reversing lever on the controllers separate from the controller handle. When it is desired to run trains of cars and to accelerate them rapidly, it is sometimes necessary to have more than one car equipped with motors. In this case all the motors must be controlled from one point, and a number of ingenious devices have been evolved to accomplish such "multiple control." In general, each car has its own controller, and the controllers are operated by either electric or pneumatic power from switches on each platform of any of the motor cars.

Brakes. For tram cars of ordinary sizes, hand-brakes are used, these being generally spindle brakes, with leverage enough to handle the comparatively heavy cars. When the size and speed of the car increase, however, these hand-brakes do not give sufficient control, and power brakes have to be adopted. Of these there are two general forms that have proved successful in practice and are largely used. The first is an air-brake, which is similar in its mechanical operation to the air-brake used on steam railroads. The compressed air required for the operation of the brake is obtained by means of an air-pump driven by an electric motor, the circuit of the motor being controlled by a switch actuated by the pressure of the air in the receiving tank. As this pressure rises to a predetermined value, the device acts and interrupts the supply of current to the motor, which is thus stopped. When the pressure falls below a determined minimum, the device operates in the opposite direction, and the motor and pump start. Sometimes, when the car has not to make many stops, the motor-driven compressor is dispensed with, and tanks stored with air at a high pressure operate the brakes during the trip or part of the trip. Of electric brakes there are several varieties. Perhaps the one most extensively employed consists of two iron discs, one keyed on the axle but capable of moving along it, and the other held firmly on the frame of the truck. By means of a coil set in a recess of annular form turned in the face of the latter the discs are magnetized transversely, and are drawn together with greater or less pressure, dependent on the amount of current that is allowed to pass. It is customary to arrange the current connexions in this form of electric brake so that when the handle of the controller is turned beyond the stopping position the current is cut off from the source of supply, and the motor running as a dynamo furnishes the current to work the brake.

Of the numerous accessories necessary in the operation of electric railways one of the most important is the trolley.

Trolleys.

For an overhead system this consists in general of a metallic rod or tube mounted upon the top of the car and pressed upward against the trolley wire by springs. At the upper end of this trolley pole is generally placed a bronze wheel which runs along the under surface of the wire. On the continent of Europe considerable use has been made of bow trolleys, which consist of light metallic bow-shaped structures, sustained in place by springs and running along on the under side of the wire against which they rub. The designs already patented for trolleys are almost innumerable. Besides the trolleys, cars are ordinarily equipped with switches which are used to break the trolley circuit, with fuses or automatic circuit-breakers, with electric lamps, lightning arresters, and with the necessary car wiring. The fuses or automatic circuit-breakers are used to guard against an excess of current through the motors, and when they are fitted the ordinary platform switch can be dispensed with. These automatic breakers can be set for any desired current. (L. DU.)

IV. Industrial Development.

The advantages resulting from the modern industrial development of electric engineering cannot be measured merely by the return upon capital invested. The indirect social benefits which have followed on electric invention are considerable and far-reaching, and examples are afforded in all the various departments of industry in which electricity has found application. The electric telegraph has proved a powerful agent in the detection and prevention of crime; the use of the electric light in houses improves health and aids cleanliness; electric traction is, by cheap fares and rapid transit, transforming the conditions of town life, and the adoption of electric power in factories is improving the morale and increasing the efficiency of labour. Thus whilst exerting elevating influences upon the advance of civilization, electricity is also an unseen factor tending to reduce the cost of production of commodities with which at first sight it has no association.

For the best commercial development of electrical science facilities are needed which can be granted only by the State or the local authorities. Wires have to be erected on poles, or attached to premises, or, preferably, placed underground, and electric traction involves interference with the public roads. It is undesirable that any of these operations should be carried on in the same place by more than one authority. This precludes effective competition; the electrical industry in Great Britain ripened at a time when public opinion was averse from the creation of further monopolies, and was disposed to think that railway, water, and gas companies had in the past received valuable concessions on terms which did not sufficiently safeguard the interests of the community. There are, unfortunately, no fixed principles governing the relations between the State or municipal authorities and commercial companies. The great development of industries by means of private enterprise in the early part of the nineteenth century produced a reaction which, between the years 1870 and 1901, had the effect of discouraging the creation by private enterprise of undertakings partaking of the nature of monopolies. The conditions which were imposed on these for the purpose of safeguarding the interests of the public were very tentative, and a former permanent secretary of the Board of Trade has stated that the remedies have sometimes proved injurious alike to the public and to the companies. One of these tentative and mischievous measures was the Tramways Act of 1870. Twelve years later it was followed by the Electric Lighting Act of 1882, and not one of the sixty-two Electric Lighting Provisional Orders granted to companies in 1883 under that Act was carried out. Capitalists declined to go on with a business which, if successful, could be taken away from them by local authorities at the end of twenty-one years upon terms of paying the then value, without regard to past or future profits, goodwill, or other like considerations. It was six years before Parliament recognized the mistake it had made by passing the Electric Lighting Act of 1882, and the Act of 1888 altered the period of purchase from twenty-one to forty-two years. Then, for the first time, electric lighting went ahead in Great Britain, although other countries had long previously enjoyed its benefits. The tramway companies, on the other hand, have never been relieved from their oppressive Act of Parliament, and their undertakings are now being bought up by local authorities at the price of the old rails and rolling stock. With the exception of a few undertakings in large cities or other favourable situations, tramway companies in Great Britain have proved failures, because, knowing that they would be bought up at the end of a few years, they have been unable to expend any capital on improvements. The adoption of electric traction involves a large outlay of capital, and no shareholder would agree to this expenditure with the risk of being bought out after the lapse of the few remaining years of the twenty-one years' period. This is the chief reason why there has been delay in substituting electric traction for older forms of tramway locomotion. There is, however, another reason which accounts for the non-success of tramways in Great Britain. The companies have, no doubt, been over-capitalized, though in many cases this is the result of the conditions imposed upon promoters by Parliament, the Board of Trade, and the local authorities. If an undertaking is surrounded by undue risks, obligations, and difficulties, it will cost more to establish and to complete than would be the case if it were a normally safe investment. The veto which the local authorities possess enables them to impose onerous conditions, which weak promoters accept rather than face the loss of the expenses they have incurred. These conditions take a variety of forms; but, unless the scheme is abandoned, they are expressed by inflated capital or reduced profits, or both, and they manifest themselves to the general public by the inability of the company to give satisfaction.

A tramway company should certainly contribute to the maintenance of the highways in proportion to the revenue which it is permitted to make. But as an authority on tramway law says, "that this amount should be left to be settled in each case by mere chance, by the fancy, the avarice, or any other motive of local officials—that, as it was put before the Committee of 1877, any kind of bargain, good or bad, pure or corrupt, may be insisted upon as the condition precedent to an application to Parliament for a public purpose, would appear far from desirable." [1] In the 1898 session of Parliament a Select Committee of both Houses, after hearing evidence tendered by the Board of Trade, local authorities, and electrical companies, reported as follows:—"The committee consider that the provisions of the Electric Lighting Act, 1888, which require the consent of the local authority as a condition precedent to the granting of a Provisional Order, should be amended. In their opinion, the local authority should be entitled to be heard before the Board of Trade, but should not have, so to speak, a provisional veto, only to be dispensed with in special cases by the Board of Trade."

The question of municipal trading in its bearing upon electrical industries has of late received much attention. Recent discussions in and out of Parliament concerning electric lighting and power-transmission schemes, telephones,

[1] Sutton, *The Tramway Acts.* London, 1883.

tramways, and light railways, show that further legislation is necessary for the proper development of electrical industries; and the direct issue is raised whether this development is to proceed upon lines of joint-stock capital or by means of municipal loans. Municipal enterprise usually involves the appointment of consulting engineers to advise whether and to what extent an undertaking should be carried out, and what system and type of apparatus should be adopted. In this respect there is an important difference in the conditions of the industry in England as compared with the United States and continental countries, where it is chiefly the manufacturing companies who determine the character of the demand. This difference accounts in a measure for the absence of uniformity of apparatus, systems of distribution, and of commercial methods in the electrical industries in Great Britain. Without standardization there cannot be production on a large scale, and consequently economy in manufacture is sacrificed, prices are relatively high, and deliveries slow. These are the chief causes which explain the backwardness of the electrical industries in England, and the reasons why American and German manufacturers have been able not merely to supplant English manufacturers in neutral markets, but even to compete with them seriously at home. The exports and imports of electrical materials indicate that the telegraph industry, which was established before the existing politico-economical influences were at work, has not suffered like the later departments of electrical engineering.

Electrical manufacturing firms and companies have laboured under many difficulties. The undue inflation of enterprise in 1881 and 1882 increased the difficulties surrounding the industry and created a keen competition for contracts, while business was almost entirely confined to the erection of separate installations of the electric light in ships, mills, factories, and residences. Prices of electrical machinery rapidly declined, and frequent alteration in design rendered profitable production on a large scale practically impossible. The manufacturing branch of the industry has not on the whole been profitable to the investor. Without including the heavy losses suffered as a result of the speculations in "Brush" licences (these were not losses in manufacturing), there have been several very considerable depreciations of capital, which probably more than neutralize all the dividends which manufacturing companies have paid. There has been very little solidarity among those interested in the commercial development of electricity, and except for the discussion of scientific subjects, there have been scarcely any organizations, having for their objects the protection and promotion of common interests.

The aggregate capital invested in shares and debentures of British electrical undertakings in 1900, apart from private firms, was £123,636,602, divided as follows:—

		No. of Undertakings.	Capital.
Telegraph (*a*)		29	£31,782,968
Telephone (*b*)		16	8,984,023
Electricity supply	Companies	108	12,434,827
	Municipalities (*c*)	169	13,776,372
Electric traction	Companies	75	26,149,859
	Municipalities	18	2,748,873
Manufacturing		135	21,708,180
Miscellaneous		103	6,051,500
		653	£123,636,602

(*a*) Does not include Government telegraphs.
(*b*) Does not include Government telephones.
(*c*) Loans authorized.

The capital, apart from Local Government capital, is mainly in the form of joint-stock enterprise. There are numerous private firms engaged in the business, but the capital they represent is estimated not to exceed five per cent. of the total. An analysis of the list of joint-stock companies shows that the principle of large financial combinations has not been characteristic of the English industry, as is the case in America and in Germany. In America the electrical industries have been controlled mainly by trusts and other powerful combinations, while in Germany the industrial banks have given them strong financial support. In the United Kingdom the capital has been provided chiefly by relatively small investors.

The following was the average rate of dividends paid for 1899 on the aggregate capital employed:—

Telegraph	4·98 per cent.
Telephone	4·91 ,,
Electricity supply	5·51 ,,
Electric traction	4·65 ,,
Manufacturing	7·52 ,,
Miscellaneous	5·79 ,,

Telegraphy.—The first practical trial of the telegraph was made in 1837 on the London and North-Western Railway, and for some years afterwards the use of the telegraph was almost entirely confined to railways. The Electric Telegraph Company—the first company formed to undertake the business of transmitting telegrams—was incorporated in 1846. For some time it restricted its operations to constructing and maintaining railway telegraphs, and was regarded as a commercial failure. Between 1846 and 1851, however, great improvements were made in the working of telegraphs, a cable was laid between Dover and Calais, and the telegraph industry began to make progress; numerous companies were formed, and keen competition led to considerable extensions of wires and reduction of tariffs, with the effect that the volume of business increased enormously. During the 10 years 1857–67 the Electric Telegraph Company's average receipts per message fell from 4s. 1¼d. to 2s. 0¾d., or just over half, but the number of messages during the same period increased from 881,271 to 3,351,910, or nearly fourfold. The working expenses were reduced in a progressively larger ratio—*e.g.*, in 1859 the average working expenses were 2s. 7d. per message, or more than 65 per cent. of the receipts, while in 1869 they were 1s. 0¼d. per message, or only 51 per cent. of the receipts. Much dissatisfaction was felt because the larger towns, where competition had been most keen, were unduly benefited, to the neglect of smaller towns, where the business was comparatively less profitable. In 1868–69 public opinion compelled the Government to acquire the business of the companies. At that time there were in the United Kingdom about 30 different companies, besides the railway companies, whose business was the transmission of telegrams, and several distinct systems were employed. The total number of telegraph offices, including railway stations transacting telegraph business, was 2500; it is now 11,188. The transfer of the telegraphs to the State took place on the 5th of February 1870, and further considerable reductions were at once made in the rates. A uniform tariff of 1s. per 20 words was established, and this reduced the average receipts during 1872 to 1s. 1d. per message. This tariff remained in force till the 1st of October 1885, when it was reduced to the existing rate of ½d. per word, with a minimum of 6d. per message.

The capital stock created for the purchases, &c., of telegraphs is upwards of £10,000,000, and the total deficiency, since the acquisition of the telegraphs by the State, of revenue to meet expenditure and the interest on stock created was, at the 31st of March 1899, £7,756,654. The monopoly of the Postmaster-General does not extend to the British Colonies and the ocean. The following figures show the amount of the capital of the existing British telegraph companies:—

No. of Undertakings, 29.

Ordinary and deferred capital . .	£20,261,470
Preference capital	7,459,130
Loan and debenture capital . .	4,062,368
Total, ...	£31,782,968

Since the early days of international telegraphy, conferences of representatives of Government telegraph departments and companies have been held from time to time, and in 1868 the International Bureau of Telegraphic Administrations was constituted at Berne, and a convention was formulated by which a central office was appointed to collect and publish information, and generally to promote the interests of international telegraphy. International service regulations have been drawn up, which possess equal authority with the convention, and constitute what may be regarded as the law relating to international telegraphy.

The total land lines of telegraphs throughout the world amount to over 781,000 miles, of which over 760,000 are aërial and 21,000 underground. The total length of conductors is 2,789,000 miles, of which 2,699,000 are aërial and 90,000 underground; of these there are in Great Britain and Ireland 32,881 miles of lines (32,023 aërial and 858 underground), with about 206,000 miles of conductors (179,500 aërial and 26,800 underground). Of submarine cables the total number is 1769, their length in nautical miles being 189,015; of these, 1349 cables of 20,324 nautical miles are owned by various Governments, and 420 cables of 168,691 miles by companies, most of which are incorporated in Great Britain. The world's cable fleet consists of about 42 steamers, having an aggregate gross tonnage of 69,204 tons, of which the British Government own the *Monarch* (1121 tons) and the *Alert* (369 tons). Companies registered in England own more than three-fourths of the rest.

All-British cable.

In 1896 a Committee was appointed to consider the proposal for laying a telegraph cable between British North America and the colonies of Australasia. The report of the Committee, which is dated January 1897, was presented to Parliament in April 1899, and dealt with the practicability of the project, the route, the cost, and the revenue. The Committee was of opinion that the cable should be owned and worked by the Governments interested, and that the general direction should be in the hands of a manager in London, under the control of a small board, on which the associated Governments should be represented. The English cable companies urged that State interference with private enterprise was neither justifiable nor necessary, as rates could be reduced and an alternative cable route to Australia arranged on reasonable terms without it, and that the Cape route would be the best alternative route. The Government policy would, they alleged, create an absolute and objectionable monopoly. In a correspondence[1] between the Eastern Telegraphic Companies and the Colonial Office the Companies pointed out:—That the late Mr. Raikes, when Postmaster-General, had stated that "it would be without precedent for the English Government itself to become interested in such a scheme in such a way as to constitute itself a competitor with existing commercial enterprises carried on by citizens of the British Empire. There would be a very serious question raised, and it will probably extend to other forms of British enterprise—for example, railways." That Mr. Leonard Courtney, when Secretary to the Treasury, had stated that "it would be highly inexpedient to encourage, upon light grounds, competition against a company in the position of the Eastern Telegraph Company, which has embarked large capital in existing lines." That the permanent official representing the Post Office before the Pacific Cable Committee had stated "that there was no precedent for the Imperial Government alone, or the Imperial Government associated with the Colonies, managing or seeking business for a line of this kind." The reply of the Colonial Office contains the following statements of general policy:—"With the progressive development of society the tendency is to enlarge the functions and widen the sphere of action of the central government, as well as of the local authorities, and to claim for them the more or less exclusive use of powers and the performance of services where the desired end is difficult to attain through private enterprise, or where the result of intrusting such powers or services to private enterprise would be detrimental to the public interest, through their being in that event necessarily conducted primarily for the benefit of the undertakers rather than of the public. This tendency is specially manifested in cases where, from the magnitude or other conditions of the enterprise, the public is deprived of the important safeguard of unrestricted competition. . . . In the case of inland telegraphs and of cable communication with the continent of Europe it has entirely superseded the private companies. Closely analogous to the action of the State in the cases referred to, is the action taken by municipal authorities, with the authority of the Legislature, in competing with or superseding private companies for the supply of electric light, gas, water, tramways, and other public services. . . . The service which Her Majesty's Government and the Colonies desire is one which neither the Eastern Telegraph Company nor any other private enterprise is prepared to undertake on terms which can be considered in comparison with the terms upon which it can be provided by the associated Governments. It is a public service as much as the carriage of parcels, the provision of life assurance, the building of light railways or of ships of war, and Her Majesty's Government cannot find any reason why in the one case a private enterprise with which the Government work may compete, should be considered entitled to compensation and not in the others." In November 1899 a committee was appointed by the Colonial Office for the further examination and elaboration of the scheme.

Much attention has been directed to what is called "Wireless Telegraphy." (See TELEGRAPHY, WIRELESS.)

Telephony.—The telephone industry in the United Kingdom has developed slowly and with difficulty. The first practical telephones were brought into England in 1877, and in the following year a company was formed to acquire and work Bell's patent. In 1879 the Edison Telephone Company, of London, was established, and proposals were set on foot to open telephone exchanges. In 1880 the Bell and Edison companies were amalgamated, under the title of the United Telephone Company. The Post Office opposed the opening of telephone exchanges, on the ground that the exclusive right to transact telegraph business conferred upon the Postmaster-General by the Telegraphs Act, 1869, was thereby infringed. In 1880 the Court decided that the telephone came within the definition of the term "telegraph." The companies did not appeal, and the Postmaster-General granted them licences. One of the conditions of the licences was the payment to the Post Office of a royalty of 10 per cent. of the gross receipts; the licences were for specified areas, and the companies had no power to make trunk lines between towns. In 1882 the London and Globe Telephone Company was formed, and obtained a licence in competition with the then existing exchanges; and in the same year the Postmaster-General granted licences for the establishment of exchanges even in towns where the Post Office had hitherto conducted the business. In 1884 the London and Globe Company was absorbed by the United

[1] Blue Book. Ed. 46, 1900.

Telephone Company. The Postmaster-General then decided to abolish all restrictions as to areas, and to throw the whole country open to the operations of the licensees. New licences were issued for a period expiring on the 31st December 1911, and determinable by six months' notice of purchase by arbitration in 1890, in 1897, and on 31st December 1904. Under these licences the companies were empowered to construct trunk lines between towns, the royalty payable to the Post Office remaining unaltered. In 1889 an amalgamation took place between the United Telephone Company and some of the subsidiary companies, the amalgamated company taking the name of one of the subsidiary companies, namely, the National Telephone Company Limited. This company has since absorbed most of the companies holding licences, and is now the only company in the United Kingdom carrying on telephonic exchange business. The New Telephone Company, incorporated in 1884, went into liquidation, but was resuscitated in 1892, and afterwards absorbed by the National Company. The Government having decided against purchase at the first period of option mentioned in the licences, adopted the policy set forth in a Treasury Minute presented to Parliament on the 27th May 1892. Amongst the proposals contained in this Minute was one that the telephone companies should connect their exchanges with post offices, so as to give subscribers additional facilities and the use of the trunk telephone wires of the State. It was also proposed that the companies should abandon their right to construct trunk wires, and that the Post Office should purchase from them such trunk wires as they had already erected, and gradually provide additional trunk wires, so as to ultimately provide a complete system of communication between all the important towns in the kingdom. A Bill carrying these proposals into effect, and giving the Treasury power to expend £1,000,000 (since increased) on the purchase and erection of trunk wires, received the royal assent on the 28th June 1892. On the 11th of August in the same year heads of arrangement were signed on behalf of the Government with the National Company and the New Telephone Company, but the agreement with the National Company embodying the arrangement was not executed till the 25th March 1896. It restricts the operations of the company to local areas, the trunk wires connecting those areas being in the hands of the Post Office. The price paid by the Government to the National Company for trunk wires was £459,114. The length of trunk routes taken over was 2651 miles, and the length of wire about 29,000 miles. Up to March 1900 the Post Office had erected 39,657 additional miles of telephone trunk wires.

The net receipts of the company for the year 1900 were £1,292,622, and the working expenses £808,181, or 62·5 per cent. of the receipts. The dividend on the ordinary shares has for some years past averaged 5⅜th per cent. The reserve fund amounts to £883,800. In December 1900 it had over 1000 exchanges and over 2300 call offices open, and 160,000 subscribers' lines. About 682,000,000 messages per annum are sent over its lines, at an average cost per message of about ·45 of a penny. The royalty paid to the Post Office in the year 1900 amounted to £140,074.[1]

In May 1898 a Select Committee of the House of Commons met "to inquire and report whether the telephone service is or is not calculated to become of such general benefit as to justify its being undertaken by municipal and other local authorities, regard being had to local finance; and if so, whether such local authorities should have power to undertake such service in the districts of other local authorities outside the area of their own jurisdiction, but comprised wholly or partially in the same telephone area; and what powers, duties, and obligations ought to be conferred or imposed upon such local authorities." In its report the committee expressed the opinion that general, immediate, and effective competition by either the Post Office or the local authority was necessary, and consider that a really efficient Post Office service afforded the best means for securing such competition.

On 8th May 1899 a Treasury Minute was issued upon the proposals for the development of the telephone system in the United Kingdom. It confirmed generally the conclusions arrived at by the committee:—(*a*) That the existing exchange service is not of general benefit to the country, and that it is not likely to become of general benefit so long as the present practical monopoly continues in the hands of a private company; (*b*) that competition by either the Post Office or the local authority is necessary in the public interest, and that the Post Office is not prevented, either by legal agreement or by good faith, from competing in any areas, either by itself or by means of licensees. The Minute also confirmed the proposals of the Postmaster-General:—(*a*) That licences should be granted to certain local authorities to transact telephone business within appropriate areas; and (*b*) that the Post Office should itself open telephone exchanges in London as soon as Parliament has provided the necessary funds. The licences to local authorities are of the same general character as that held by the National Company, and contain a provision that the local authorities licensed by the Postmaster-General shall connect their exchanges with post offices; licensed local authorities are to open call offices at post offices; and the restriction hitherto imposed upon renters of telephones, that they shall not allow their telephones to be used by other persons, is to be removed in all cases where messages are paid for on the "toll" system, whether the telephones are rented from the local authority or from the National Company. The royalties payable under these licences will be the same as those specified in the National Company's licences. All licences will be terminable on the 31st December 1911. Subject to the condition that the Government shall not purchase useless or antiquated plant,—including in this category single-wire circuits,—the licence to a local authority will provide that on the termination by the Postmaster-General of such licence, the local authority shall sell, and the Postmaster-General shall purchase, all plant then in use in the telephone service of the local authority which is suitable for the actual requirements at the time of the local service of the Post Office. The question of suitability will be left, if the parties differ, to the decision of an arbitrator, subject to the provision that no plant shall in any case be considered suitable which has been brought into use without the sanction of the Postmaster-General. The plant will be taken at its fair market value at the time of the purchase, without any addition in respect of compulsory purchase or goodwill. Where within a reasonable period *bonâ fide* competition between the National Company and any local authority is established in any area where the company is now working, similar treatment should be applied to so much of the plant of the company in such area as existed at the time when the competition was inaugurated. Further, if the company within a reasonable period gives intercommunication in such area between their exchanges and the exchanges of the local authority, on conditions approved by the Postmaster-General, the purchase will extend (on the same terms) to the plant of the company constructed (with the sanction of the Postmaster-General) after the commencement of the competition.

The Telegraphs (Telephonic Communication, &c.) Bill was subsequently introduced by the Government, and after much discussion in and out of Parliament, referred to the Standing Committee on Trade. It was amended in some respects, but in the main it gave effect to the recommendations contained in the Treasury Minute. It received the royal assent on 9th August 1899. The Postmaster-General decided to establish a competitive service with the National Company in the metropolitan area, and after considerable delay in laying the wires, the system was inaugurated in November 1901. The new Post Office rates however, instead of introducing a substantial competition, were almost the same as those of the National Company, and their announcement was followed by very general public complaint. (See also TELEPHONE, and POST OFFICE.) As a result of the Treasury Minute of May 1899, several corporations also decided to apply for licences to establish municipal telephone services.

[1] For a comparison of the English conditions with those obtaining on the continent of Europe, see Bennett, *Telephone Systems of the Continent of Europe*, pp. 2–16. Longmans, Green, & Co., London, 1895.

Telephonic communication, originally a purely urban affair, next became interurban and national; it has now become international. A cable for providing telephonic communication between London and Paris was laid across the Straits of Dover, from St Margaret's Bay to Sangatte, in 1891, and was connected to land wires specially erected for the purpose in both countries. The distance in miles is:—London to St Margaret's Bay, 84·5; St Margaret's Bay to Sangatte, 23·0; Sangatte to Paris, 200·0. There are extension lines in London to the General Post Office, to the Threadneedle Street Office (Stock Exchange), and to the West Strand Post Office, and connexion with Paris can be made at any of these points. The charge is eight shillings for three minutes, and two consecutive periods of three minutes may be arranged for.

A still later development is that by which users of the exchange telephone system can, by an extra payment of £10 per annum for receivers for four persons, be connected with the leading London theatres, music halls, and places of worship. The receiving apparatus is portable, and may be fitted in any room, and it can be installed in a few hours.

Light and Power Supply.—In March 1879 a Select Committee was appointed to consider whether municipal corporations should be authorized to adopt electric lighting schemes, and under what conditions, if at all, gas or other public companies should be authorized to do so. Some of the leading scientific authorities of the time gave evidence, but the conclusions arrived at were of a tentative character. The committee pointed out the desirability of giving facilities for conducting experiments, and recommended that the Legislature should show its willingness, when the demand arose, to give all reasonable powers for the development of electricity as a source of light and power. The Paris Exhibition in 1881, and the Electrical Exhibition at the Crystal Palace in the following year, combined with many improvements in electrical machinery and lamps, stimulated considerable enthusiasm for the subject. In the session of 1882 several Bills were promoted to confer on companies general powers to produce and supply electric light and power. This led the Board of Trade to introduce a Bill dealing with the whole question, and all the Bills were referred to a Select Committee. The Government Bill was amended, and received the royal assent on 18th August 1882. This Act conferred powers on undertakers to break open streets, and gave local authorities power to raise money for the purpose of electricity supply. The powers were conferred either by seven years' licence, which the Board of Trade might grant, with the consent of the local authorities; or by Provisional Order granted by the Board of Trade, with or without the consent of the local authorities. The Provisional Orders did not limit the period of the concession, but gave local authorities the option to buy up the land, buildings, plant, &c., upon the expiration of twenty-one years, or every subsequent seven years, at their value at the time of purchase, without any addition for compulsory purchase, goodwill, or other similar considerations.

Many companies were formed to acquire patents and carry on the electric light business, and a considerable amount of capital was subscribed. The exceedingly onerous character of the purchase clause of the 1882 Act was not realized, for during the session following the passing of the Act no less than sixty-nine Provisional Orders were confirmed by Parliament. But a reaction followed very quickly; in 1884 the Board of Trade received only four applications for Provisional Orders, and during the subsequent four years only one Order was granted. Only eight of these Orders are still in force. In 1884, upon the suggestion of the President of the Board of Trade, a Committee of Engineers and others interested was formed to draw up clauses amending the Act. A Bill based on the analogy of the Gas Acts, submitted by this committee, was not adopted by the Board of Trade, but was introduced in the House of Lords by Lord Rayleigh in 1886. At the same time Lord Bury introduced an alternative Bill, and thereupon the Government brought in a Bill of their own. The three Bills were referred to a Committee of the House of Lords, who recommended that the Government Bill as amended should be proceeded with. Political exigencies prevented the Government passing the Bill that year and the next. In the session of 1888 Lord Thurlow, then Chairman of the Brush Company, reintroduced the Bill, and it passed through Parliament, and received the royal assent on the 28th June 1888. The Act, though still requiring the consent of local authorities to the granting of Provisional Orders, gives the Board of Trade power, in exceptional cases, to dispense with the consent; and it amends the objectionable purchase clause of the 1882 Act by substituting forty-two years for twenty-one, and ten years for seven years, and by ameliorating the terms of purchase. Power is also given to the Board of Trade to vary the terms of sale in such manner as may be agreed upon between the local authority and the undertakers. The passing of this Act gave a new impetus to the establishment of electricity supply undertakings, and since 1888, 164 Provisional Orders have been granted to companies, and 353 to municipal authorities.

Recent developments.

During 1898 four Bills were introduced into Parliament which raised several new principles in connection with the supply of electric energy. 1. By a company desiring powers to purchase *compulsorily* certain lands for the extension of their existing generating station, such lands being within the area of supply under their Provisional Order.

The compulsory purchase clauses in the Lands Clauses Acts are expressly excluded from the Electric Lighting Acts. Sites for generating stations have been invariably purchased by agreement, and all Provisional Orders have contained a clause making undertakers liable for any nuisance committed by them. The result has been that even in cases where the nuisance has been inseparable from carrying on the undertaking, injunctions have been granted against undertakers, to the great detriment of the electric lighting industry.

2. By a company desiring to obtain powers to lay mains from their area of supply to a site which they had purchased for a generating station *outside* the area of supply.

Heretofore undertakers have been compelled to erect their generating stations within their area of supply, as the Board of Trade have always refused to grant orders for wayleaves.

3. By a company having no area of supply under the Electric Lighting Acts, but desiring to acquire powers to take lands for a generating station by compulsion, and to lay down mains for the purpose of supplying electric energy to *authorized undertakers only*.

4. By a company proposing to generate electricity at a central station in the Midlands, and to give a supply, in a district comprising in all an area of about 2000 square miles, to authorized undertakers, and also to ordinary consumers, notwithstanding the fact that in many of these places the local authorities already possessed Orders, and that consents of the local authorities had not been given in any case.

Powers to supply have been heretofore granted by Provisional Order or licence only, for which the consent of the local authority is a condition precedent.

These Bills were regarded as so important that a Joint-Committee of both Houses was appointed to consider the principles they involved. They were not dealt with by the committee in detail, except incidentally as showing the trend of the industry. The committee laid down general principles which they suggested should guide Parliament and the Board of Trade, and expressed the opinion that it must be decided in each individual case whether those principles should in whole or in part be applied, and whether any and what special conditions should be imposed.

The principles enunciated were :—(1) That the proved public advantages of electric energy in the generation of light and power warrant the granting to undertakers of compulsory powers for acquiring sites for generating stations, and lands or easements for pipes and mains therefrom, and other works. (2) That where the site for a generating station is acquired under compulsory powers, and is specified in the Provisional Order or Special Act, the undertakers should not be subjected to any further liability than that which is imposed by the common law in the case of persons exercising statutory powers and duties, but where the site for a generating station is acquired by agreement, the undertakers ought to be subject to the liability imposed by the common law. (3) That subject to observations contained in the report, these compulsory powers might also properly be given where the proposed site is not within the area of supply. (4) That where sufficient public advantage is shown, power might be given for the supply of electric energy over an area including districts of numerous local authorities, and involving plant of exceptional dimensions and high voltage, and that undertakings of this character might properly be authorized on conditions differing in some respects from those imposed by and under the existing Acts. This would include undertakers supplying energy chiefly in bulk or wholesale to other undertakers, whether local authorities or companies, whose areas of supply are wholly or partly within the area of such bulk or wholesale supplying company, and who distribute the energy so obtained to consumers. (5) As to giving compulsory powers of purchase of undertakings to local authorities, the committee, without questioning the policy of Parliament in having given such powers, observed : That when the power of purchase was granted in 1882 and 1888, no such schemes of supplying energy in bulk were contemplated as are now before Parliament. That when the power of purchase was thus granted, the question then before Parliament was chiefly one of light ; whereas although electric light is at present the predominant feature of the enterprises now before the public and Parliament, the application of electric energy in the form of power to an infinite variety of other purposes is likely to be in the near future the predominant feature and function of these undertakings. That the provisions of the Electric Lighting Act, 1888, enabling the local authority to purchase an undertaking after a term of years, are inapplicable, as a general rule, to the case of an undertaker supplying energy in bulk at high voltage, but as it might in special cases be desirable that the local authorities should have the right to purchase reserved to them, the Board of Trade should have power to insert the purchase clause in the Provisional Order, if the local authorities concerned can, in the opinion of the Board, show good cause for such a course. That in cases of the exemption from liability to purchase, some kind of sliding scale, as in the case of gas undertakings, should be imposed in the interest of consumers.

Bills Nos. 1 and 2 above referred to obtained the royal assent; Bill No. 3 was rejected; Bill No. 4, promoted by the General Power Distributing Company, passed, but was ultimately suspended till next session.

Another important question was raised in the session of 1898 by the Provisional Orders applied for by the Marylebone and Bermondsey Vestries for power to supply electricity. In each case an Order had already been granted, with the consent of the Vestry, to a company in 1889, and the Vestry has the right to purchase in 1931 so much of the undertaking as lies within the area of the local authority. The Bill confirming these Orders to the Vestries was read a second time in the House of Commons, and was referred to a Select Committee, who threw out the former but passed the latter. In the case of Bermondsey very little work had been done by the company. The Bill confirming the Bermondsey Order was passed by the House of Commons and read a first time in the House of Lords, but owing to a rule that a Confirmation Bill brought from the Commons cannot be read a second time after 28th June, no further progress was made.

The General Power Distributing Company's Bill was again proceeded with in the session of 1899, when the second reading was opposed on the ground that the measure would enable a private company to compete with municipal authorities, and would prevent such authorities from instituting new electric lighting schemes themselves. To propitiate the opponents of the measure, it was suggested that provisions should be introduced to exclude from its operation corporations to which it might be obnoxious. The President of the Board of Trade, on the understanding that that would be done, expressed the opinion that the Bill might be read a second time and referred to a Select Committee. The motion for the second reading was, however, negatived by 164 to 132. In 1900 parliamentary interest was again aroused in the question of the distribution of electric energy "in bulk" over large areas, Bills for this purpose having been deposited by several companies. The promoters of these Bills overcame the opposition of local authorities by agreeing not to compete with them, and to ask only for wayleave powers, subject to the consent in each case of the local authority, to lay their mains in the district so as to enable them to supply energy in bulk to local authorities and others authorized to distribute the energy.

A matter of serious import to investors in electric lighting undertakings, and in fact in all industrial undertakings founded on concessions granted by local authorities, is the decision of the Board of Trade and of Parliament to permit competition in the supply of electricity in the City of London, notwithstanding the agreement by which the Corporation of the City of London granted, "so far as they were able to do so," the exclusive right of supplying electricity for private purposes within the city. The Provisional Order granted by the Board of Trade to the Charing Cross and Strand Electricity Supply Corporation Limited was confirmed by Parliament, notwithstanding the strenuous opposition of the City of London Company.

Of the 525 Provisional Orders which are in force, 360 have been granted to local authorities and 165 to companies. Of those granted to local authorities, only 247 are in course of being carried out, while of those granted to companies, 132 are being carried out. From the published accounts of 239 undertakings it appears that at the end of 1899 companies had expended £11,445,133 on 92 undertakings, and local authorities £11,834,214 on 147 undertakings. The following figures give the average details of capital expenditure, stated in percentage, to total capital expenditure :—

Lands and buildings	18·47 per cent.
Plant and machinery	37·36 ,,
Mains	35·28 ,,
Meters	4·72 ,,
Instruments	1·53 ,,
Provisional orders, &c.	2·24 ,,

The number of lamps connected (equivalent to 8 candle-power) by 201 undertakings at the end of 1899 was 7,660,388, and the number of Board of Trade units sold by 193 undertakings was 125,116,615.

The following table gives details of average working expenses per Board of Trade unit sold (exclusive of Depreciation and Sinking Fund) :—

Year.	Number of Undertakings.	Generation.	Distribution.	Rents, Rates, and Taxes.	Management.	Special.
1895	60	2·45d.	·36d.	·35d.	·81d.	·1d.
1896	61	2·13d.	·26d.	·28d.	·62d.	·08d.
1897	84	1·97d.	·26d.	·24d.	·57d.	·06d.
1898	98	1·79d.	·25d.	·22d.	·49d.	·06d.
1899	118	1·77d.	·22d.	·19d.	·44d.	·05d.

A coloured diagram showing the average revenue per Board of Trade unit of electricity, and details of the cost of production of all electricity supply undertakings, is published annually with the *Manual of Electrical Undertakings*.

The following table shows the financial results of the supply of electricity by the undertakings in regard to which the figures are obtainable :—

Year	Number of Undertakings.	Revenue from Sale of Current.	Working Expenses.	Profit.	Per Cent. of Profit on Capital Expended.	Price obtained for Current.
Companies—		£	£	£		
1895	27	515,533	277,371	238,162	5·49	6·08d.
1896	29	616,382	314,996	301,386	6·33	5·77d.
1897	36	812,734	410,991	401,743	6·54	5·62d.
1898	37	897,628	480,280	417,348	5·51	5·51d.
1899	43	1,053,291	580,548	472,743	5·45	5·26d.
Municipalities—						
1895	33	206,868	119,632	87,235	4·92	5·32d.
1896	42	310,098	172,581	137,517	5·61	5·18d.
1897	54	502,947	265,074	237,873	5·73	4·68d.
1898	61	709,335	376,381	332,954	5·55	4·35d.
1899	75	988,404	555,682	432,722	4·90	4·06d.

The following table shows the average dividends paid during the years 1896–7–8–9 by the number of electricity supply companies mentioned :—

Year.	Number of Companies.	Aggregate Capital.	Average Ordinary Capital.	Average Preference Capital.	Average Loan and Debenture.	Total Average.
		£				
1896 .	35	5,176,301	5·22%	6·05%	4·69%	5·23%
1897 .	38	6,184,310	7·04%	5·97%	4·70%	6·28%
1898 .	44	8,284,212	5·57%	5·90%	4·46%	5·32%
1899 .	51	10,250,385	5·93%	5·82%	4·61%	5·51%

As municipalities do not pay dividends on the capital employed, the net result cannot be stated in the same way as in the case of companies. An analysis of municipal electricity accounts for the years ending December 1895–6–7 and March 1896–7–8, shows that the net profits earned by corporations supplying electricity amounted in the aggregate to £510,992, without taking into account reductions in the price of the current sold. During the years over which the analysis extends, £47,042 was taken from the rates, and £43,083 was applied in reduction of same.

Cost.

The supply of electric energy from central stations has now been systematically carried on for some nine or ten years, and the various items making up the cost of production have been analysed with great exactness. It is found that the cost of raw materials, namely, coal, water, and sundry stores, which are consumed in the actual generation of the electricity sold, forms only a small part of the total cost, the major portion of which is made up of the fixed charges and expenses of administration attributable to the time during which the works are unproductive. The reason for this is that it is not generally found expedient to store electricity in large quantities. In gas-works the production goes on throughout the twenty-four hours, but electricity-supply works generate the electricity for the most part at the moment it is used by the consumer. Electric lamps are normally in use on an average for only about four hours per day, and therefore the plant and organization are idle and unremunerative for about 20 hours out of the 24. It is necessary to have in readiness machinery capable of supplying the maximum possible requirements of all the consumers at any hour of the year—as, for instance, on Christmas Eve; and this accounts for a very large proportion of the total working expenses. The cost of supplying electricity depends more upon the *rate* of supply than upon the *quantity* supplied, or as the late Dr John Hopkinson put it: "The cost of supplying electricity for 1000 lamps for ten hours is very much less than ten times the cost of supplying the same number of lamps for one hour." Interest and sinking fund, rent, rates and taxes, salaries, wages, &c., are all of them, in a greater or less degree, governed by this potential maximum demand. These conditions exist in other industrial works, but there are few, if any, in which the standing charges are so high in relation to the running costs. Of course consumers vary largely, but the cost of supplying any one of them with a given amount of electricity is chiefly governed by the amount of his maximum demand at any one time.

The correct way to charge for electricity is to give liberal rebates to those consumers who make prolonged use of the plant regularly throughout the year—that is to say, the lower the maximum demand, and the more continuous the consumption, the better should be the discount. Such a tariff has been in use in Brighton for some years, and is being adopted by many other undertakings. The system necessitates the use of a special indicator (not to measure the quantity of electricity taken—that is done by the ordinary meter) to indicate the maximum number of lamps which the consumer has ever had on simultaneously during the period for which he is to be charged. In effect it shows the amount of plant which the station has had to keep on hand for his use. If the indicator shows that, say, twenty lamps is the greatest number which the consumer has turned on simultaneously, then he gets a large discount on all the current which his ordinary meter shows that he has taken beyond the equivalent of one hour's daily use of those twenty lamps. In Brighton the rate is 7d. per unit for the equivalent of one hour's daily use of the maximum demand, and 1d. per unit for all surplus. It is on this principle that it pays to supply current for tramways or other power purposes at a price which *primâ facie* is below the cost of production; it is only apparently so in comparison with the cost of producing electricity for lighting purposes. In the case of tramways the electricity is required for 15 or 16 hours per day. Electricity for a single lamp would cost on the basis of the Brighton system, for 15 hours per day only 1·86d. per unit. Therefore the much larger and very regular demand for current by tramways can be supplied at a very low figure as compared with the price of current for lighting. The cost of power if generated continuously on a large scale should not exceed ·25d. per Board of Trade unit, and even with interest on capital the cost should not exceed ½d. In many cities in the United States electric power is sold at from £12 to £25 per horse-power per year on the basis of 10 hours' operation per day; and at this price a good profit is made. Several contracts have been made in England for the supply of energy to tramways at 1½d. per Board of Trade unit on the basis of a minimum supply of about 300,000 units per annum, and at lower prices for larger quantities.

In ordinary practice it is found that 1000 cubic feet of gas are equal to 6 or 7 units of electricity, so that at 6d. per unit the cost of electric lighting would compare with gas at about 3s. to 3s. 6d. per 1000 cubic feet. A Board of Trade unit will supply one 8 candle-power lamp for 30 hours, or 30 such lamps for one hour. The price, however, is not the only measure of the relative economy of the two lights. In average use an incandescent lamp will last about 1000 hours, which is equal to about 12 months normal use; a good lamp will frequently last 2000 or 3000 hours before it actually breaks down, but it is not advisable to use lamps longer than 1000 hours, as after that the candle-power rapidly diminishes. The free supply of incandescent lamps by electricity-supply works is becoming general. Under this system a consumer is entitled to one 8 or 16 c.p. incandescent lamp free of charge, for every 60 units of electricity consumed in the year by the use of incandescent lamps only.

For large spaces arc lamps are more suitable and cheaper than incandescent lamps. The ordinary arc lamp, nominally of 2000 candle-power, consumes half a unit of electricity per hour. The carbons consumed in the arc lamps work out at a cost of less than $\frac{1}{4}$d. per lamp per hour.

Electric motors, which form an important branch of the electric-supply industry, can be adopted in a variety of ways for operating domestic and industrial apparatus requiring small power, and in calculating the consumption of electricity one may allow $\frac{8}{10}$ths of a unit per brake-horse-power hour. The capital expenditure for an electric motor is less than that for either a gas or oil engine, and motors can generally be obtained on hire or on the hire-purchase system.

Most new houses within an electricity-supply area are wired for electricity during construction. The cost of wiring varies according to number of lights and character of fittings; it may be taken at 15s. to £2 per lamp installed, including all necessary wire, switches, fuses, lamps, holders, casing, but not electroliers or shades. In many instances the supply undertakings carry out the wiring of houses, for an increased payment for the current, or arrange with a separate company to fix the wires and fittings in the houses, the charge being 1d. per unit upon all current used, with a minimum payment of 1s. per 8 candle-power lamp. This charge of 1d. per unit is collected by the supply undertaking for the wiring company. The consumer has to enter into an agreement, and if he is but a tenant, the landlord has to sign a memorandum to the effect that the wiring and fittings belong to the supply undertaking.

A recent development of municipal enterprise takes the form of the erection of blocks of "model" dwellings for the better housing of the working classes, and electric light is supplied in these dwellings, the charge for the current taking the form of an increased rent of 8d. per week for two rooms and 10d. per week for three rooms. One 16 c.p. lamp is fitted in the living room and one 8 c.p. lamp in each of the bedrooms, and the current is available each day at dusk and is turned off at midnight; in winter it can also be obtained from 5 a.m. until daylight.

In the opinion of most of the insurance companies "the electric light is the safest of all illuminants, and is preferable to any others when the installation has been thoroughly well put up." The Phœnix Fire Office rules were the first to be drawn up and are generally followed, but some other leading insurance offices have their own rules, under which risks are accepted without extra premium.

Electric Traction.—Until recent years comparatively very little progress has been made in Great Britain in the application of electricity to tramways, notwithstanding that in America, and on the continent of Europe, there has been for some years past a general movement in the direction of substituting electric power for horses, and also a tendency to supersede steam on railways. In large American cities the proportion of miles of tramway to the population varies from 1 mile for every 1300 persons to 1 mile for every 4000 persons. In Europe the proportion is from 1 mile for every 10,000 persons in Berlin, to 1 mile for every 55,000 persons in Cardiff.

The first street tramway was laid in 1860 at Birkenhead. In 1890 (20 years after the passing of the General Tramways Act) there were 922 miles worked by horses, cable, and steam, and 70 miles worked by electricity, while 439 Acts of Parliament authorizing tramways had been passed. There was a period of increasing activity in tramway promotion which culminated in 1882, when 43 Acts were passed. Then followed a period of decreasing activity until 1890, when only 2 Acts were passed. As soon as the effect of the purchase clause of the Tramways Act, 1870, and of the veto possessed by local authorities, was understood, there was a total cessation of new tramway enterprise until the potentialities of electric traction were realized, and until the law in regard to the promotion and working of tramways had been modified in a way to facilitate the use of electric power.

The decisions of the House of Lords in the cases of the tramways arbitrations at London and Edinburgh may be accepted as fixing the price to be paid for an undertaking on the basis of the Tramways Act. The arbitrator in the Edinburgh case assessed the value of the track per mile of single line at £5100, and allowed a sum of £2500 which had been expended on widening a bridge, also the expenses incurred in obtaining parliamentary powers. The tramway company had asked £305,000; they obtained £212,979 as the value of the undertaking, such value being simply what it would cost to construct the lines and necessary buildings, and provide necessary cars, horses, and machinery, less depreciation. The expenses of the arbitration were laid upon the corporation, those of the tramway company being taxed. In the London case £213,450 was demanded as the capitalized value of 4 miles 861 yards of single line. The arbitrator awarded £22,872 as the value of the track and the company's interest in a depôt; parliamentary costs, engineers' fees, and cost of street widening were also allowed; the sale of the cars, horses, &c., was effected at an agreed valuation between the parties. In the Leeds tramway a length of 22 miles of single track was valued at £58,000, or only £2636 per single mile; but the line is said to have been in bad condition. A more recent case is that of Wolverhampton. The company owned $8\frac{1}{2}$ miles, of which about $5\frac{1}{4}$ miles were within the borough. There had been only slight renewals of the track. The total price awarded to the company was £22,500, and this was made up of £11,000 for track, £7500 freehold depôts, £1800 for 75 horses, £1200 for 11 cars, harness, &c., and £1000 for parliamentary costs.

The principle on which clause 43 has thus far been interpreted is simply that of awarding such sum as it would cost to replace the part of the undertaking purchased, less a sum for depreciation, allowance being made for the expense of obtaining parliamentary authority to construct, and for other expenditure proper to the construction. Thus whether earning 1 per cent. or 10 per cent., two different undertakings, if in equal condition and costing the same to construct, would have to be sold at the same price.

In May 1893 a joint committee of both Houses was appointed to consider whether the grant of statutory powers to use electricity ought to be qualified by any prohibition or restriction as to earth-return circuits, or by any provisions as to leakage, induction, or similar matters; and as a result of the evidence presented, model clauses were drawn up to be inserted in Bills and Provisional Orders authorizing undertakers to use large electric currents and uninsulated return conductors. In February 1894 a conference took place between the Board of Trade and various parties interested in electric traction; and on the 6th March 1894 rules were issued by that department for preventing electrolytic action on gas or other pipes, and for minimizing, as far as practicable, injurious interference with the electric wires, lines, and apparatus of other parties. The model clauses, and the regulations of the Board of Trade, settled as they were after consultation with all parties concerned, afford every guarantee that in the application of electricity to tramways all interests are adequately protected.

The passing of the Light Railways Act, 1896, coupled with the confidence in the better commercial results of electric traction, gave new hope to the tramway *entrepreneur*. The Act contains no definition of "light railway," and tramways have been authorized under it; it relieves promoters of the heavy expenses of an application to Parliament; it contains no purchase clause, though in most cases a clause, which is the result of a bargain between the promoter and the local authority, is inserted in the Order; it provides for compulsory purchase of lands, and an even more important advantage of the Act is that it does not require the assent of the local authorities as a condition precedent to the promotion of a scheme. Many undertakings have already been sanctioned under this Act which it would have been impossible to promote under the Tramways Act. Nevertheless, the hopes which persons interested in the business entertained as to its operation have not been fully realized. It was believed that Parliament had recognized the evil of giving local authorities a veto; but promoters, even under this Act, have in many cases either to agree to conditions which make the undertaking commercially doubtful, or have to incur the risk of the Order being rejected, because the local authorities do not assent.

The following data [1] concerning the tramway industry in Great Britain before the general adoption of electric traction serve to show the progress made with tramways since the introduction of electric power. The total capital expenditure in 1890 amounted to about 13¾ millions, distributed as follows:—

	Capital Expenditure on Lines and Works open for Traffic.	Total Expenditure on Capital Account.	Length open for Traffic.	Number of Undertakings.
	£	£	Miles.	
Tramways belonging to Local Authorities	2,152,392	2,911,419	243·75	29
Tramways belonging to others	8,215,125	10,824,350	704·51	129
Total in United Kingdom	10,367,517	13,735,769	948·26	158

The expenditure on lines open in 1890 was equal to about £10,580 per mile. The working stock in 1890 was:—

27,719 horses, or 29·27 per mile open.
575 locomotives, or ·61 ,, ,,
3,801 cars 4·01 ,, ,,

The number of miles run amounted to 65,174,955 for the year; and taking the mean number of cars for the year at 3723, the mileage run per car averages 17,506 car miles for the year, or 48 miles per car per day. The average mileage per pair of horses was 12·5 per day. The gross receipts for the year amounted to £3,214,743, and the expenses to £2,402,800, or 75 per cent. of the receipts, leaving net receipts £811,943.

Since 1890 the tramway industry in Great Britain has been passing through a transition stage. On the one hand, in view of the right of local authorities to purchase the undertakings after 21 years, very few of the tramway companies have felt any inducement to develop their undertakings; and on the other, the gradual adoption of electricity as the motive-power has led to the reconstruction of the lines by local authorities. Some of the companies are enabled to substitute electricity by reason of arrangements with the local authorities to postpone the date for the exercise of their rights to purchase.

One of the fundamental advantages possessed by the more generally used methods of electric traction is that the energy is generated for all the cars at one or more central points, and is distributed over the entire system and expended at the points where the traffic requires it, and in proportion to its volume; while in the case of either horses or steam, and also in the case of the self-contained electric-accumulator car, and some other systems, each car requires to be accompanied, for the whole of its journey, by its own motive-power, which must be sufficient to start the car and carry the maximum load of passengers, and be able to overcome the steepest gradient. As the abnormal demand for power for these purposes is only occasional in time and place, it follows that there is considerable waste when the car is empty, or on the level, or at rest. Moreover, in the case of horse traction, about four-fifths of the horses required for the cars are resting or feeding, while only one-fifth are doing work; and the service of cars cannot be increased to meet an exceptional demand without permanently providing this wasteful margin of power. Likewise, in the case of steam tramways, an additional car cannot be put into use without an additional locomotive, which must be powerful enough to do the maximum work. The result of these conditions is an infrequent service of cars. With electric traction, if the traffic calls for a more frequent service, it can be provided without very largely increasing the working expenses. Additional capital expenditure has to be incurred to furnish more cars and other plant, but a much smaller increase of traffic will justify an addition to the number running. The greater facility with which electric cars are started, and the greater speed which can be attained, enable them to perform a much larger number of journeys. In America they frequently run between 100 and 200 miles per day. Other advantages of electric traction, such as its avoiding the objections arising out of the employment of horses or steam locomotives in the streets, are obvious. The net result of the adoption of electricity for tramways is not only that, up to a certain point, an increasing traffic can be carried at a relatively less cost of working, but this very fact tends to produce the increased traffic. An improved and quicker service encourages people to patronize the tram car who otherwise would never think of travelling in that fashion.

Cost of construction.

The cost of construction per mile of single line may be taken at £6000, and the overhead electric equipment at £2000, having regard to present enhanced prices; in addition, cars have to be provided, which cost about £650 each, and electrical power-houses, the cost of which are dependent upon their situation and capacity. Generally, it may be said that a new electric tramway cannot be completed in an urban district under £12,000 per mile single track.

For the Oldham Ashton Hyde tramway, which consists of 8·14 miles single track, the capital expenditure was £120,000, including the cost of the concession, but not the cost of the power-house, as in this case the electric energy is sold to the tramway company by the corporation of Ashton. In the case of the Potteries tramways and light railways, the capital expenditure on 30 miles was about £600,000. This includes power-houses, cost of concessions, and the acquisition and conversion of about 8 miles of tramways formerly worked by steam.

The following are particulars appertaining to a typical undertaking in England, consisting of 8 miles of road, 5¾ miles of single and 2¼ miles of double track. Working expenses per car mile:—

Power and running	Cost of current	1·00d.
	Wages	2·41d.
	Inspection and distribution	·31d.
	Uniforms, tickets, punches, car licences, and sundries	·44d.
Repairs and maintenance		·37d.
Administration and general expenses		·85d.
Total		5·38d.

The number of cars in use is 29, and the car miles run per annum are 580,000. The district served has a population of 250,000, and 4,050,000 passengers are carried yearly. The consumption of electricity amounts to 550,000 units. The fares charged average 1·6 miles for 1 penny. The drivers work on an average 60 hours per week, and receive 27s. per week; the conductors receive 22s. per week, and are supplied with uniforms. The receipts per car mile are 10·16d., and the total receipts per annum £24,500. The total expenses per annum amount to £14,500, equal to 59 per cent. of the receipts. The company is bound to run at least two cars each way every morning and every evening in the week, at such hours, not being later than 7 in the morning or earlier than 6 in the evening, as the company consider most convenient for workmen, at a fare not exceeding a ½d. per mile.

There is scope for considerable development of the overhead trolley system in Great Britain, notwithstanding that it possesses features which are tolerated only because its general advantages outweigh its æsthetic objections. There are several directions from which improvements may come. Many engineers look to the surface-contact system, others rely on the appearance of an accumulator so light in weight as to be suitable for tramway work. The open-slot conduit system has many advocates, but its physical difficulties in old cities are great, and its cost is prohibitive for most places. An important factor in the future development of the tramway industry is the question of municipalization. Whether the trolley is superseded by the conduit,

[1] D. Kinnear Clark's *Tramways, their Construction and Working.*

the surface-contact, or the accumulator system, tramway rails and consequent interference with the roads cannot be avoided. Hence on the one hand private enterprise is exposed to the retarding and deterring influences of local authorities, and on the other, local authorities are placed under the disability of being confined more or less to their respective districts. It has been said that tramway rails are a protest against bad roads. If the surface of public roads were better, automobiles would have a chance. Even as it is, private enterprise may decide to develop the business by means of automobiles, in spite of their smaller commercial efficiency, rather than incur the financial risk of constructing costly permanent way under limited tenure, and furthermore submit to the excessive demands for way-leaves and street widenings which are made by local authorities whenever a tramway or light railway is proposed. The attempts hitherto made in Great Britain to utilize electricity for automobile cabs and omnibuses have not been successful. The only possible methods are by primary batteries or by accumulators. The former may be dismissed as being much too expensive, and the latter, besides being too heavy and very costly in wear and tear, suffer from the inconvenience of requiring to be too frequently recharged, and in the absence of charging-stations near the routes traversed, a large amount of useless mileage must be run. For the propulsion of launches, however, accumulators have been found satistory. On the Thames such launches are regularly let out on hire during the summer. There are charging-stations at various points along the river.

Electric traction on railways.

The question of the equipment of main-line railways with electric power is one of the most important economic problems of the present day. In America branch railways of some of the trunk lines have already been electrically equipped, and on the continent of Europe advances have been made in the direction of demonstrating the practicability of working main-line railways by electricity. In England the only working instances of electric traction on railways in 1901 were those of the City and South London, the Liverpool Overhead, the Waterloo and City, and the Central London.

City and South London Railway.—Length of line open for traffic, 3 miles 53 chains (under construction, 3 miles 11½ chains). Working stock: 84 carriages and 28 locomotives. Capital subscribed: ordinary and preferred shares, £1,500,772; 4 per cent. debentures stock, £244,315. Passengers carried (exclusive of season ticket-holders) for the year 1899, 6,983,040. Receipts from passengers for the year 1899, £52,947. Train mileage for the year 1899, 477,227. Receipts from passengers per train mile run. 26·63d. Working expenses per train mile run:—

Maintenance	7d.
Power	5·9
Traffic expenses	6·1
Carriage repairs	·5
General expenses	1·9
Other expenses	·9
	16d.

Average dividend paid since 1892, 5 per cent. on preference shares per annum; on ordinary stock, 1½ per cent. per annum.

Liverpool Overhead Railway.—Length of line open for traffic, 6 miles 57 chains, double (tramway extensions under construction). Capital subscribed: ordinary and preference shares, £570,000; 4 per cent. debentures, £170,000. Passengers carried for the year 1899, 9,690,236. Train mileage for the year 1899, 778,252. Receipts from passengers for the year 1899, £77,971. Receipts from passengers per train mile run, 24·04d. Working expenses per train mile run:—

Maintenance	2·55d.
Power	4·24
Traffic expenses	5·59
Carriage repairs	·36
General expenses	1·35
Other expenses	1·31
	15·40d.

Average dividend paid since 1893: 5 per cent. on preference shares, 2¾ per cent. on ordinary shares per annum.

Waterloo and City Railway.—Length of line open for traffic, 1 mile 46 chains, double. Working stock: 4 trains, and 1 held in reserve. Capital subscribed: ordinary stock, £540,000; 3 per cent. debenture stock, £32,000. Passengers carried for the year 1899, 3,485,556, exclusive of 776 season ticket-holders. Passengers receipts, including season ticket-holders, for the year 1899, £26,577. Working expenses for the year 1899, £15,335. Dividends paid under agreement by London and South-Western Railway Company, 3 per cent. per annum.

Central London Railway.—Length of line constructed, 6 miles 34·7 chains, double. Capital subscribed, £2,850,000.

(E. GA.)

Electro-Chemistry.—The present article will deal with processes that involve the electrolysis of aqueous solutions, whilst those in which electricity is used in the manufacture of chemical products at furnace temperatures will be treated of under ELECTRO-METALLURGY, although, strictly speaking, in some cases (*e.g.* calcium carbide and phosphorus manufacture) they are not truly metallurgical in character. For the theory and elementary laws of electro-deposition, and for the construction and use of electric generators, whether chemical or mechanical, reference must be made to the articles on these subjects, while, for full details of industrial processes which can here be sketched only in outline, recourse must be had to the text-books and journals, of which some are named at the end of the article and others in the text. The importance of the subject may be gauged by a calculation made by Borchers in a paper (*Zeitschrift für Elektrochemie*, 1899, vol. vi. p. 61) on the position of the electro-chemical and electro-metallurgical industries, excluding electro-plating and -typing; this purports to show that when all the electro-chemical works at that time actually, or about to be, erected, should be working up to their full capacity, the annual value of their products, calculated at the prices ruling in 1899, would amount to nearly thirty million pounds sterling. It should be remembered, also, that all the aluminium, magnesium, sodium, potassium, calcium carbide, carborundum, and artificial graphite, now placed on the market, is made by electrical processes, and that the use of such processes for the refining of copper and silver, and in the manufacture of phosphorus, potassium, chlorate, and bleach, already pressing very heavily on the older non-electrical systems, is every year extending. The convenience also with which the energy of waterfalls can be converted into electric energy has led to the introduction of chemical industries into countries and districts where, owing to the absence of coal, they were previously unknown. Norway and Switzerland are rapidly growing into important producers of chemicals, and pastoral districts such as those in which Niagara or Foyers are situated, are being converted into manufacturing centres. In this way the development of the electro-chemical industry is in a marked degree altering the distribution of trade throughout the world.

Electrolytic Refining of Metals.—The principle usually followed in the electrolytic refining of metals is to cast the impure metal into plates, which are exposed as anodes in a suitable solvent, commonly a salt of the metal under treatment. On passing a current of electricity, of which the volume and pressure are adjusted to the conditions of the electrolyte and electrodes, the anode slowly dissolves, leaving the insoluble impurities in the form of a sponge, if the proportion be considerable, but otherwise as a mud or slime which becomes detached from the anode surface and must be prevented from coming into contact with the cathode. The metal to be refined passing into solution is concurrently deposited at the cathode. Soluble impurities which are more electro-negative than the metal under treatment must, if present, be removed by a preliminary process, and the voltage and other conditions must be so selected that none of the more electro-positive metals are co-deposited with the metal to be refined. From these and other considerations it is obvious that (1) the electrolyte must be such as will freely dissolve the metal to be refined; (2) the electrolyte must be able to dissolve the major portion of the anode, otherwise the mass of insoluble matter on the outer layer will prevent access of electrolyte to the core, which will thus escape refining; (3) the electrolyte should, if possible, be incapable of dissolving metals more electro-negative than that to be refined; (4) the proportion of soluble electro-positive impurities must not be excessive, or these substances will accumulate too rapidly in the solution and necessitate its frequent purification; (5) the current density must be so adjusted to the strength of the solution and to other conditions that no relatively electro-positive metal is deposited, and that the cathode deposit is physically suitable for subsequent treatment; (6) the current density should be as high as is consistent with the production of a pure and sound deposit, without undue expense of voltage, so that the operation may be rapid and the "turnover" large; (7) the electrolyte should be as good a conductor of electricity as possible, and should not, ordinarily, be altered chemically by exposure to air; and (8) the use of porous partitions should be avoided, as they increase the resistance and usually require frequent renewal.

Copper. The earliest serious attempt to refine copper industrially was made by Elkington, whose first patent is dated 1865. He cast crude copper, as obtained from the ore, into plates measuring about 24 in. by 8 in. by 1 in., each with a T-shaped support of wrought copper cast into the middle of one end. These plates were used as anodes, sheets of electro-deposited copper forming the cathodes. Six anodes were suspended, alternately with four cathodes, in a saturated solution of copper sulphate in a cylindrical fire-clay trough, all the anodes being connected in one parallel group, and all the cathodes in another. A hundred or more jars were coupled in series, the cathodes of one to the anodes of the next, and were so arranged that with the aid of side-pipes with leaden connexions and india-rubber joints the electrolyte could, once daily, be made to circulate through them all from the top of one jar to the bottom of the next. The current from a Wilde's dynamo was passed, apparently with a current density of 5 or 6 amperes per sq. ft., until the anodes were too crippled for further use, when they were removed, the T-supports (which were protected by wax from the action of the solution) were taken out and used again, and the fragments of the anodes were washed and re-melted. The cathodes, when thick enough, were either cast and rolled or sent into the market direct. Silver and other insoluble impurities collected at the bottom of the trough up to the level of the lower side-tube, and were then run off through a plug in the bottom into settling tanks, from which they were removed for metallurgical treatment. The electrolyte was used until the accumulation of iron in it was too great, but was mixed from time to time with a little water acidulated by sulphuric acid. This process has been described at some length, not only on account of its historic interest, but because in principle it is identical with that now used. The modifications introduced have been chiefly in details, in order to economize materials and labour, to ensure purity of product, and to increase the rate of deposition.

The chemistry of the process has been studied by Kiliani (*Berg- und Hüttenmännisches Zeitung*, 1885, p. 249), who found that, using the (low) current-density of 1·8 ampere per sq. ft. of cathode, and an electrolyte containing 1½ ℔ of copper sulphate and ½ ℔ of sulphuric acid per gallon, all the gold, platinum, and silver present in the crude copper anode remain as metals, undissolved, in the anode slime or mud, and all the lead remains there as sulphate, formed by the action of the sulphuric acid (or SO_4 ions); he found also that arsenic forms arsenious oxide, As_2O_3, which dissolves until the solution is saturated, and then remains in the slime, from which on long standing it gradually dissolves, after conversion by secondary reactions into arsenic oxide; antimony forms a basic sulphate which in part dissolves; bismuth partly dissolves and partly remains, but the dissolved portion tends slowly to separate out as a basic salt which becomes added to the slime; cuprous oxide, sulphide, and selenides remain in the slime, and very slowly pass into solution by simple chemical action; tin partly dissolves (but in part separates again as basic salt) and partly remains as basic sulphate and stannic oxide; zinc, iron, nickel, and cobalt pass into solution—more readily indeed than does the copper. Of the metals which dissolve, none (except bismuth, which is rarely present in any quantity) deposit at the anode so long as the solution retains its proper proportion of copper and acid, and the current-density is not too great. Neutral solutions are to be avoided because in them silver dissolves from the anode and, being more electro-negative than copper, is deposited at the cathode, while antimony and arsenic are also deposited, imparting a dark colour to the copper. Electrolytic copper should contain at least 99·92 per cent. of metallic copper, the balance consisting mainly of oxygen with not more than 0·01 per cent. in all of lead, arsenic, antimony, bismuth, and silver. Such a degree of purity is, however, unattainable unless the conditions of electrolysis are rigidly adhered to. It should be observed that the free acid is gradually neutralized, partly by chemical action on certain constituents of the slime, partly by local action between different metals of the anode, both of which effect solution independently of the current, and partly by the peroxidation (or aëration) of ferrous sulphate formed from the iron in the anode. At the same time there is a gradual substitution of other metals for copper in the solution, because although copper *plus* other (more electro-positive) metals are constantly dissolving at the anode, only copper is deposited at the cathode. Hence the composition and acidity of the solution, on which so much depends, must be constantly watched.

The dependence of the mechanical qualities of the copper upon the current-density employed is well known. A very weak current gives a pale and brittle deposit, but as the current-density is increased up to a certain point, the properties of the metal improve; beyond this point they deteriorate, the colour becoming darker and the deposit less coherent, until at last it is dark brown and spongy or pulverulent. The presence of even a small proportion of hydrochloric acid imparts a brown tint to the deposit. Baron v. Hübl (*Mittheil. der k. k. militär-geograph. Inst.*, 1886, vol. vi. p. 51) has found that with neutral solutions a 5 per cent. solution of copper sulphate gave no good result, while with a 20 per cent. solution the best deposit was obtained with a current-density of 28 amperes per sq. ft.; with solutions containing 2 per cent. of sulphuric acid, the 5 per cent. solution gave good deposits with current-densities of 4 to 7·5 amperes, and the 20 per cent. solution with 11·5 to 37 amperes, per sq. ft. The maximum current-densities for a *pure* acid solution at rest were: for 15 per cent. pure copper sulphate solutions, 14 to 21 amperes, and for 20 per cent. solutions 18·5 to 28 amperes per sq. ft.; but when the solutions were kept in gentle motion these maxima could be increased to 21–28 and 28–37 amperes per sq. ft. respectively. The necessity for adjusting the current-density to the composition and treatment of the electrolyte is thus apparent. The advantage of keeping the solution in motion is due partly to the renewal of solution thus effected in the neighbourhood of the electrodes, and partly to the neutralization of the tendency of liquids undergoing electrolysis to separate into layers, due to the different specific gravities of the solutions flowing from the opposing electrodes. Such an irregular distribution of the bath, with strong copper sulphate solution from the anode at the bottom and acid solution from the cathode at the top, not only alters the conductivity in different strata and so causes irregular current-distribution, but may lead to the current-density in the upper layers being too great for the proportion of copper there present. Irregular and defective deposits are therefore obtained. Provision for circulation of solution is made in the systems of copper-refining now in use. Wilde, in 1875, in depositing copper on iron printing-rollers, recognized this principle and rotated the rollers during electrolysis, thereby renewing the surfaces of metal and liquid in mutual contact, and imparting sufficient motion to the solution to prevent stratification; as an alternative he imparted motion to the electrolyte by means of propeller blades. Other workers have followed more or less on the same lines; reference may be made to the patents of Elmore, who sought to improve the character of the deposit by burnishing during electrolysis, of Dumoulin, and to a recent paper by Cowper-Coles (*Journ. Inst. Elec. Eng.*, 1900, vol. xxix. p. 258), who prefers to rotate the cathode at a speed that maintains a peripheral velocity of at least 1000 ft. per minute. Certain other inventors have applied the same principle in a different way. Thofehrn in America and Graham in England have patented processes by which jets of the electrolyte are caused to impinge with considerable force upon the surface of the cathode, so that the renewal of the liquid at this point takes place very rapidly, and current-densities per sq. ft. of 50 to 100 amperes are recommended by the former, and of 300 amperes by the latter. Graham has described experiments in this direction, using a jet of electrolyte forced (beneath the surface of the bath) through a hole in the anode upon the surface of the cathode. Whilst the jet was playing, a good deposit was formed with so high a current-density as 280 amperes per sq. ft., but if the jet was checked, the deposit (now in a still liquid) was instantaneously ruined. When two or more jets were used side by side the deposit was good opposite the centre of each, but bad at the point where two currents met, because the rate of flow was reduced. By introducing perforated shields of ebonite between the electrodes, so that the full current-density was only attained at the centres of the jets, these ill effects could be prevented. One of the chief troubles met with was the formation of arborescent growths around the edges of the cathode, due to the greater current-density in this region; this, however, was also obviated by the use of screens. By means of a very brisk rotation of cathode, combined with a rapid current of electrolyte, Swan has succeeded in depositing excellent copper at current densities exceeding 1000 amperes per sq. ft. The methods by which such results are to be obtained cannot, however, as yet be practised economically on a working scale; one great difficulty in applying them to the refining of metals is that the jets of liquid would be liable to carry with them particles of anode mud, and Swan has shown that the presence of solid particles in the electrolyte is one of the most fruitful causes of the well-known nodular growths on electro-deposited copper. Experiments on a working scale with one of the jet processes in America have, it is reported, been given up after a full trial.

In copper-refining practice, the current-density commonly ranges from 7·5 to 12 or 15, and occasionally to 18, amperes per sq. ft. The electrical pressure required to force a current of this intensity through the solution, and to overcome a certain opposing electromotive force arising from the more electro-negative impurities of the anode, depends upon the composition of the bath and of the anodes, the distance between the electrodes, and the temperature, but under the usual working conditions averages 0·3 volt for every pair of electrodes in series. In nearly all the processes now used, the solution contains about $1\frac{1}{2}$ to 2 lb of copper sulphate and from 5 to 10 oz. of sulphuric acid per gallon of water, and the space between the electrodes is from $1\frac{1}{2}$ to 2 in., whilst the total area of cathode surface in each tank may be 200 sq. ft., more or less. The anodes are usually cast copper plates about (say) 3 ft. by 2 ft. by $\frac{3}{4}$ or 1 in. The cathodes are frequently of electro-deposited copper, deposited to a thickness of about $\frac{1}{32}$ in. on black-leaded copper plates, from which they are stripped before use. The tanks are commonly constructed of wood lined with lead, or tarred inside, and are placed in terrace fashion each a little higher than the next in series, to facilitate the flow of solution through them all from a cistern at one end to a well at the other. Gangways are left between adjoining rows of tanks, and an overhead travelling-crane facilitates the removal of the electrodes. The arrangement of the tanks depends largely upon the voltage available from the electric generator selected; commonly they are divided into groups, all the baths in each group being in series. In the huge Anaconda Plant, for example, in which 150 tons of refined copper can be produced daily by the Thofehrn multiple system (not the jet system alluded to above), there are 600 tanks about $8\frac{1}{4}$ ft. by $4\frac{1}{2}$ ft. by $3\frac{1}{4}$ ft. deep, arranged in three groups of 200 tanks in series. The connexions are made by copper rods, each of which, in length, is twice the width of the tank, with a bayonet-bend in the middle, and serves to support the cathodes in the one and the anodes in the next tank. Self-registering voltmeters indicate at any moment the potential difference in every tank, and therefore give notice of short circuits occurring at any part of the installation. The chief differences between the commercial systems of refining lie in the arrangement of the baths, in the disposition and manner of supporting the electrodes in each, in the method of circulating the solution, and in the current density employed. The various systems are often classed in two groups, known respectively as the *Multiple* and *Series* systems, depending upon the arrangement of the electrodes in each tank. Under the multiple system anodes and cathodes are placed alternately, all the anodes in one tank being connected to one rod, and all the cathodes to another, and the potential difference between the terminals of each tank is that between a single pair of plates. Under the series system only the first anode and the last cathode are connected to the conductors; between these are suspended, isolated from one another, a number of intermediate bi-polar electrode plates of raw copper, each of these plates acting on one side as a cathode, receiving a deposit of copper, and on the other as an anode, passing into solution; the voltage between the terminals of the tank will be as many times as great as that between a single pair of plates as there are spaces between electrodes in the tank. In time the original impure copper of the plates becomes replaced by refined copper, but if the plates are initially very impure and dissolve irregularly, it may happen that much residual scrap may have to be remelted, or that some of the metal may be twice refined, thus involving a waste of energy. Moreover, the high potential difference between the terminals of the series tank introduces a greater danger of short-circuiting through scraps of metal at the bottom of the bath; for this reason, also, lead-lined vats are inadmissible, and tarred slate tanks are often used instead. A valuable comparison of the multiple and series systems has been published by Kellar (see *The Mineral Industry*, New York, 1899, vol. vii. p. 229). Kroupa and Barnett have calculated that the cost of refining is 8s. per ton of copper higher under the series than it is under the multiple system; but against this, it must be remembered that the new works of the Baltimore Copper Smelting and Refining Company, which are as large as those of the Anaconda Company, are using the Hayden process, which is the chief representative of the several series systems. In this system rolled copper anodes are used; these, being purer than many cast anodes, having flat surfaces, and being held in place by guides, dissolve with great regularity and require a space of only $\frac{5}{8}$ in. between the electrodes, so that the potential difference between each pair of plates may be reduced to 0·15–0·2 volt.

Borchers, in Germany, and Schneider and Szontagh, in America, have introduced a method of circulating the solution in each vat by forcing air into a vertical pipe communicating between the bottom and top of a tank, with the result that the bubbling of the air upward aspirates solution through the vertical pipe from below, at the same time aërating it, and causing it to overflow into the top of the tank. Obviously this slow circulation has but little effect on the rate at which the copper may be deposited. The electrolyte, when too impure for further use, is commonly recrystallized, or electrolysed with insoluble anodes to recover the copper.

The yield of copper per ampere (in round numbers, 1 oz. of copper per ampere per diem) by Faraday's law is never attained in practice; and although 98 per cent. may with care be obtained, from 94 to 96 per cent. represents the more usual current-efficiency. With 100 per cent. current-efficiency and a P.D. of 0·3 volt between the electrodes, 1 lb of copper should require about 0·154 electrical horse-power hours as the amount of energy to be expended in the tank for its production. In practice the expenditure is somewhat greater than this; in large works the gross horse-power required for the refining itself and for power and lighting in the factory may not exceed 0·19 to 0·2 (or in smaller works 0·25) horse-power hours per pound of copper refined.

Many attempts have been made to use crude sulphide of copper or matte as an anode, and recover the copper at the cathode, the sulphur and other insoluble constituents being left at the anode. The best known of these is the Marchese process, which was tested on a working scale at Genoa and Stolberg. As the operation proceeded, it was found that the voltage had to be raised until it became prohibitive, while the anodes rapidly became honeycombed through and, crumbling away, filled up the space at the bottom of the vat. The process was abandoned, but in a modified form appears to be now in use in Nijni Novogorod in Russia. Siemens and Halske introduced a combined process in which the ore, after being part-roasted, is leached by solutions from a previous electrolytic operation, and the resulting copper solution electrolysed. In this process the anode solution had to be kept separate from the cathode solution, and the membrane which had in consequence to be used, was liable to become torn, and so to cause trouble by permitting the two solutions to mix. Modifications of the process have therefore been tried.

Silver.

In the electrolytic refining of copper with acid sulphate solutions, practically the whole of the silver in the anode is left in the slime, from which it is readily recovered; but when the silver forms the bulk of the metal to be purified, a method must be used which will involve the solution of the silver itself at the anode and its deposition at the cathode. The only process to which reference need here be made is that of Mœbius. Under his earlier patent of 1884, cast crude silver anode plates, about $\frac{1}{2}$ in. thick, and thin rolled silver cathodes, were suspended in a $\frac{1}{2}$ per cent., slightly acid, solution of silver nitrate contained in tarred wooden tanks. The deposit from this solution even with low current-densities is pulverulent and non-coherent, and therefore during electrolysis wooden scrapers are automatically and intermittently passed over the surface of the cathode to detach the loose silver, which falls into cloth trays at the bottom of the tanks. These trays are removed at intervals, and the silver washed and cast into bars, which should contain over 99·9 per cent. of pure metal. The relatively electro-negative character of silver ensures that with moderate current densities no metal (other than precious metals) will be deposited with it; hence, while the solution is pure a current-density of 30 amperes per sq. ft. of cathode may be used, but as copper accumulates in it, the current density must be diminished to (say) 15 to 20 amperes per sq. ft., and a little extra nitric acid must be added, in order to prevent the co-deposition of copper. A pressure of 1·5 volt usually suffices when the space between the electrodes is 2 in. The tanks were arranged in groups of seven on the multiple system. Of the metals present in the anode, practically all, except gold, pass into solution but, under the right conditions, only silver should deposit. The whole of the gold is recovered as anode slime in cloth bags surrounding the anodes. Practical results with a large plant indicate an expenditure of 1·23 electrical horse-power hours per 100 oz. (Troy) of refined silver. In later installations, under the 1895 patent, the anodes are placed horizontally on a porous tray resting within the solution above an endless silver band revolving, also horizontally, over rollers placed near the ends of a long shallow tank. The revolving band forms the cathode, and at one end makes a rubbing contact with a travelling belt placed at an angle so that the crystals of silver detached thereby from the cathode are conveyed by it from the solution and deposited outside.

Alloy scrap containing chiefly copper with, say 5 or 6 per cent. of gold, and other metals, and up to 40 or 50 per cent. of silver, is often treated electrolytically. Obviously, with modifications, the Mœbius process could be applied. Other systems have been devised. Borchers uses the alloy, granulated, in an anode chamber separated from the cathode cell by a porous partition through which the current, but not electrolyte, can pass freely. The anode residue is collected in the angular bottom of the tank, the electrolyte passes from the anode chamber to a series of tanks in which the more electro-negative constituents (silver, &c.) are chemically separated, and thence to the cathode chamber, where the copper is deposited electrolytically, thence it passes again to the anode chamber and so completes the cycle. In one form of the apparatus a rotating cathode is used. Dietzel has described (*Zeitschrift für Elektrochem.*, 1899, vol. vi. p. 81) the working of his, somewhat similar, process at Pforzheim, where about 130 ℔ of the alloy were being treated by it daily in 1899. The alloy is cast into anode plates about ⅛ in. thick, and placed in the anode chamber beneath the cathode cell, and separated from it by linen cloth. In the upper compartment are two large revolving horizontal cathode cylinders. Acidified copper nitrate solution is run into this cell, copper is deposited, and the more or less spent solution then passes through the linen partition, and, taking up metal from the anodes by electrolytic solution, is run out of the trough through a series of vessels filled with copper by which the silver is precipitated by simple exchange; after acidification the resulting silver-free copper solution is returned to the cathode cell for the deposition of the copper, the solution being employed again and again until too impure for use.

Gold. Gold is left in the anode slime when copper or silver are refined by the usual processes, but if the gold preponderate in the anode these processes are inapplicable. A cyanide bath, as used in electroplating, would dissolve the gold, but is not suitable for refining, because other metals (silver, copper, &c.) passing with gold into the solution would deposit with it. Bock, however, in 1880 (*Berg- und Hüttenmännische Zeitung*, 1880, p. 411) described a process used at the North German Refinery in Hamburg for the refining of gold containing platinum with a small proportion of silver, lead, or bismuth, and a more recent patent specification (1896) and a paper by Wohlwill (*Zeitschrift f. Elektrochem.*, 1898, pp. 379, 402, 421) have thrown more light upon the process. The electrolyte is gold chloride (2·5-3 parts of pure gold per 100 of solution) mixed with from 2 to 6 per cent. of the strongest hydrochloric acid to render the gold anodes readily soluble, which they are not in the neutral chloride solution. The bath is used at 65° to 70° C. (150° to 158° F.), and if free chlorine be evolved, which is known at once by its pungent smell, the temperature is raised, or more acid is added, to promote the solubility of the gold. The bath is used with a current-density of 100 amperes per sq. ft. at 1 volt (or higher), with electrodes about 1·2 in. apart. In this process all the anode metals pass into solution except iridium and other refractory metals of that group, which remain as metals, and silver, which is converted into insoluble chloride; lead and bismuth form chloride and oxychloride respectively, and these dissolve until the bath is saturated with them, and then precipitate with the silver in the tank. But if the gold-strength of the bath be maintained, only gold is deposited at the cathode—in a loose powdery condition from pure solutions, but in a smooth detachable deposit from impure liquors. Under good conditions the gold should contain 99·98 per cent. of the pure metal. The tank is of porcelain or glazed earthenware, the electrodes for impure solutions are ½ in. apart (or more with pure solutions), and are on the multiple system, and the potential difference at the terminals of the bath is 1 volt. A high current-density being employed, the turn-over of gold is rapid—an essential factor of success when the costliness of the metal is taken into account. Platinum and palladium dissolved from the anode accumulate in the solution, and are removed at intervals of, say, a few months by chemical precipitation. It is essential that the bath should not contain more than 5 per cent. of palladium, or some of this metal will deposit with the gold. The slimes are treated chemically for the separation of the metals contained in them.

Many patents have been taken out for the electrolytic solution of gold from its ores; but the difficulty of extracting in this way so little, perhaps, as a fraction of an ounce of the metal from each ton of sand or other finely crushed material renders the problem an exceedingly difficult one. In some of the processes electrolytic chlorine is used, in some an attempt is made to render the gold particles anodes, whilst in others electrolysis is called in to aid the solvent power of mercury for the precious metal. It is unnecessary here to refer further to any of these. Electrolysis has, however, been successfully applied by Siemens and Halske to the recovery of gold from the potassium cyanide solutions now so largely employed to dissolve gold from ores and tailings. The solution of the double cyanide of gold and potassium formed by the action of potassium cyanide on gold in the presence of air is run off and washed from the ore, and is passed through a series of iron tanks, in which it is electrolysed between lead cathodes and iron anodes (which do not dissolve, although Prussian blue and other insoluble iron compounds are formed), with a current-density of about 0·04 to 0·06 amperes per sq. ft., at a pressure of about 4 volts. The lead cathodes with their adherent gold deposit are removed about once a month, and melted up, the gold being recovered by cupellation. Several modifications of the process have been proposed, *e.g.*, Andreoli uses lead peroxide anodes, and iron cathodes from which the gold is removed from time to time by a brief immersion in molten lead, and Cowper-Coles uses an aluminium cathode, from which the gold is readily stripped, being imperfectly adherent by reason of the film of oxide which always exists on the surface of aluminium.

Nickel. Thin deposits of nickel have long been obtained with readiness, but thick deposits are troublesome, as they tend to curl up and peel off the cathode surface. Cathode-nickel is now made both in England and in America, but the details of the process used have not been disclosed. Foerster (*Zeitschrift f. Elektrochem.*, 1897, vol. iv. p. 160) has, however, found that with a suitable current-density, using soluble nickel anodes and a neutral solution of nickel sulphate at 50°-90° C. (120°-200° F.), a perfect deposit of any desired thickness can be obtained. Thus with the electrodes 1·5 in. apart in a bath at 60° C. (140° F.) containing 1 ℔ of (metallic) nickel dissolved as sulphate per gallon, a current-density of 14·5-18·5 amperes per sq. ft., at 1-1·3 volt, gave a solid deposit ⅛ in. thick. Nickel chloride could be used, but less satisfactorily. Practically all the cobalt and iron present were deposited with the nickel, and this fact renders the problem of the continuous and direct electrolytic refining of nickel a very difficult one. According to the patent of Salve, iron, zinc, and cobalt can be separated electrolytically from nickel in solution by a process which necessitates intermittency and the use of insoluble anodes. André, Hoepfner, Ulke, and others have devised processes for the treatment of nickel ores, sulphides, or other compounds electrolytically.

Zinc. The deposition of pure zinc is beset with many difficulties. Zinc being more electro-positive even than nickel, all the heavy metals must be removed before its deposition is attempted. Moreover, unless the conditions are closely watched, it is liable to be thrown down in a spongy form. Kiliani found that the sponge was produced chiefly when a weak solution, or a low current-density, was used, and that hydrogen was usually evolved simultaneously; sound deposits resulted from the use of a current-density of 200 amperes, or more, per sq. ft., and strong solutions. The cause of the spongy deposit is variously explained, some (Siemens and Halske) ascribing it to the existence of a compound of zinc and hydrogen, and others, among whom are Nahnsen, Mylius and Fromm, Foerster and Borchers, trace it to the presence of oxide, produced, for example, either by the use of a solution containing a trace of basic salt of zinc (to prevent which the bath should be kept just—almost imperceptibly—acid), or by the presence of a more electro-negative metal, which, being co-deposited, sets up local action at the expense of the zinc. Many processes have been patented, the ore being acted upon by acid, and the resulting solution treated, by either chemical or electrolytic means, for the successive removal of the other heavy metals. The pure solution of zinc is then electrolysed. Ashcroft patented a process of dealing with complex ores of the well-known Broken Hill type, containing sulphides of silver, lead, and zinc, but the system was abandoned after a long trial on a practical scale. A full account of the process (*Trans. Inst. Min. and Met.*, 1898, vol. vi. p. 282) has been published by the inventor, describing the practical trial at the Cockle Creek Works. The ore was crushed, roasted, and leached with sulphuric acid (with or without ferric sulphate); the solution was purified and then electrolysed for zinc with lead anodes and with a current-density of 5 amperes per sq. ft. at 2·75 volts when diaphragms were used, or 2·5 volts when they were dispensed with, or with 10 amperes per sq. ft. at 3 or 2·5 volts respectively, the electrolyte containing 1·2 ℔ of zinc in the form of sulphate, and ½ to ¾ oz. of sulphuric acid, per gallon. The current efficiency was about 83 per cent. Canvas diaphragms were used to prevent the acid formed by electrolysis at the anode from mixing with the cathode liquor, and so hindering deposition. Hoepfner has patented several processes, in one of which (No. 13,336 of 1894) a rapidly rotating cathode is used in a chloride solution, a porous partition separating the tank into anode and cathode compartments, and the chlorine generated by electrolysis at the anode being recovered. Hoepfner's processes have been employed both in England and in Germany. Nahnsen's process, with an electrolyte containing alkali-metal sulphate and zinc sulphate, has been used in Germany, and a process invented by Dieffenbach has also been tried in that country. Siemens and Halske have proposed the addition of oxidizing agents such as free halogens, to prevent the formation of zinc hydride, to which they attribute the formation of zinc-sponge. Borchers and others deposit zinc from the fused chloride. In Borchers' process the chloride is heated partly by external firing partly by the heat generated owing to the use of a current-density of 90 to 100 amperes per sq. ft.

Lead and antimony. Keith electrolysed lead in an acetate solution, choosing this compound because, being organic and oxidizable in character, it prevents the formation of lead peroxide at the anode. It was tried, but its use appears to have been generally discontinued on a large scale. Tommasi has also introduced a process in which the acetates of lead and an alkali-metal are electrolysed. A certain amount of electrolytically refined antimony has been placed on the market. Siemens and Halske patented a process in which the antimony sulphide from the ore is dissolved in an alkaline sulphohydrate and electrolysed in a tank with two divisions, the anode compartment containing an alkaline chloride, and the cathode cell the antimony solution; in another process the antimony is deposited from the chloride. Borchers recommends the solution of the antimony sulphide in sodium sulphide, forming soluble sodium thio-antimonite; this solution is then electrolysed with iron electrodes, between which a pressure of about 2 volts produces a current-density of 9–14 amperes per sq. ft. at first. As the solution loses antimony by deposition, the current-density is reduced to 3·5–4 amperes per sq. ft. The antimony deposit from the sulphide process is loose, and therefore requires to be scraped off the cathode and fused together under a flux.

Electrotyping.—Reference should be made to the article Electro-Metallurgy, *Ency. Brit.*, 9th ed., vol. viii. In copying engraved plates for printing purposes, copper may be deposited upon the original plate, the surface of which is first rendered slightly dirty, by means of a weak solution of wax in turpentine or otherwise, to prevent adhesion. The reversed plate thus produced is then stripped from the first and used as cathode in its turn, with the result that even the finest lines of the original are faithfully reproduced. The electrolyte commonly contains about $1\frac{1}{2}$ lb of copper sulphate and $\frac{1}{2}$ lb of strong sulphuric acid per gallon, and is worked with a current-density of about 10 amperes per sq. ft., which should give a thickness of 0·000563 in. of copper per hour. As time is an object, the conditions alluded to under the head of copper refining as being favourable to the use of high current-densities should be studied, bearing in mind that a tough copper deposit of high quality is essential. Moulds for reproducing plates or art-work are often taken in plaster, beeswax mixed with Venice turpentine, fusible metal, or gutta-percha, and the surface being rendered conductive by powdered black-lead, copper is deposited upon it evenly throughout. The details of these processes may be found in the text-books referred to at the end of this article. For statuary, and "undercut" work generally, an elastic mould—of glue and treacle (80 : 20 parts)—may be used; the mould, when set, is waterproofed by immersion in a bichromate solution followed by exposure to sunlight, or in some other way. The best results, however, are obtained by taking a wax cast from the elastic mould, and then from this a plaster mould, which may be waterproofed with wax, black-leaded, and used as cathode. In art-work of this nature the principal points to be looked to in depositing are the electrical connexions to the cathode, the shape of the anode (to secure uniformity of deposition), the circulation of the electrolyte, and, in some cases, the means for escape of anode oxygen. Silver electrotyping is occasionally resorted to for special purposes.

Electroplating. — As the durability of the electro-deposited coat on plated wares of all kinds is of the utmost importance, the greatest care must be taken to ensure its complete adhesion. This can only be effected if the surface of the metal on which the deposit is to be made is chemically clean, and the cleansing processes referred to in the article Electro-Metallurgy (*Ency. Brit.*, 9th ed.) must be rigorously applied. Grease must be removed by potash, whiting, or other means, and tarnish by acid or potassium cyanide, washing in plenty of water being resorted to after each operation. The vats for depositing may be of enamelled iron, slate, glazed earthenware, glass, lead-lined wood, &c. The current-densities and potential differences frequently used for some of the commoner metals are given in the following table, taken from M'Millan's *Treatise on Electro-Metallurgy*. It must be remembered, however, that variations in conditions modify the electromotive force required for any given process. For example, a rise in temperature of the bath causes an increase in its conductivity, so that a lower E.M.F. will suffice to give the required current-density; on the other hand, an abnormally great distance between the electrodes, or a diminution in acidity of an acid bath, or in the strength of the solution used, will increase the resistance, and so require the application of a higher E.M.F.

Metal.	Amperes.		Volts between Anode and Cathode.
	Per Sq. Decimetre of Cathode Surface.	Per Sq. In. of Cathode Surface.	
Antimony	0·4–0·5	0·02–0·03	1·0–1·2
Brass	0·5–0·8	0·03–0·05	3·0–4·0
Copper, acid bath	1·0–1·5	0·065–0·10	0·5–1·5
,, alkaline ,,	0·3–0·5	0·02–0·03	3·0–5·0
Gold	0·1	0·006	0·5–4·0
Iron	0·5	0·03	1·0
Nickel, at first	1·4–1·5	0·09–0·10	5·0
,, after	0·2–0·3	0·015–0·02	1·5–2·0
,, on zinc	0·4	0·025	4·0–5·0
Silver	0·2–0·5	0·015–0·03	0·75–1·0
Zinc	0·3–0·6	0·02–0·04	2·5–3·0

Large objects are suspended in the tanks by hooks or wires, care being taken to shift their position and so avoid wire-marks. Small objects are often heaped together in perforated trays or ladles, the cathode connecting-rod being buried in the midst of them. These require constant shifting because the objects are in contact at many points, and because the top ones shield those below from the depositing action of the current. Hence processes have been patented in which the objects to be plated are suspended in revolving drums between the anodes, the rotation of the drum causing the constant renewal of surfaces and affording a burnishing action at the same time. Care must be taken not to expose goods in the plating-bath to too high a current-density, else they may be "burnt"; they must never be exposed one at a time to the full anode surface, with the current flowing in an empty bath, but either one piece at a time should be replaced, or some of the anodes should be transferred temporarily to the place of the cathodes, in order to distribute the current over a sufficient cathode-area. Burnt deposits are dark coloured, or even pulverulent, and useless. The strength of the current may also be regulated by introducing lengths of German silver or iron wire, carbon rod, or other inferior conductors in the path of the current, and a series of such resistances should always be provided close to the tanks. Ammeters to measure the volume, and voltmeters to determine the pressure of current supplied to the baths, should also be provided. Very irregular surfaces may require the use of specially shaped anodes in order that the distance between the electrodes may be fairly uniform, otherwise the portion of the cathode lying nearest to the anode may receive an undue share of the current, and therefore a greater thickness of coat. Supplementary anodes are sometimes used in difficult cases of this kind. Large metallic surfaces (especially external surfaces) are sometimes plated by means of a "doctor," which, in its simplest form, is a brush constantly wetted with the electrolyte, with a wire anode buried amid the hairs or bristles; this brush is painted slowly over the surface of the metal to be coated, which must be connected to the negative terminal of the electrical generator. Under these conditions electrolysis of the solution in the brush takes place. Iron ships' plates have recently been coated with copper in sections (to prevent the adhesion of barnacles), by building up a temporary trough against the side of the ship, making the thoroughly cleansed plate act both as cathode and as one side of the trough. Decorative plating-work in several colours (*e.g.*, "parcel-gilding") is effected by painting a portion of an object with a stopping-out (*i.e.*, a non-conducting) varnish, such as copal varnish, so that this portion is not coated. The varnish is then removed, a different design stopped out, and another metal deposited. By varying this process, designs in metals of different colours may readily be obtained.

Reference must be made to ELECTRO-METALLURGY (*Ency. Brit.*, 9th ed.) for a slight indication of the solutions commonly used, and to the text-books (see the end of this article) for a fuller account of the very varied solutions and methods employed for electroplating with silver, gold, copper, iron, and nickel. It should be mentioned here, however, that solutions which would deposit their metal on any object by simple immersion should not be generally used for electroplating that object, as the resulting deposit is usually non-adhesive. For this reason the acid copper-bath is not used for iron or zinc objects, a bath containing copper cyanide or oxide dissolved in potassium cyanide being substituted. This solution, being an inferior conductor of electricity, requires a much higher electromotive force to drive the current through it, and is therefore more costly in use. It is, however, commonly employed hot, whereby its resistance is reduced. *Zinc* is now commonly deposited by electrolysis on iron or steel goods which would ordinarily be "galvanized," but which for any reason may not conveniently be treated by the method of immersion in fused zinc. The zinc cyanide bath may be used for small objects, but for heavy goods the sulphate bath is employed. Cowper-Coles has patented a process in which, working with a high current-density, a lead anode is used, and powdered zinc is kept suspended in the solution to maintain the proportion of zinc in the electrolyte, and so to guard against the gradual acidification of the bath. *Cobalt* is deposited by a method analogous to that used for its sister-metal nickel. *Platinum*, *palladium*, and *tin* are occasionally deposited for special purposes. In the deposition of *gold* the colour of the deposit is influenced by the presence of impurities in the solution; when copper is present, some is deposited with the gold, imparting to it a reddish colour, whilst a little silver gives it a greenish shade. Thus so-called coloured-gold deposits may be produced by the judicious introduction of suitable impurities. Even pure gold, it may be noted, is darker or lighter in colour according as a stronger or a weaker current is used. The electro-deposition of *brass*—mainly on iron ware, such as bedstead tubes—is now very widely practised, the bath employed being a mixture of copper, zinc, and potassium cyanides, the proportions of which vary according to the character of the brass required, and to the mode of treatment. The colour depends in part upon the proportion of copper and zinc, and in part upon the current-density, weaker currents tending to produce a redder or yellower metal. Other alloys may be produced, such as bronze, or German silver, by selecting solutions (usually cyanides) from which the current is able to deposit the constituent metals simultaneously.

Electrolysis has in a few instances been applied to processes of manufacture. For example, Wilde produced copper printing surfaces for calico printing-rollers and the like by immersing rotating iron cylinders as cathodes in a copper bath. Elmore, Dumoulin, Cowper-Coles, and others have prepared copper cylinders and plates by depositing copper on rotating mandrels with special arrangements, to which allusion has already been made. Others have arranged a means of obtaining high conductivity wire from cathode-copper without fusion, by depositing the metal in the form of a spiral strip on a cylinder, the strip being subsequently drawn down in the usual way; at present, however, the ordinary methods of wire-production are found to be cheaper. Swan (*Journ. Inst. Elec. Eng.*, 1898, vol. xxvii. p. 16) also worked out, but did not proceed with, a process in which a copper wire whilst receiving a deposit of copper was continuously passed through the draw-plate, and thus indefinitely extended in length. Cowper-Coles (*Journ. Inst. Elec. Eng.*, 1898, vol. xxvii. p. 99) has very successfully produced true parabolic reflectors for projectors, by depositing copper upon carefully ground and polished glass surfaces rendered conductive by a film of deposited silver.

Electrolytic Manufacture of Chemical Products.—When aqueous solution of the salt of an alkali-metal is electrolysed, the metal reacts with the water, as is well known, forming caustic alkali, which dissolves in the solution, and hydrogen, which comes off as a gas. So early as 1851 a patent was taken out by Cooke for the production of caustic alkali without the use of a separate current, by immersing iron and copper plates on opposite sides of a porous (biscuit-ware) partition in a suitable cell, containing a solution of the salt to be electrolysed, at 21°–65° C. (70°–150° F.). The solution of the iron anode was intended to afford the necessary energy. In the same year another patent was granted to C. Watt for a similar process, involving the employment of an externally generated current. When an alkaline chloride, say sodium chloride, is electrolysed with one electrode immersed in a porous cell, while caustic soda is formed at the cathode, chlorine is deposited at the anode. If the latter be insoluble, the gas diffuses into the solution and, when this becomes saturated, escapes into the air. If, however, no porous division be used to prevent the intermingling by diffusion of the anode and cathode solutions, a complicated set of subsidiary reactions takes place. The chlorine reacts with the caustic soda, forming sodium hypochlorite, and this in turn, with an excess of chlorine and at higher temperatures, becomes for the most part converted into chlorate, whilst any simultaneous electrolysis of a hydroxide or water and a chloride (so that hydroxyl and chlorine are simultaneously liberated at the anode) also produces oxygen-chlorine compounds direct. At the same time, the diffusion of these compounds into contact with the cathode leads to a partial reduction to chloride, by the removal of combined oxygen by the instrumentality of the hydrogen there evolved. In proportion as the original chloride is thus reproduced, the efficiency of the process is of course diminished. It is obvious that, with suitable methods and apparatus, the electrolysis of alkaline chlorides may be made to yield chlorine, hypochlorites (bleaching liquors), chlorates, or caustic alkali, but that great care must be exercised if any of these products is to be obtained pure and with economy. Many patents have been taken out in this branch of electro-chemistry, but it is to be remarked that that granted to C. Watt traversed the whole of the ground. In his process a current was passed through a tank divided into two or three cells by porous partitions, hoods and tubes were arranged to carry off chlorine and hydrogen respectively, and the whole was heated to 120° F. by a steam jacket when caustic alkali was being made. Hypochlorites were made, at ordinary temperatures, and chlorates at higher temperatures, in a cell without a partition in which the cathode was placed horizontally immediately above the anode, to favour the mixing of the ascending chlorine with the descending caustic solution.

The relation between the composition of the electrolyte and the various conditions of current-density, temperature, and the like has been studied by Oettel (*Zeitschrift f. Elektrochem.*, 1894, vol. i. pp. 354 and 474) in connexion with the production of hypochlorites and chlorates in tanks without diaphragms, by Häussermann and Naschold (*Chemiker Zeitung*, 1894, vol. xviii. p. 857) for their production in cells with porous diaphragms, and by Haber and Grinberg (*Zeitschrift f. anorgan. Chem.*, 1898, vol. xvi. pp. 198, 329, 438) in connexion with the electrolysis of hydrochloric acid. Oettel, using a 20 per cent. solution of potassium chloride, obtained the best yield of hypochlorite with a high current-density, but as soon as 1¼ per cent. of bleaching chlorine (as hypochlorite) was present, the formation of chlorate commenced. The yield was at best very low as compared with that theoretically possible. The best yield of chlorate was obtained when from 1 to 4 per cent. of caustic potash was present. With high current-density, heating the solution tended to increase the proportion of chlorate to hypochlorite, but as the proportion of water decomposed is then higher, the amount of chlorine produced must be less and the total chlorine efficiency lower. He also traced a connexion between alkalinity, temperature, and current-density, and showed that these conditions should be mutually adjusted. With a current-density of 130–140 amperes per sq. ft., at 3 volts, passing between platinum electrodes, he attained to a current-efficiency of 52 per cent., and each (British) electrical horse-power hour was equivalent to a production of 1378·5 grains of potassium chlorate. In other words, each pound of chlorate would require an expenditure of nearly 5·1 E.H.P. hours One of the earliest of the more modern processes was that of Hermite, which consisted in the production of bleach-liquors by the electrolysis (according to the 1st edition of the 1884 patent) of magnesium or calcium chloride between platinum anodes carried in wooden frames, and zinc cathodes. The solution, containing hypochlorites and chlorates, was then applied to the bleaching of linen, paper-pulp, or the like, the solution being used over and over again. Many modifications have been patented by Hermite, one of the latest (1895) specifying the use of platinum gauze anodes, held in ebonite or other frames. Rotating zinc cathodes were used, with scrapers to prevent the accumulation of a layer of insoluble magnesium compounds, which would otherwise increase the electrical resistance beyond reasonable limits. The same inventor has patented the application of electrolysed chlorides to the purification of starch by the oxidation of less stable organic bodies, to the bleaching of oils, and to the purification of coal gas, spirit, and other substances. His system for the disinfection of sewage and similar matter by the electrolysis of chlorides, or of sea-water, has been tried, but for the most part abandoned on the score of expense. Reference may be made to papers written in the early days of the process by Cross and Bevan (*Journ. Soc. Chem. Industry*, 1887, vol. vi. p. 170, and 1888, vol. vii. p. 292), and to later papers by Schoop (*Zeitschrift f. Elektrochem.*, 1895, vol. ii. pp. 68, 88, 107, 209, 289).

Kellner, who in 1886 patented the use of cathode (caustic soda) and anode (chlorine) liquors in the manufacture of cellulose from wood-fibre, and has since evolved many similar processes, has produced an apparatus that has been largely used. It consists of a stoneware tank with a thin sheet of platinum-iridium alloy at either end forming the primary electrodes, and between them a number of glass plates reaching nearly to the bottom, each having a platinum gauze sheet on either side; the two sheets belonging to each plate are in metallic connexion, but insulated from all the others, and form intermediary or bi-polar electrodes. A 10–12 per cent. solution of sodium chloride is caused to flow upwards through the apparatus and to overflow into troughs, by which it is conveyed (if necessary through a cooling apparatus) back to the circulating pump. Such a plant has been reported as giving 0·229 gallon of a liquor containing 1 per cent. of available chlorine per kilowatt hour, or 0·171 gallon per E.H.P. hour. Kellner has also patented a "bleaching-block," as he terms it, consisting of a frame carrying parallel plates similar in principle to those last described. The block is immersed in the solution to be bleached, and may be lifted in or out as required. Knöfler and Gebauer have also a system of bi-polar electrodes, mounted in a frame in appearance resembling a filter-press.

Chlorate manufacture.

It is estimated that fully two-thirds of the annual production of chlorate is obtained by electrolytic methods. The experiments of Oettel and those of Häussermann and Naschold, above referred to, showed that the best results were obtained when the (anode) solution was maintained slightly alkaline throughout. The electrolyte should also be at a temperature of 70°–80° C. (160°–180° F.), as a better yield of chloride is then obtained; the current-density should also be high. Häussermann and Naschold, with a current-density of 31 amperes per sq. ft. of platinum anode surface (at 4 volts), obtained on a small scale a yield of 7·7 grains of chlorate per ampere hour, or a current-efficiency of 67 per cent. Oettel obtained about 52 per cent. in practice. These numbers are equivalent to an expenditure of 4·77, and 5·07, E.H.P. hours respectively, per pound of chlorate. In the practical working of the process, platinum or carbon electrodes were commonly employed. Platinum, however, is liable to become slowly attached when used as anode with chlorine, deposition taking place at its surface, although the action is far less with neutral chlorides than with hydrochloric acid as electrolyte, and carbon is subject to rapid disintegration unless the pores can be filled up, or a very dense form of it, such as graphite, be used. An alloy containing 90 per cent. of platinum and 10 of iridium is very largely employed, on account of its high power of resisting the attack of anode chlorine; and many other anode materials have been suggested for various purposes, among them being ferrosilicon, chromium phosphide, and lead peroxide. The Gall and Montlaur process is that most commonly used at the large Continental works. At Vallorbes, in Switzerland, 3000 H.P. were being consumed in this industry so far back as 1891. Here a 25 per cent. solution of potassium chloride was electrolysed in 270 rectangular lead-lined tanks, each holding 1765 cb. ft. of liquid, with thin (0·1 mm.) platinum-iridium anodes and iron cathodes, with a porous diaphragm between. The current-density was 460 amperes per sq. ft., and the pressure required to force this current through the liquid and diaphragm was 5 volts, the temperature of the bath being 45°–55° C. (115°–130° F.). The anode and cathode solutions were kept distinct, each having its own system of circulation. Potassium chlorate is far less soluble than the chloride, and the liquid rapidly becomes saturated with it; from this period, onward, the chlorate crystallizes out as fast as it is formed, and may be removed in the solid form for recrystallization for the market; meanwhile fresh chloride is constantly introduced, to take the place of that which has been converted into chlorate. At the St Michael Works in the Rhone Valley (France) the same process is employed, but the cathodes are of ferronickel covered by asbestos cloth. It is believed by Kershaw (*Elec. Review*, 1898, vol. xliii. p. 791) that the use of diaphragms has now been abandoned.

Alkali manufacture.

In any process by which it is attempted to utilize the caustic alkali produced at the cathode in the electrolysis of sodium chloride, it is obvious that the chlorine from the anode must be prevented from coming in contact with the cathode solution. Porous partitions have naturally been largely used in many electrolytic alkali processes; but they are costly, inasmuch as they entail the expenditure of electromotive force to urge the current through them and require more or less frequent renewal. Being subject to the action of caustic alkali on the one side, and of chlorine and hypochlorites on the other, it is not easy to find a substance of low electrical resistance that is able chemically to withstand the influence of both classes of corrosive. Moreover, no suitable porous partition yet found can entirely prevent intermingling of solutions and, therefore, loss.

Cooke and Watt were the first to patent electrolytic alkali manufacture, but before the invention of the dynamo no such process could compete economically with the existing chemical methods. Fitzgerald and Molloy patented a process in 1872; and Marx in 1887, in the first of a series of patents, protected the use of carbon dioxide gas in the electrolytic cell to precipitate sodium bicarbonate from the caustic soda solution formed by the electrolysis of common salt solutions, and so to remove it from the influence of chlorine. The principal processes lately in use on a practical scale, some of them still on their trial, are the Kellner, Castner-Kellner (now very extensively employed), the Hargreaves-Bird, the Richardson and Holland, the Le Sueur and the Hulin process. Of these, Richardson and Holland avoided the use of porous partitions by separating the anode and cathode compartments by a non-porous wall reaching above the top, but not down to the bottom, of the cell, so that electrolytic conduction could take place freely between the electrodes through the medium of the liquid beneath the division, yet the chlorine gas would for the most part escape upwards from the anode, and the hydrogen liberated at the cathode was depended upon to carry upwards the caustic alkali produced in the cathode cell. Obviously by this process it would be difficult entirely to prevent diffusion and also to obtain a caustic alkali free from admixture with the original chloride electrolyte. In another patent, open to the same objections, the same inventors protected the use of copper-oxide cathodes placed horizontally beneath the anodes; here the oxide would be reduced by the electrolytic hydrogen, and the caustic alkali formed would sink downwards from the electrode. This process has been used in paper-mills. In the Hargreaves-Bird apparatus (of which the first British patent was No. 18,039 of 1892) a combined porous cell and cathode is used; the cathode itself is of wire gauze, which is covered with a mixture of lime and asbestos dipped into a solution of silicate of soda, after drying, in order to bind the material together; the whole is then dried again. According to a later specification, a layer of Portland cement is

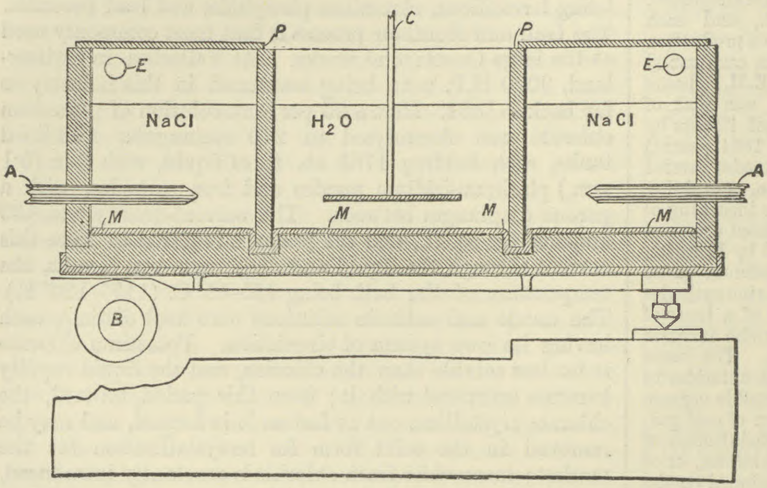


Fig. 1.

introduced between the gauze and the asbestos lime mixture, and means are taken to prevent the gauze being in absolute contact with the cement. There results a thin sheet, which forms one side of the electrolytic cell, the gauze being outwards. Electrolysis of the sodium chloride takes place as usual, the electrolyte passes, by osmosis, through the partition to the gauze, sodium is there deposited and, with the water present, forms caustic soda, which is washed away by a spray of water, the hydrogen liberated in the reaction escaping. If necessary, the caustic soda may be carbonated by bringing carbon dioxide into contact with the gauze during electrolysis. Hulin, in an early process, proposed to use a porous carbon cathode through which the solution filtered, the rate of flow being so adjusted that the whole of the salt was decomposed and only solution of cathode alkali escaped. Obviously, however, such regulation would be exceedingly difficult. In the Le Sueur process, which has been for some time used in certain American works, a porous division is used, and the liquid in the anode compartment is said to be maintained at a higher level than in the cathode cell, in order to lessen the loss by diffusion of alkaline liquid from the latter to the former. In Le Sueur's 1891 patent, it is provided that hydrochloric acid shall be added to the anode liquid to neutralize any caustic soda that may diffuse through.

Kellner has taken out many patents. In one of them a mercury cathode is used, which dissolves the sodium deposited, forming an amalgam that, on exposure to water, gives up its alkali and leaves a solution of caustic soda. Almost simultaneously Castner also patented a mercury process, which in its modified form is now in constant use. The tank, of which the principle is illustrated in Fig 1, may be 6 ft. long by 3 ft. wide by 3 in. deep, and is divided by vertical partitions P P (impervious to water) into three compartments. The whole of the floor is covered with a layer of mercury M, and beneath each partition a groove is cut in the bottom of the tank to allow mercury to flow between the compartments. It is essential, however, that at all times this passage should be filled with mercury, which acts as a seal, effectually preventing any interchange of solutions between the compartments. The cell is kept at a constant level at one end, but at the other end is alternately raised and depressed through a very small space by means of the cam B, so that a slight rocking motion is given, causing the mercury to flow gently to and fro without at any moment leaving space for the electrolyte to pass under the partitions. In each end compartment is a carbon anode A, placed horizontally just above the surface of the mercury, and beneath the level of a 20 per cent. solution of sodium chloride (NaCl); these compartments are covered, and are provided with pipes E to carry off the anode-chlorine. The middle compartment contains an iron cathode C immersed in water (H_2O), and is open above. Means are provided for the circulation of the anode liquors and to replenish them with salt; the cathode solution may be drawn off at will. In operation the current flows from the anode, where it deposits chlorine (ultimately given off in the gaseous form), through the sodium chloride solution to the mercury layer in the outer compartments, and thence by metallic conduction to the mercury in the centre compartment, and from this through the water to the cathode, where hydrogen is evolved. Thus the mercury forms an intermediary, bi-polar electrode, acting as cathode in the outer and as anode in the inner division. The sodium deposited on the mercury in the outer cells is at once dissolved, forming an amalgam. The amalgam-laden mercury mixes by the rocking action with the mercury in the inner cell, and there (being an anode) passes into the water, forming caustic soda. A current of 550 amperes and 4 volts per cell has been employed. No chlorine or chloride can escape into the cathode cell, and the caustic alkali may therefore contain 99½ per cent. of pure sodium hydroxide. A certain amount of energy-loss is inevitable, owing to the recombination of a little of the sodium dissolved in the mercury in the outer cells with chlorine, and with oxygen from the water (the chlorine contains commonly 3 to 5 per cent. of hydrogen, indicating that some water is attacked). But the constant flux of the mercury and loss of sodium in the inner cell should keep down the quantity of sodium in the mercury to about 0·02 per cent., so that the loss due to this cause is minimized. The same mercury is used constantly, and as it need not suffer appreciable loss, and only a thin layer is required, it does not add greatly to the cost of the process, one of the great recommendations of which is that a strong solution of a pure soda may be readily produced. In the Hulin process a furnace method is employed, molten lead being used as cathode, and carbon as anode, in a bath of fused lead and sodium chlorides, with a current-density of about 700 amperes per sq. ft. A rich alloy of sodium with lead is deposited. This is cast into plates and, on cooling, treated with water, whereby the sodium contained in it dissolves, forming caustic soda.

The following table, calculated into British units from Kershaw's account (*Engineering and Mining Journal*, 1899, vol. lxvii. p. 497) of the Hulin process at Clavaux, shows the comparative efficiencies of these processes from published data, the term current-efficiency showing the proportion of the actual yield per coulomb actually obtained, and the energy-efficiency the proportion use-

	Process.	E.M.F. required in Volts.	Actual Yield. Per Amp. Hr. in Grains. NaOH.	Per Amp. Hr. in Grains. Cl.	Per Kw-Hr. in lb. NaOH.	Per Kw-Hr. in lb. Cl.	Approx. H.P. Hrs. per Ton of Pure NaOH.	Approx. H.P. Hrs. per Ton of 70% Caustic Soda.	Efficiency per cent. Current.	Efficiency per cent. Energy.
Wet Processes	Hargreaves-Bird .	3·4	18·46	16·31	0·77	0·68	3880	3500	80	54
	Castner-Kellner .	4·0	21·03	17·53	0·75	0·63	4000	3610	91	52·3
	Theoretical Figures .	2·3	23·07	20·40	1·43	1·26	2100	1900	100	100
Dry Processes	Hulin .	7·0	16·23	14·00	0·34	0·28	8730	7880	69·3	41·5
	Theoretical Figures .	4·2	23·07	20·40	0·78	0·69	3825	3450	100	100

fully applied of the energy theoretically necessary. The relatively low efficiency of the Hulin (dry) process is, to some extent, compensated for by the high current-density used, and by consequent rapidity of working.

It is obvious that electrolytic *iodine* and *bromine*, and oxygen compounds of these elements, may be produced by methods similar to those last described, and Kellner and others have patented processes with this end in view.

Hydrogen and *oxygen* may also be produced electrolytically as gases, and their respective reducing and oxidizing powers at the moment of deposition on the electrode are frequently used in the laboratory, and to some extent industrially, chiefly in the field of organic chemistry. Similarly, the formation of organic halogen products may be effected by electrolytic chlorine, as, for example, in the production of *chloral* by the gradual introduction of alcohol into an anode cell in which the electrolyte is a strong solution of potassium chloride. Again, anode reactions, such as are observed in the electrolysis of the fatty acids, may be utilized, as, for example, when the radical CH_3CO_2O—deposited at the anode in the electrolysis of acetic acid—is dissociated, two of the groups react to give one molecule of *ethane*, C_2H_6, and two of carbon dioxide. This, which has long been recognized as a class-reaction, is obviously capable of endless variation. Many electrolytic methods have been proposed for the purification of *sugar*; in some of them soluble anodes are used for a few minutes in weak alkaline solutions, so that the caustic alkali from the cathode reaction may precipitate chemically the hydroxide of the anode metal dissolved in the liquid, the precipitate carrying with it mechanically some of the impurities present, and thus clarifying the solution. In others the current is applied for a longer time to the original sugar-solution with insoluble (*e.g.*, carbon) anodes. Peters has found that with these methods the best results are obtained when ozone is employed in addition to electrolytic oxygen. Use has been made of electrolysis in *tanning* operations, the current being passed through the tan-liquors containing the hides. The current, by endosmosis, favours the passage of the solution into the hide-substance, and at the same time appears to assist the chemical combinations there occurring; hence a great reduction in the time required for the completion of the process. Many patents have been taken out in this direction, one of the best known being that of Groth, experimented upon by Rideal and Trotter (*Journ. Soc. Chem. Indust.*, 1891, vol. x. p. 425), who employed copper anodes, 4 sq. ft. in area, with current-densities of 0·375 to 1 (ranging in some cases to 7·5) ampere per sq. ft., the best results being obtained with the smaller current-densities. Electro-chemical processes are often indirectly used, as for example in the Villon process (*Elec. Rev.*, New York, 1899, vol. xxxv. p. 375) applied in Russia to the manufacture of *alcohol*, by a series of chemical reactions starting from the production of acetylene by the action of water upon calcium carbide. The production of *ozone* in small quantities during electrolysis, and by the so-called silent discharge, has long been known, and the Siemens induction tube has been devoloped for use industrially. The Siemens and Halske ozonizer, in form somewhat resembling the old laboratory instrument, is largely used in Germany; working with an alternating current transformed up to 6500 volts, it has been found to give 280 grains or more of ozone per E.H.P. hour. Andreoli (whose first British ozone-patent was No. 17,426 of 1891) uses flat aluminium plates and points, and working with an alternating current of 3000 volts is said to have obtained 1440 grains per E.H.P. hour. Yarnold's process, using corrugated glass plates coated on one side with gold or other metal leaf, is stated to have yielded as much as 2700 grains per E.H.P. hour. The ozone so prepared has numerous uses, as, for example, in bleaching oils, waxes, fabrics, &c., sterilizing drinking-water, maturing wines, cleansing foul beer-casks, oxidizing oil, and in the manufacture of vanillin.

Other electro-chemical processes.

For further information the following books, among others, may be consulted:—Haber. *Grundriss der Technischen Elektrochemie.* München, 1898.—Borchers and M'Millan. *Electric Smelting and Refining.* London, 1897.—E. D. Peters. *Modern Copper Smelting* (chap. xviii.). New York, 1895.—F. Peters. *Angewandte Elektrochemie*, vols. ii. and iii. Leipzig, 1898.—Gore. *The Art of Electrolytic Separation of Metals.* London, 1890.—M'Millan. *A Treatise on Electro-Metallurgy* (2nd ed.). London, 1899.—Blount. *Practical Electro-Chemistry.* London, 1901.—Langbein. *Vollständiges Handbuch der galvanischen Metall-Niederschläge.* Leipzig, 1895.—Watt. *Electro-Deposition* (2nd ed.). London, 1887.—Wahl. *Practical Guide to the Gold and Silver Electroplater, &c.* Philadelphia, 1883.—Wilson. *Stereotyping and Electrotyping.* London.—Lunge. *Sulphuric Acid and Alkali*, vol. iii. London, 1896. Also papers in various technical periodicals, many of which have been quoted in the course of this article.

(W. G. M.)

Electromagnet.—The technical applications of electricity and magnetism depend to a very large extent upon the employment of electromagnets.

Iron and other ferromagnetic materials, such as steel, cobalt, nickel, and some of their mixtures, alloys, and oxides, can be thrown into a state in which they are said to be magnetized (see Magnetism). This magnetization may be more or less permanent, as in the case of an ordinary hardened steel magnet or the natural magnetized material *Magnetite*, or it may be temporary and due to the continual action on the iron or ferromagnetic material of magnetic force arising from the proximity of a conductor conveying an electric current. The term electromagnet is generally employed to describe an arrangement in which a core of iron of some kind is surrounded with coils of insulated wire which create in and around it a magnetic force when they are traversed by an electric current.

Magnetic force is defined as the cause, whatever its nature, which produces or changes the state called *magnetization*. In the neighbourhood of every polar magnet, and also every conductor conveying an electric current, there is a distribution of magnetic force. If a piece of soft iron or any ferromagnetic substance is placed in this region it becomes magnetized, and its magnetization may be in part or entirely retained when the magnetizing force is withdrawn. If the magnetizing force arises from the presence of an electric current in the neighbourhood, and if the ferromagnetic material which is in its field is a piece of annealed or wrought-iron, then the persistence of the magnetization of the iron will be largely dependent upon the presence of the current in the conductor. If the iron is of such a form that the lines of magnetization are entirely closed lines, the arrangement constitutes a poleless electromagnet. Such a magnet may be realised in practice by closely winding insulated copper wire uniformly round an iron ring. If, on the other hand, the coils embrace an iron bar not forming a closed circuit, then the arrangement will constitute a polar electromagnet.

Magnetization.

It is essential to distinguish between the mere retentivity and the power of preserving magnetization against demagnetizing influences, called the coercivity. Pure annealed or soft iron can retain 90 per cent. or more of the magnetization it acquires under the influence of a strong magnetizing force when the force is removed, but the magnetization so retained is held very lightly, and even a slight knock or twist or any form of mechanical shock is sufficient to deprive the iron of nearly all its magnetization if it is in the form of a short bar. On the other hand, hardened high carbon steel, though not able to acquire such a high degree of magnetization under the action of a given magnetizing force, retains it with much greater tenacity, and a much stronger reverse magnetized force is required to demagnetize the steel than is the case with soft iron. Steel containing tungsten possesses a large coercivity.

Whatever may be the material which is thrown into a state of magnetization, if the lines of magnetization terminate anywhere on the surface they give rise to magnetic poles. These points or regions are themselves sources of magnetic force. If a uniformly magnetized magnetic filament has everywhere a section S, and if its magnetization is denoted by I, the product IS is called the *magnetic strength* of the filament, and this product is also a measure of the *strength of the pole* of the filament. If a ferromagnetic body is magnetized so that its lines of magnetization are self-closed lines, it is also said to form a complete or *closed magnetic circuit.* If, on the other hand, they are not self-closed, the magnetic circuit is called an *open magnetic circuit.* Abrupt or gradual changes in the magnetization along the circuit create in the magnetic circuit (even if closed) polar regions from which magnetic force proceeds.

The most simple and direct method of estimating the condition of a substance as regards magnetization in the case of open magnet circuits or linear magnets is to measure the magnetic force at some assigned position outside the magnetic body, where in virtue of the presence of free poles a production of magnetic force takes place. The magnetic force at any point can be estimated as regards magnitude by its mechanical action on another movable magnetic pole or polar magnet. This is called the magnetometric method.

So far we have directed consideration only to two magnetic quantities, namely, magnetization and magnetic force, but at this stage a third magnetic vector claims attention. If in front of the pole of a polar magnet a loop of insulated wire of one turn, and connected to a galvanometer, is held with its plane normal to the field, and the loop then snatched away, this circuit becomes the seat of an electromotive force which creates an induced electric current in the loop. The induced electromotive force is proportional to the time-rate of change of the surface integral of the magnetic force integrated all over the area of the loop, and hence the time-integral of the induced current, multiplied by the value of the resistance of the loop circuit, must be equal to the value of this surface integral of the normal magnetic force. The quantity so measured is now generally called the *magnetic flux*, but also denominated the *total magnetic induction*, or *total number of lines of force perforating through the loop.* We find that if a loop is held in front of the pole of a polar magnet and snatched away, the electromotive force set up in it is in the same direction as if the loop were placed like a girdle closely round the centre of the bar magnet and then suddenly drawn off, all other circumstances remaining the same. This experiment is sufficient to show that the vector with which we are here concerned is not identical with that properly called the magnetic force, since in a permanent straight steel bar magnet, when not in the neighbourhood of other magnets or electric currents, the magnetic force in the interior of the bar is in the opposite direction to the magnetic force just outside either of its poles.

Magnetic flux.

The quantity, therefore, measured by the time-integral of this induced current is a definite physical quantity, and in this article will be called *the magnetic flux.* The flux, through a unit of surface normal to the direction of the flux, is called *the flux density*, and is denoted by B. It is called by Maxwell and other writers following him the *induction*, or the *number of lines of force per square centimetre.* It is essential, however, to notice that the exploring loop used in the above manner measures a magnetic vector quantity which is not to be confused with the magnetic force. In the region outside the polar magnet the flux in the space and the magnetic force have the same direction, and as there is nothing to distinguish them they may be assumed to have the same magnitude. Inside the magnet, however, the flux and the force have not the same magnitude, and not always the same direction. The flux through any area may, however, always be evaluated by the time-integral of the current set up in a conducting loop placed in that locality with its plane normal to the direction of the flux when the flux is suppressed, or the loop suddenly removed. The flux is a quantity which, mathematically considered, is circuital. Its direction may be delineated by lines of flux, and every line of flux is a self-closed line.

The quantity called B is more important than I from an electro-technical point of view, because the chief practical use of magnets or electromagnets is to create in conductive circuits an electromotive force by varying the magnetic flux linked with them. This effect depends upon the variation of the total flux linked with the conductive circuit. The ratio of B to H is denoted by μ, and is called the magnetic *permeability* of the material corresponding to that particular flux density. The permeability is a function of the flux density, and varies with it. Corresponding to a certain value of the flux density, μ has a maximum value. The relation of B and H and B and μ are best represented by two curves called respectively the *flux-density curve* and the *permeability curve* (see Figs. 2 and 3). We may also in the same manner set out in the form of a curve the relation of the magnetization I to the magnetizing force H, and the ratio of I to H, which is called the susceptibility (k) of the material.

An immense number of observations have been carried out of late years on the permeability and susceptibility of different forms of iron and steel, and in the following tables are given some typical results, mostly from experiments made by Ewing (see *Proc. Inst. C. E.* vol. cxxvi.), in which the ballistic method has been employed to determine the flux density corresponding to various magnetizing forces acting upon samples of iron and steel in the form of rings. The samples were prepared and furnished by various manufacturers of iron and steel, and may be taken as typical of the materials which are at present (1899) in demand for the construction of cores of electromagnets of different kinds.

TABLE I.—*Magnetic Flux Density corresponding to various Magnetizing Forces in the case of certain Samples of Iron and Steel (Ewing).*

Magnetizing Force H (C.G.S. Units).	Magnetic Flux Density B (C.G.S. units).					
	I.	II.	III.	IV.	V.	VI.
5	12,700	10,900	12,300	4,700	9,600	10,900
10	14,980	13,120	14,920	12,250	13,050	13,320
15	15,800	14,010	15,800	14,000	14,600	14,350
20	16,300	14,580	16,280	15,050	15,310	14,950
30	16,950	15,280	16,810	16,200	16,000	15,660
40	17,350	15,760	17,190	16,800	16,510	16,150
50	...	16,060	17,500	17,140	16,900	16,480
60	...	16,340	17,750	17,450	17,180	16,780
70	...	16,580	17,970	17,750	17,400	17,000
80	...	16,800	18,180	18,040	17,620	17,200
90	...	17,000	18,390	18,230	17,830	17,400
100	...	17,200	18,600	18,420	18,030	17,600

The figures under heading I. are values given in a paper by Messrs Lydall and Pocklington (*Proc. Roy. Soc.* vol. ii. p. 228) as the results of a magnetic test of an exceptionally pure iron supplied for the purpose of experiment by Colonel Dyer, of the Elswick Works. The substances other than iron in this sample were stated to be: carbon, *trace;* silicon, *trace;* phosphorus, *none;* sulphur, 0·013 per cent.; manganese, 0·1 per cent. The other five specimens, II. to VI., are samples of commercial iron or steel. No. II. is a sample of Low Moor bar iron forged into a ring, annealed, and turned. No. III. is a steel forging furnished by Mr R. Jenkins as a sample of forged ingot-metal for dynamo magnets. No. IV. is a steel casting for dynamo magnets, unforged, made by Messrs Edgar Allen and Company by a special pneumatic process under the patents of Mr A. Tropenas. No. V. is also an unforged steel casting for dynamo magnets, made by Messrs Samuel Osborne and Company by the Siemens process. No. VI. is also an unforged steel casting for dynamo magnets, made by Messrs Fried. Krupp, of Essen.

It will be seen from the figures and the description of the materials that the steel forgings and castings have a remarkably high permeability under small magnetizing force.

Table II. shows the magnetic qualities of some of these materials as found by Ewing when tested with small magnetizing forces.

TABLE II.—*Magnetic Permeability of Samples of Iron and Steel under Weak Magnetizing Forces.*

Magnetic Flux Density B (C.G.S. Units).	I. Pure Iron.		III. Steel Forging.		VI. Steel Casting.	
	H.	μ	H.	μ	H.	μ
2,000	0·90	2220	1·38	1450	1·18	1690
4,000	1·40	2850	1·91	2090	1·66	2410
6,000	1·85	3240	2·38	2520	2·15	2790
8,000	2·30	3480	2·92	2740	2·83	2830
10,000	3·10	3220	3·62	2760	4·05	2470
12,000	4·40	2760	4·80	2500	6·65	1810

The numbers I., III., and VI. in the above table refer to the samples mentioned in connexion with Table I.

It is a remarkable fact that certain varieties of low carbon steel (commonly called mild steel), have a higher permeability than even annealed Swedish wrought iron under large magnetizing forces. The term *steel*, however, here used has reference rather to the mode of production than the final chemical nature of the material. In some of the mild-steel castings used for dynamo electromagnets, it appears that the total foreign matter, including carbon, manganese, and silicon, is not more than 0·3 per cent. of the whole, the material being 99·7 per cent. pure iron.

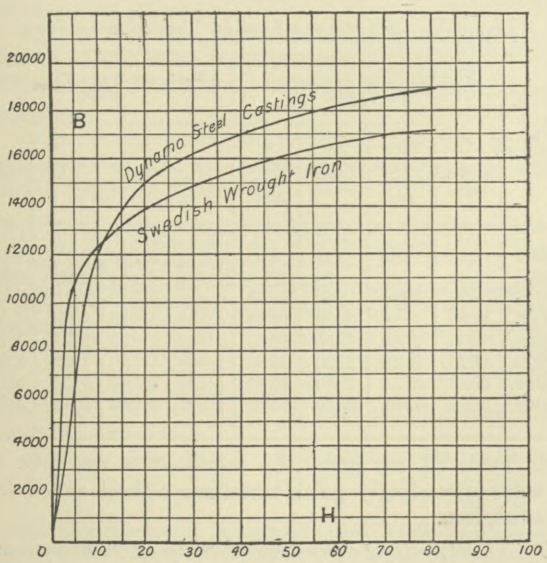


Fig. 1.

This valuable magnetic property of steel capable of being cast is, however, of great utility in modern dynamo building, as it enables field magnets of very high permeability to be constructed, which can be fashioned into shape by casting instead of being built up as formerly out of masses of forged wrought iron. The curves in Fig. 1 illustrate the manner in which the flux density or, as it is usually called, the magnetization curve of this mild cast steel crosses that of Swedish wrought iron, and enables us to obtain a higher flux density corresponding to a given magnetizing force with the steel than with the iron.

From the same paper by Ewing we extract a number of results relating to permeability tests of thin sheet iron and sheet steel, such as is used in the construction of dynamo armatures and transformer cores.

TABLE III.—*Permeability Tests of Transformer Plate and Wire.*

Magnetic Flux Density B (C.G.S. Units).	VII. Transformer-plate of Swedish Iron.		VIII. Transformer-plate of Scrap-iron.		IX. Transformer-plate of Steel.		X. Transformer-wire.	
	H.	μ	H.	μ	H.	μ	H.	μ
1,000	0·81	1230	1·08	920	0·60	1470	1·71	590
2,000	1·05	1900	1·46	1370	0·90	2230	2·10	950
3,000	1·26	2320	1·77	1690	1·04	2880	2·30	1300
4,000	1·54	2600	2·10	1900	1·19	3360	2·50	1600
5,000	1·82	2750	2·53	1980	1·38	3620	2·70	1850
6,000	2·14	2800	3·04	1970	1·59	3770	2·92	2070
7,000	2·54	2760	3·62	1930	1·89	3700	3·16	2210
8,000	3·09	2590	4·37	1830	2·25	3600	3·43	2330
9,000	3·77	2390	5·3	1700	2·72	3310	3·77	2390
10,000	4·6	2170	6·5	1540	3·33	3000	4·17	2400
11,000	5·7	1930	7·9	1390	4·15	2650	4·70	2340
12,000	7·0	1710	9·8	1220	5·40	2220	5·45	2200
13,000	8·5	1530	11·9	1190	7·1	1830	6·5	2000
14,000	11·0	1270	15·0	930	10·0	1400	8·4	1670
15,000	15·1	990	19·5	770	...	...	11·9	1260
16,000	21·4	750	27·5	580	...	...	21·0	760

No. VII. is a specimen of good transformer-plate, 0·301 millimetre thick, rolled from Swedish iron by Messrs Sankey of Bilston. No. VIII. is a specimen of specially thin transformer-plate rolled from scrap iron. No. IX. is a specimen of transformer-plate rolled from ingot-steel. No. X. is a specimen of the wire which was used by Mr Swinburne some years ago to form the core of his "hedgehog" transformers. Its diameter was 0·602 millimetre. All these samples were tested in the form of rings by the ballistic method, the rings of sheet-metal being stamped or turned in the flat. The wire ring No. X. was coiled and annealed after coiling.

Some typical flux-density curves of iron and steel as used in dynamo and transformer building are given in Fig. 2.

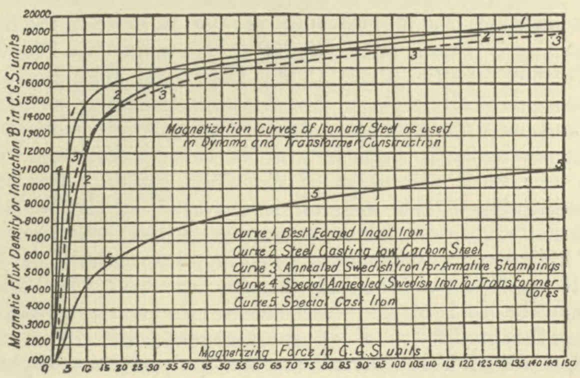


Fig. 2.

The numbers in Table III. well illustrate the statement already made that the permeability $\mu = B/H$ has a maximum value corresponding to a certain flux density. The tables also are explanatory of the fact that steel has gradually replaced iron in the manufacture of dynamo electromagnets and transformer-cores.

Materials for cores.

Broadly speaking, the materials which are now employed in the manufacture of the cores of electromagnets for technical purposes of various kinds may be said to fall into three classes, namely, forgings, castings, and stampings. In some cases the iron or steel core which is to be magnetized is simply a mass of iron hammered or pressed into shape by hydraulic pressure;

in other cases it has to be fused and cast; and for certain other purposes it must be rolled first into thin sheets, which are subsequently stamped out into the required forms.

For particular purposes it is necessary to obtain the highest possible magnetic permeability corresponding to a high, or the highest attainable flux density. This is generally the case in the electromagnets which are employed as the field magnets in dynamo machines. It may generally be said that whilst the best wrought iron, such as annealed Low Moor or Swedish iron, is more permeable for low flux densities than steel castings, the cast steel may surpass the wrought metal for high flux density. For most electro-technical purposes the best magnetic results are given by the employment of forged ingot-iron. This material is probably the most permeable throughout the whole scale of attainable flux densities.

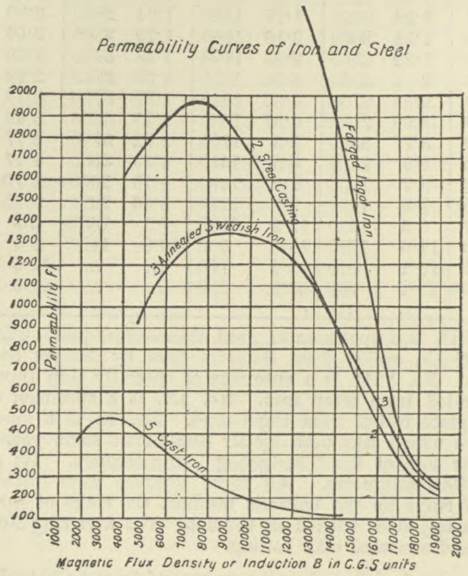


Fig. 3.

It is slightly superior to wrought iron, and it only becomes inferior to the highest class of cast steel when the flux density is pressed above 18,000 C.G.S. units (see Fig. 3). For flux densities above 13,000 the forged ingot-iron has now practically replaced for electric engineering purposes the Low Moor or Swedish iron. Owing to the method of its production it might in truth be called a soft steel with a very small percentage of combined carbon. The best description of this material is conveyed by the German term "Flusseisen," but its nearest British equivalent is "ingot-iron." Chemically speaking, the material is for all practical purposes very nearly pure iron. The same may be said of the cast steels now much employed for the production of dynamo magnet-cores. The cast steel which is in demand for this purpose has a slightly lower permeability than the ingot-iron for low flux densities, but for flux densities above 16,000 the required result may be more cheaply obtained with a steel casting than with a forging. When high tensile strength is required in addition to considerable magnetic permeability, it has been found advantageous to employ a steel containing 5 per cent. of nickel. The rolled sheet iron and sheet steel which is in request for the construction of magnet cores, especially those in which the exciting current is an alternating current, are, generally speaking, produced from Swedish iron. Owing to the mechanical treatment necessary to reduce the material to a thin sheet, the permeability at low flux densities is rather higher than, although at high flux densities it is inferior to, the same iron and steel when tested in bulk. For most purposes, however, where a laminated iron magnet-core is required, the flux density is not pressed up above 6000 units, and it is then more important to secure small hysteresis loss than high permeability. The magnetic permeability of cast iron is much inferior to that of wrought or ingot-iron, or the mild steels taken at the same flux densities.

The following Table IV. gives the flux density and permeability of a typical cast iron taken by Fleming by the ballistic method.

TABLE IV.—*Magnetic Permeability and Magnetization Curve of Cast Iron.*

H.	B.	μ	H.	B.	μ	H.	B.	μ
·19	27	139	8·84	4030	456	44·65	8,071	181
·41	62	150	10·60	4491	424	56·57	8,548	151
1·11	206	176	12·33	4884	396	71·98	9,097	126
2·53	768	303	13·95	5276	378	88·99	9,600	108
3·41	1251	367	15·61	5504	353	106·35	10,066	95
4·45	1898	427	18·21	5829	320	120·60	10,375	86
5·67	2589	456	26·37	6814	258	140·37	10,725	76
7·16	3350	468	36·54	7580	207	152·73	10,985	72

The metal, of which the tests are given in Table IV., contained 2 per cent. of silicon, 2·85 per cent. of total carbon, and 0·5 per cent. of manganese. It will be seen that a magnetizing force of about 5 C.G.S. units is sufficient to impart to a wrought-iron ring a flux density of 18,000 C.G.S. units, but the same force hardly produces more than one-tenth of this flux density in cast iron.

The testing of sheet iron and steel for magnetic hysteresis loss has developed into an important factory process, giving as it does a means of ascertaining the suitability of the metal for use in the manufacture of transformers and alternating-current electromagnets.

In Table V. are given the results of hysteresis tests by Ewing on samples of commercial sheet iron and steel. The numbers VII., VIII., IX., and X. refer to the same samples as those for which permeability results are given in Table III.

TABLE V.—*Hysteresis Loss in Transformer-iron.*

Maximum Flux Density B.	Ergs per Cubic Centimetre per Cycle.				Watts per lb at a Frequency of 100.			
	VII. Swedish Iron.	VIII. Forged Scrap-iron.	IX. Ingot-steel.	X. Soft Iron Wire.	VII.	VIII.	IX.	X.
2000	240	400	215	600	0·141	0·236	0·127	0·356
3000	520	790	430	1150	0·306	0·465	0·253	0·630
4000	830	1220	700	1780	0·490	0·720	0·410	1·050
5000	1190	1710	1000	2640	0·700	1·010	0·590	1·550
6000	1600	2260	1350	3360	0·940	1·330	0·790	1·980
7000	2020	2940	1730	4300	1·200	1·730	1·020	2·530
8000	2510	3710	2150	5300	1·480	2·180	1·270	3·120
9000	3050	4560	2620	6380	1·800	2·680	1·540	3·750

In Table VI. are given the results of a magnetic test of some exceedingly good transformer-sheet rolled from Swedish iron.

TABLE VI.—*Hysteresis Loss in Strip of Transformer-plate rolled from Swedish Iron.*

Maximum Flux Density B.	Ergs per Cubic Centimetre per Cycle.	Watts per lb at a Frequency of 100.
2000	220	0·129
3000	410	0·242
4000	640	0·376
5000	910	0·535
6000	1200	0·710
7000	1520	0·890
8000	1900	1·120
9000	2310	1·360

In Table VII. are given some values obtained by Fleming for the hysteresis loss in the sample of cast iron, the permeability test of which is recorded in Table IV.

TABLE VII.—*Observations on the Magnetic Hysteresis of Cast Iron.*

Loop.	B. (max.)	Hysteresis Loss.	
		Ergs per cc. per Cycle.	Watts per lb per 100 Cycles per sec.
I.	1475	466	·300
II.	2545	1,288	·829
III.	3865	2,997	1·934
IV.	5972	7,397	4·765
V.	8930	13,423	8·658

For most practical purposes the constructor of electromagnetic machinery requires his iron or steel to have some one of the following characteristics. If for dynamo or magnet making it should have the highest possible permeability at a flux density corresponding to practically maximum magnetization. If for transformer or alternating-current magnet building it should have the smallest possible hysteresis loss at a maximum flux density of 2500 C.G.S. units during the cycle. If required for permanent magnet making it should have the highest possible coercivity combined with a high retentivity. Manufacturers of iron and steel have been able to meet these demands in a very remarkable manner, during the last few years, by the commercial production of material of a quality which at one time would have been considered a scientific curiosity.

It is usual now to specify iron and steel for the first purpose by naming the minimum permeability it should possess corresponding to a flux density of 18,000 C.G.S. units; for the second, by stating the hysteresis loss in watts per lb, per 100 cycles, per second, corresponding to a maximum flux density of 2500 C.G.S. units during the cycle; and for the third, by mentioning the coercive force required to reduce to zero magnetization a sample of the metal in the form of a long bar magnetized to a stated magnetization.

In dealing with problems involving the use of an electromagnet, we are confronted with the notion and laws of the magnetic circuit.

Consider in the first instance the simple case of a ring of iron magnetized by an endless solenoid. Let the section of the ring be S and the mean perimeter L.

Let H be the magnetizing force to which the iron is subjected. In the interior of the solenoid this force is equal to $4\pi/10$ times the exciting ampere-turns per unit length of perimeter. The product HL is called the line integral of magnetic force, or the magnetomotive force (M.M.F.). It is obviously measured by $0{\cdot}4\pi$ times the exciting ampere-turns (A.T.)

Hence since $\mu H = B$ if we write ρ^{-1} for μ and call ρ the *reluctivity* of the material, we have—

$$BS = \frac{HL}{\frac{\rho L}{S}} = \frac{\text{M.M.F.}}{R} = \frac{0{\cdot}4\pi\,\text{A.T.}}{R}$$

or the total magnetic flux is numerically equal to the quotient of the magnetomotive force by a quantity (R) called the magnetic reluctance of the circuit.

Hence if the reluctivity (ρ) of the material or its reciprocal the permeability (μ) corresponding to a given flux density (B) is known, we can calculate the ampere-turns (A.T.) required to produce a given total flux in the iron core.

The value of μ corresponding to any given flux density can always be obtained from the permeability curve of the material (see Fig. 3).

Hence the ampere-turns (A.T.) necessary to produce a required total flux in a magnetic circuit of length L and section S can be calculated from the expression

$$\text{A.T.} = 0{\cdot}8\,(BS) \times R = 0{\cdot}8 \times (BS) \times \frac{L}{S\mu}$$

where BS is the total flux and R is the reluctance of the circuit. This last is equal to $i/\mu S$ where μ is the permeability corresponding to B. (For all practical purposes $0{\cdot}8 = 10/4\pi$.)

The fundamental law of the non-homogeneous magnetic circuit traversed by one and the same total magnetic flux is that the sum of all the magnetomotive forces acting on the circuit is numerically equal to the product of 0·8 times the total flux in the circuit, and the sum of all the reluctances of the various parts of the circuit. If then the circuit consists of materials of different permeability, and it is desired to know the ampere-turns required to produce a given total of flux round the circuit, we have to calculate from the magnetization curves of each part the necessary magnetomotive forces and add these forces together. The practical application of this principle to the predetermination of the field windings of dynamo magnets was first made by Drs J. and E. Hopkinson (see *Phil. Trans. Roy. Soc.* vol. clxxvii. p. 331).

We may illustrate the principles of this predetermination by a simple example. Suppose a ring of iron has a mean diameter of 10 cms. and a cross section of 2 square cms. and a transverse cut or air gap made in it one millimetre wide, required the ampere-turns to be put upon the ring to create in it a total flux of 24,000 C.G.S. units. The total length of the iron part of the circuit is $(10\pi - 0{\cdot}1)$ cms., and its section is 2 sq. cms., and the flux density in it is to be 12,000. From Table II. we see that the permeability of pure iron corresponding to a flux density of 12,000 is 2760. Hence the reluctance of the iron circuit is equal to $\frac{10\pi - 0{\cdot}1}{2760 \times 2} = \frac{220}{38640}$ C.G.S. units.

The length of the air gap is 0·1 cm., its section 2 sq. cms., and its permeability is unity. Hence the reluctance of the air gap is

$$\frac{0{\cdot}1}{1 \times 2} = \frac{1}{20}\ \text{C.G.S.}$$

Accordingly the magnetomotive force in ampere-turns required to produce the required flux is equal to

$$0{\cdot}8(24{,}000)\left(\frac{1}{20} + \frac{220}{38640}\right) = 1070 \text{ nearly.}$$

It will be seen that the part of the magnetomotive force required to overcome the reluctance of the narrow air gap is about nine times that required for the iron alone.

In the above example we have for simplicity assumed that the flux in passing across the air gap does not spread out at all. In dealing with dynamo designing we have to take into consideration this spreading as well as the leakage of flux across the circuit (see DYNAMO).

It will be seen, therefore, that in order that we may predict the effect of a certain kind of iron or steel when used as the core of an electromagnet we must be provided with tables or curves showing the reluctivity corresponding to given flux densities or —which comes to the same thing—with (B, H) curves for the sample.

The commercial testing of iron for electro-technical purposes has of late years become a very important matter. The electrical engineer is now enabled to specify the particular kind of iron or steel required for his purpose with the same accuracy and definiteness that a mechanical engineer specifies for certain mechanical qualities in the materials he employs. The process for obtaining hysteresis loops and permeability curves from the series of observations made with the ballistic galvanometer to determine a (B, H) curve or (B, H) cycle is a tedious operation, yet at the same time it is the most accurate and trustworthy method. In order to shorten the process many instruments have been devised of late years for use in the workshop. Instruments of this kind for determining the flux density corresponding to a given magnetizing force in a complete magnetic circuit formed in part or in whole of a particular material are called permeameters (see MAGNETISM).

The measurement of hysteresis losses in samples of sheet iron is facilitated by the employment of various forms of hysteresis meter. The principle on which some of these instruments depend for their operation is the fact that if a mass of laminated iron or steel is caused to revolve in a magnetic field, or suspended in a revolving magnetic field with the plane of the laminations parallel to the direction of the field, forces will be brought to bear tending to create a rotation either of the magnet or of the mass of laminated metal. In order that sources of error may be eliminated it is necessary that the specimen tested should be so well laminated as to destroy all electric eddy-currents in its mass. A simple yet convenient instrument of this kind has been devised by Ewing, and is shown in Fig. 4. The instrument consists of a curved permanent steel magnet, nicely balanced on knife edges, and having attached to it a long index needle. The specimen of iron to be tested for hysteresis is prepared in the form of thin sheets of a rectangular shape, 3 inches long and $\frac{5}{8}$ of an inch wide. Seven of these little sheets are fixed together and attached to a shaft which can be caused to revolve between the poles of the magnet. The user of the instrument by rotating the handle causes the specimen to revolve rapidly between the poles of the balanced magnet with the plane of its laminations parallel to the direction of the interpolar field. In consequence of the waste of energy in the sample due to hysteresis a torque is brought into existence which displaces the magnet through a certain angle depending upon the counter-balance attached

Hysteresis meters.

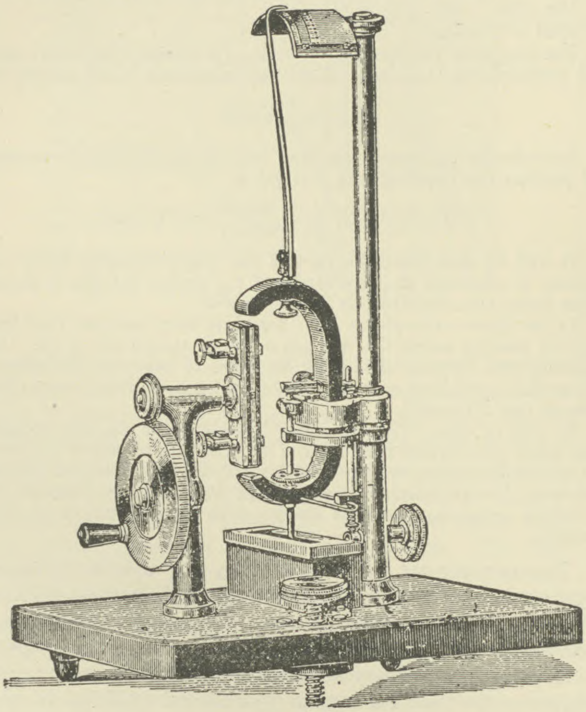


Fig. 4.

to the magnet, which tends to bring it back into a vertical position. The instrument is provided with certain samples of iron plate cut to the proper size, the hysteresis loss in which is accurately known. By comparing the deflexions of the permanent magnet given by these standard specimens with that produced by the specimen under test, the hysteresis loss in the specimen can be at once obtained. The assumptions made in the construction of the instrument are that for samples of iron not differing very much in magnetic quality the hysteresis losses at different induction densities are in the same ratio; also that slight differences in permeability do not affect the result by causing the magnetic forces on the two specimens to be very different.

One objection which has been raised to the employment of such a rotating hysteresis meter is, that the character of the cyclic change of the magnetizing force is quite different in this case from that which it is when the magnetic force undergoes the periodic change without any alteration in this direction. These two cases are clearly different. In the first case, which is that of the alternating transformer, the magnetic force passes through a cycle of values, the iron remaining stationary, and the direction of the magnetic force being always the same. In the other case, the direction of the magnetic force in the iron is constantly changing, and at the same time undergoing a change in magnitude.

It has been shown by F. G. Baily that if a mass of laminated iron is rotating in a magnetic field, the field remaining constant in direction and magnitude in any one experiment, as the magnitude of the flux density in the iron is increased the hysteresis loss rises to a maximum, and then falls away again to nearly zero value. These observations have been confirmed by other observers. The question has been much debated whether the values of the hysteresis loss obtained by these two different methods are identical for magnetic cycles in which the flux density reaches the same maximum value. This question is also connected with another one, namely, whether the hysteresis loss per cycle is or is not a function of the speed with which the cycle is traversed. Early experiments by Steinmetz and others seemed to show that there was a difference between slow-speed and high-speed hysteresis cycles, but later experiments by Hopkinson and by Tanakadate, though not absolutely exhaustive, tend to prove that up to 400 cycles per second the hysteresis loss per cycle is practically unchanged.

Experiments made in 1896 by Fleming, Beattie, and Clinker on magnetic hysteresis in rotating fields were partly directed to determine whether the hysteresis loss at moderate flux densities, such as are employed in transformer-work, was the same as that found by measurements made with alternating-current fields on the same iron and steel specimens. These experiments showed that over moderate ranges of induction, such as may be expected in electro-technical work, the hysteresis loss per cycle per cubic centimetre was practically the same when the iron was tested in an alternating field with a periodicity of 100, the field remaining constant in direction, and when the iron was tested in a rotating field giving the same maximum flux density.

In the hysteresis tester of Ewing the field magnet is arranged to give a mean flux density of about 4000 C. G. S. units on the specimen under test. Hence the hysteresis loss in the standard specimens is determined for that value. If the loss is required at any other flux density, it is determined by means of a series of factors which show the ratio of hysteresis losses at various flux densities. The factors are as follows:—

Maximum Flux Density in C.G.S. Units.	Relative Amount of Hysteresis Loss.
2000	0·33
2500	0·47
3000	0·63
4000	1·00
5000	1·41
6000	1·89
7000	2·41
8000	3·00

With respect to the variation of hysteresis loss in magnetic cycles having different maximum values for the flux density, Steinmetz found that the hysteresis loss (W) as measured by the area of the complete (B, H) cycle and expressed in ergs per centimetre-cube per cycle, varies proportionately to a constant called the *hysteretic constant*, and to the 1·6th power of the maximum flux density (B), or $W = \eta B^{1 \cdot 6}$.

The hysteretic constants for various kinds of iron and steel are given in the table below:—

Metal.	Hysteretic Constant.
Swedish wrought iron, well annealed .	·0010 to ·0017
Annealed cast steel of good quality; small percentage of carbon	·0017 to ·0029
Cast Siemens-Martin steel . . .	·0019 to ·0028
Cast ingot-iron	·0021 to ·0026
Cast steel, with higher percentages of carbon, or inferior qualities of wrought iron	·0031 to ·0054

Steinmetz's law, though not strictly true for very low or very high maximum flux densities, is yet a convenient empirical rule for obtaining approximately the hysteresis loss at any one maximum flux density, knowing it at another, provided these values fall within a range varying say from 1 to 9000 C.G.S. units. (See also MAGNETISM.)

The standard maximum flux density which is adopted in electro-technical work is 2500, hence in the construction of the cores of alternating-current electromagnets and transformers iron has to be employed having a known hysteretic constant at the standard flux density. It is generally expressed by stating the number of watts per ℔ of metal which would be dissipated for a frequency of 100 cycles, and a maximum flux density (B max.) during the cycle of 2500. In the case of good iron or steel for transformer-core making, it should not exceed 1·25 watt per ℔ per 100 cycles per 2500 B (maximum value).

It has been found that if the sheet iron employed for cores of alternating electromagnets or transformers is heated to a temperature somewhere in the neighbourhood of 200° C. the hysteresis loss is very greatly increased. It was noticed in 1894 by Partridge that alternating-current transformers which had been in use some time had a very considerably augmented core loss when compared with their initial condition. Bláthy and Mordey in 1895 showed that this augmentation in hysteresis loss in iron was due to heating. Parshall investigated the effect up to moderate temperatures, such as 140° C., and an extensive series of experiments was made in 1898 by Roget (*Proc. Roy. Soc.*, May and Dec. 1898). Roget found that below 40° C. a rise in temperature did not produce any augmentation in the hysteresis loss in iron, but if it is heated to between 40° C. and 135° C. the hysteresis loss increases continuously with time, and this increase is now called "ageing" of the iron. It proceeds more slowly as the temperature is higher. If heated to above 135° C., the hysteresis loss soon attains a maximum, but then begins to decrease. Certain specimens heated to 160° C. were found to have their hysteresis loss doubled in a few days. The effect seems to come to a maximum at about 180° C. or 200° C. Mere lapse of time does not remove the increase, but if the iron is re-annealed the augmentation in hysteresis disappears. If the iron is heated to a higher temperature, say between 300° C. and 700° C., Roget found the initial rise of hysteresis happens more quickly, but that the metal soon settles down into a state in which the hysteresis loss has a small but still augmented constant value. The augmentation in value, however, becomes more nearly zero as the temperature approaches 700° C. Brands of steel are now obtainable which do not age in this manner, but these *non-ageing* varieties of steel have not generally such low initial hysteresis values as the "Swedish Iron," commonly considered best for the cores of transformers and alternating current magnets.

The following conclusions have been reached in the matter:—(1) Iron and mild steel in the annealed state are more liable to change their hysteresis value by heating than when in the harder condition; (2) all changes are removed by re-annealing; (3) the changes thus produced by heating affect not only the amount of the hysteresis loss, but also the form of the lower part of the (B, H) curve.

The form which an electromagnet must take will greatly depend upon the purposes for which it is to be used. A design or form of electromagnet which will be very suitable for some purposes will be useless for others. Supposing it is desired to make an electromagnet which shall be capable of undergoing very rapid changes of strength, it must have such a form that the coercivity of the material is overcome by a self-demagnetizing force. This can be achieved by making the magnet in the form of a short and stout bar rather than a long thin one. It has already been explained that the ends or poles of a polar magnet exert a demagnetizing power upon the mass of the metal in the interior of the bar. If then the electromagnet has the form of a long thin bar, the length of which is several hundred times its diameter, the poles are very far removed from the centre of the bar, and the demagnetizing action will be very feeble; such a long thin electromagnet, although made of very soft iron, retains a considerable amount of magnetism after the magnetizing force is withdrawn. On the other hand, a very thick bar very quickly demagnetizes itself, because no part of the metal is far removed from the action of the free poles. Hence when, as in many telegraphic instruments, a piece of soft iron, called an armature, has to be attracted to the poles of a horseshoe-shaped electromagnet, this armature should be prevented from quite touching the polar surfaces of the magnet. If a soft iron mass does quite touch the poles, then it completes the magnetic circuit and abolishes the free poles, and the magnet is to a very large extent deprived of its self-demagnetizing power. This is the explanation of the well-known fact that after exciting the electromagnet and then stopping the current, it still requires a good pull to detach the "keeper"; but when once the keeper has been detached, the magnetism is found to have nearly disappeared.

Forms of electro-magnet.

Various forms of electromagnets used in connexion with dynamo machines are considered in another place (see DYNAMO), and there is, therefore, no necessity to refer particularly to the numerous different shapes and types employed in electro-technics.

For additional information on the above subject the reader may be referred to the following works and original papers:—
DU BOIS. *The Magnetic Circuit in Theory and Practice.*—S. P. THOMPSON. *The Electromagnet.*—J. A. FLEMING. *Magnets and Electric Currents.*—J. A. EWING. *Magnetic Induction in Iron and other Metals.*—J. A. FLEMING. "The Ferromagnetic Properties of Iron and Steel," *Proceedings of Sheffield Society of Engineers and Metallurgists*, Oct. 1897.—J. A. EWING. *The Magnetic Testing of Iron and Steel.*—H. F. PARSHALL. "The Magnetic Data of Iron and Steel," *Proc. Inst. Civil Engineers*, vol. cxxvi. 1895–96.—J. A. EWING. "The Molecular Theory of Induced Magnetism," *Phil. Mag.*, Sept. 1890.—W. M. MORDEY. "Slow Changes in the Permeability of Iron," *Proc. Roy. Soc.* vol. lvii. p. 224.—F. G. BAILY. "Hysteresis of Iron in a Rotating Magnetic Field," *Proc. Roy. Soc.*, 1896.—J. A. EWING. "Magnetism," James Forrest Lecture, *Proc. Inst. Civil Engineers*, vol. cxxxviii.—S. P. THOMPSON. "Electromagnetic Mechanism," *Electrician*, vol. xxvi. pp. 238, 269, 293.—J. A. EWING. "Experimental Researches in Magnetism," *Phil. Trans. Roy. Soc.*, 1885, Part ii.—EWING and KLASSEN. "Magnetic Qualities of Iron," *Proc. Roy. Soc.*, 1893. (J. A. F.)

Electro-Metallurgy.—The present article will, as explained under ELECTRO-CHEMISTRY, treat only of those processes in which electricity is applied to the production of chemical reactions or molecular changes at furnace temperatures. In many of these the application of heat is necessary to bring the substances used into the liquid state for the purpose of electrolysis, aqueous solutions being unsuitable. Among the earliest experiments in this branch of the subject were those of Davy, who in 1807

(*Phil. Trans. Roy. Soc.*, 1808, p. 1), produced the alkali metals by passing an intense current of electricity, from a platinum wire to a platinum dish, through a mass of fused caustic alkali. The action was started in the cold, the alkali being slightly moistened to render it a conductor; then, as the current passed, heat was produced, and the alkali fused, the metal being deposited in the liquid condition. Later, Matthiessen (*Quarterly Journ. Chem. Soc.* vol. viii. p. 30) obtained potassium by the electrolysis of a mixture of potassium and calcium chlorides fused over a lamp. There are here foreshadowed two types of electrolytic furnace-operations: (*a*) those in which external heating maintains the electrolyte in the fused condition, and (*b*) those in which a current-density is applied sufficiently high to develop the heat necessary to effect this object unaided. Much of the earlier electro-metallurgical work was done with furnaces of the (*a*) type, while nearly all the later developments have been with those of class (*b*). There is a third class of operations, exemplified by the manufacture of calcium carbide, in which electricity is employed solely as a heating agent; these are termed *electrothermal*, as distinguished from *electrolytic*. In certain electrothermal processes (*e.g.*, calcium carbide production) the heat from the current is employed in raising mixtures of substances to the temperature at which a desired chemical reaction will take place between them, while in others (*e.g.*, the production of graphite from coke or gas-carbon) the heat is applied solely to the production of molecular or physical changes. In ordinary electrolytic work only the continuous current may of course be used, but in electrothermal work an alternating-current is equally available.

Electric Furnaces.—Independently of the question of the application of external heating, the furnaces used in electro-metallurgy may be broadly classified into (i) arc furnaces, in which the intense heat of the electric arc is utilized, and (ii) resistance and incandescence furnaces, in which the heat is generated by an electric current overcoming the resistance of an inferior conductor.

Excepting such experimental arrangements as that of Depretz, for use on a small scale in the laboratory, Pichou in France and Johnson in England appear, in 1853, to have introduced the earliest practical form of furnace. In these arrangements, which were similar if not identical, the furnace charge was crushed to a fine powder and passed through two or more electric arcs in succession.

Arc furnaces.

When used for ore smelting, the reduced metal and the accompanying slag were to be caught, after leaving the arc and while still liquid, in a hearth fired with ordinary fuel. Although this primitive furnace could be made to act, its efficiency was low, and the use of a separate fire was disadvantageous. In 1878 Sir William Siemens patented a form of furnace [1] which is the type of a very large number of those designed by later inventors.

In the best known form a plumbago crucible was used with a hole cut in the bottom to receive a carbon rod, which was ground in so as to make a tight joint. This rod was connected with the positive pole of the dynamo or electric generator. The crucible was fitted with a cover in which were two holes; one at the side to serve at once as sight-hole and charging door, the other in the centre to allow a second carbon rod to pass freely (without touching) into the interior. This rod was connected with the negative pole of the generator, and was suspended from one arm of a balance-beam, while from the other end of the beam was suspended a vertical hollow iron cylinder, which could be moved into or out of a wire coil or solenoid joined as a shunt across the two carbon rods of the furnace. The solenoid was above the iron cylinder, the supporting rod of which passed through it as a core. When the furnace with this well-known regulating device was to be used, say, for the melting of metals or other conductors of electricity, the fragments of metal were placed in the crucible and the positive electrode was brought near them. Immediately the current passed through the solenoid it caused the iron cylinder to rise and, by means of its supporting rod, forced the end of the balance beam upwards, so depressing the other end that the negative carbon rod was forced downwards into contact with the metal in the crucible. This action completed the furnace-circuit, and current passed freely from the positive carbon through the fragments of metal to the negative carbon, thereby reducing the current through the shunt. At once the attractive force of the solenoid on the iron cylinder was automatically reduced, and the falling of the latter caused the negative carbon to rise, starting an arc between it and the metal in the crucible. A counterpoise was placed on the solenoid end of the balance beam to act against the attraction of the solenoid, the position of the counterpoise determining the length of the arc in the crucible. Any change in the resistance of the arc, either by lengthening, due to the sinking of the charge in the crucible, or by the burning of the carbon, affected the proportion of current flowing in the two shunt circuits, and so altered the position of the iron cylinder in the solenoid that the length of arc was, within limits, automatically regulated. Were it not for the use of some such device the arc would be liable to constant fluctuation and to frequent extinction. The crucible was surrounded with a bad conductor of heat to minimize loss by radiation. The positive carbon was in some cases replaced by a water-cooled metal tube, or ferrule, closed, of course, at the end inserted in the crucible. Several modifications were proposed, in one of which, intended for the heating of non-conducting substances, the electrodes were passed horizontally through perforations in the upper part of the crucible walls, and the charge in the lower part of the crucible was heated by radiation.

The furnace used by Moissan in his experiments on reactions at high temperatures, on the fusion and volatilization of refractory materials, and on the formation of carbides, silicides, and borides of various metals consisted, in its simplest form, of two superposed blocks of lime or of limestone with a central cavity cut in the lower block, and with a corresponding but much shallower inverted cavity in the upper block, which thus formed the lid of the furnace. Horizontal channels were cut on opposite walls, through which the carbon poles or electrodes were passed into the upper part of the cavity. Such a furnace, to take a current of 4 H.P. (say, of 60 amperes and 50 volts), measured externally about 6 by 6 by 7 in., and the electrodes were about 0·4 in. in diameter, while for a current of 100 H.P. (say, of 746 amperes and 100 volts) it measured about 14 by 12 by 14 in., and the electrodes were about 1·5 in. in diameter. In the latter case the crucible, which was placed in the cavity immediately beneath the arc, was about 3 in. in diameter (internally), and about 3½ in. in height. The fact that energy is being used at so high a rate as 100 H.P. on so small a charge of material sufficiently indicates that the furnace is only used for experimental work, or for the fusion of metals which, like tungsten or chromium, can only be melted at temperatures attainable by electrical means. Moissan succeeded in fusing about ¾ ℔ of either of these metals in 5 or 6 minutes in a furnace similar to that last described. He has also arranged an experimental tube-furnace by passing a carbon tube horizontally beneath the arc in the cavity of the lime blocks. When prolonged heating is required at very high temperatures it is found necessary to line the furnace-cavity with alternate layers of magnesia and carbon, taking care that the lamina next to the lime is of magnesia; if this were not done the lime in contact with the carbon crucible would form calcium carbide and would slag down, but magnesia does not yield a carbide in this way. Chaplet has patented a muffle or tube furnace, similar in principle, for use on a larger scale, with a number of electrodes placed above and below the muffle-tube. The arc furnaces now widely used in the manufacture of calcium carbide on a large scale are chiefly developments of the Siemens furnace. But whereas, from its construction, the Siemens furnace was intermittent in operation, necessitating stop-

[1] Cf. Siemens's account of the use of this furnace for experimental purposes in *British Association Report* for 1882.

page of the current while the contents of the crucible were poured out, many of the newer forms are specially designed either to minimize the time required in affecting the withdrawal of one charge and the introduction of the next, or to ensure absolute continuity of action, raw material being constantly charged in at the top and the finished substance and bye-products (slag, &c.) withdrawn either continuously or at intervals, as sufficient quantity shall have accumulated. In the King furnace, for example, the crucible, or lowest part of the furnace, is made detachable, so that when full it may be removed and an empty crucible substituted. In the United States a revolving furnace is used which is quite continuous in action.

Incandescence furnaces.

The class of furnaces heated by electrically incandescent materials has been divided by Borchers into two groups: (1) those in which the substance is heated by contact with a substance offering a high resistance to the current passing through it, and (2) those in which the substance to be heated itself affords the resistance to the passage of the current whereby electric energy is converted into heat. Practically the first of these furnaces was that of Depretz, in which the mixture to be heated was placed in a carbon tube rendered incandescent by the passage of a current through its substance from end to end. In 1880 Borchers introduced his resistance-furnace, which, in one sense, is the converse of the Depretz apparatus. A thin carbon pencil, forming a bridge between two stout carbon rods, is set in the midst of the mixture to be heated. On passing a current through the carbon the small rod is heated to incandescence, and imparts heat to the surrounding mass. On a larger scale several pencils are used to make the connexions between carbon blocks which form the end walls of the furnace, while the side walls are of fire-bricks laid upon one another without mortar. Many of the furnaces now in constant use depend mainly on this principle, a core of granular carbon fragments stamped together in the direct line between the electrodes, as in Acheson's carborundum furnace, being substituted for the carbon pencils. In other cases carbon fragments are mixed throughout the charge, as in Cowles's zinc-smelting retort. In practice, in these furnaces, it is possible for small local arcs to be temporarily set up by the shifting of the charge, and these would contribute to the heating of the mass. In the remaining class of furnace, in which the electrical resistance of the charge itself is utilized, are the continuous-current furnaces, such as are used for the smelting of aluminium, and those alternating-current furnaces (*e.g.*, for the production of calcium carbide) in which a portion of the charge is first actually fused, and then maintained in the molten condition by the current passing through it, while the reaction between further portions of the charge is proceeding.

Uses and advantages.

For ordinary metallurgical work the electric furnace, requiring as it does (excepting where waterfalls or other cheap sources of power are available) the intervention of the boiler and steam engine, or of the gas or oil engine, with a consequent loss of energy, has not usually proved so economical as an ordinary direct fired furnace. But in some cases in which the current is used for electrolysis and for the production of extremely high temperatures, for which the calorific intensity of ordinary fuel is insufficient, the electric furnace is employed with advantage. The temperature of the electric furnace, whether of the arc or incandescence type, is practically limited to that at which the least easily vaporized material available for electrodes is converted into vapour. This material is carbon, and as its vaporizing point is (estimated at) over 3500° C., and less than 4000° C., the temperature of the electric furnace cannot rise much above 3500° C. (6330° F.); but Moissan has shown that at this temperature the most stable of mineral combinations are dissociated, and the most refractory elements are converted into vapour, only certain borides, silicides, and metallic carbides having been found to resist the action of the heat. It is not necessary that all electric furnaces shall be run at these high temperatures; obviously, those of the incandescence or resistance type may be worked at any convenient temperature below the maximum. The electric furnace has several advantages as compared with some of the ordinary types of furnace, arising from the fact that the heat is generated from within the mass of material operated upon, and (unlike the blast-furnace, which presents the same advantage) without a large volume of gaseous products of combustion and atmospheric nitrogen being passed through it. In ordinary reverberatory and other heating furnaces the burning fuel is without the mass, so that the vessel containing the charge, and other parts of the plant, are raised to a higher temperature than would otherwise be necessary, in order to compensate for losses by radiation, convection, and conduction. This advantage is especially observed in some cases in which the charge of the furnace is liable to attack the containing vessel at high temperatures, as it is often possible to maintain the outer walls of the electric furnace relatively cool, and even to keep them lined with a protecting crust of unfused charge. Again, the construction of electric furnaces may often be exceedingly crude and simple; in the carborundum furnace, for example, the outer walls are of loosely piled bricks, and in one type of furnace the charge is simply heaped on the ground around the carbon resistance used for heating, without containing-walls of any kind. There is, however, one (not insuperable) drawback in the use of the electric furnace for the smelting of pure metals. Ordinarily carbon is used as the electrode material, but when carbon comes in contact at high temperatures with any metal that is capable of forming a carbide a certain amount of combination between them is inevitable, and the carbon thus introduced impairs the mechanical properties of the ultimate metallic product. Aluminium, iron, platinum, and many other metals may thus take up so much carbon as to become brittle and unforgeable. It is for this reason that Siemens, Borchers, and others substituted a hollow water-cooled metal block for the carbon cathode upon which the melted metal rests while in the furnace. Liquid metal coming in contact with such a surface forms a crust of solidified metal over it, and this crust thickens up to a certain point, namely, until the heat from within the furnace just overbalances that lost by conduction through the solidified crust and the cathode material to the flowing water. In such an arrangement, after the first instant, the melted metal in the furnace does not come in contact with the cathode material.

Electrothermal Processes.—In these processes the electric current is used solely to generate heat, either to induce chemical reactions between admixed substances, or to produce a physical (allotropic) modification of a given substance. Borchers predicted that, at the high temperatures available with the electric furnace, every oxide would prove to be reducible by the action of carbon, and this prediction has in most instances been justified. Alumina and lime, for example, which cannot be reduced at ordinary furnace temperatures, readily give up their oxygen to carbon in the electric furnace, and then combine with an excess of carbon to form metallic carbides. In 1885 the brothers Cowles patented a process for the electrothermal reduction of oxidized ores by exposure to an intense current of electricity when admixed with carbon in a retort. Later in that year they patented a process for the reduction of aluminium by carbon, and in 1886 an electric furnace with sliding carbon rods passed through the end walls to the centre of a rectangular furnace. The impossibility of working with just sufficient carbon to reduce the alumina, without using any excess which would be free to form at least so much carbide as would suffice, when diffused through the metal, to render it brittle, practically restricts the use of such processes to the production of aluminium alloys. Aluminium bronze (aluminium and copper) and ferroaluminium (aluminium and iron) have been made in this way; the latter is the more satisfactory product, because a certain proportion of carbon is expected in an alloy of this character, as in ferromanganese and cast-iron, and its presence is not objectionable. The furnace is built of fire-brick and may measure (internally) 5 ft. in length by 1 ft. 8 in. in width, and 3 ft. in height. Into each end wall is built a short iron tube sloping downwards towards the centre, and through this is passed a bundle of five 3-in. carbon rods, bound together at the outer end by being cast into a head of cast-iron for use with iron alloys, or of cast-copper for aluminium bronze. This head slides freely in the cast-iron tubes, and is connected by a copper rod with one of the terminals of the dynamo supplying the current. The carbons can thus, by the application of suitable mechanism, be withdrawn from or plunged into the furnace at will. In starting the furnace, the bottom is prepared by ramming it with charcoal-powder that has been soaked in milk of lime and dried, so that each particle is coated with a film of lime, which serves to reduce the loss of current by conduction through the lining when the furnace becomes hot. A sheet-iron case is then placed within the furnace, and the space between it and the walls rammed with limed charcoal; the interior is filled with fragments of the iron or copper to be alloyed, mixed with alumina and coarse charcoal, broken pieces of carbon being placed in position to connect the electrodes. The iron case is then removed, the whole is covered with charcoal, and a cast-iron cover with a central flue is placed above all. The current, either continuous or alternating, is then started, and continued for about 1 to 1½ hours, until the operation is complete, the carbon rods being gradually withdrawn as the action proceeds. In such a furnace a continuous current, for example, of 3000 amperes, at 50 to 60 volts, may be used at first, increasing to 5000 amperes in about half an hour. The reduction is not due to electrolysis, but to the action of carbon on alumina ($Al_2O_3 + 3C = Al_2 + 3CO$), a part of the carbon in the charge being consumed and evolved as carbon monoxide gas, which burns at the orifice in the cover so long as reduction is taking place. The reduced aluminium alloys itself immediately with the fused globules of metal in its midst, and as the charge becomes reduced the globules of alloy unite until, in the end, they are run out of the tap-hole after the current has been diverted to another furnace. It was found in practice (in 1889) that the expenditure of energy per pound of reduced aluminium was about 23 H.P.-hours, a number considerably in excess of that required at the present time for the production of pure aluminium by the electrolytic process hereafter to be described.

Aluminium alloys.

Calcium carbide.

Wöhler, in 1862, had obtained an impure calcium carbide, and Borchers had unintentionally produced some of the carbide (CaC_2) in his incandescence electric-furnace, but Willson, in America, working with an arc furnace, seems to have been the first to make the product industrially, and to have realized the possibilities of its use in the manufacture of acetylene by mere contact with water. Willson and Moissan (*Comptes Rendus*, vol. cxv. p. 558), in 1892, described the production of the carbide in their respective electric furnaces, the one commercially the other experimentally, and since then many inventors have turned their attention to its manufacture by electrothermal methods. In every case the principle is the same, the charge, consisting of pure lime and good hard coke-dust, very finely crushed and intimately mixed in the approximate proportion of 10 to 7, is introduced into a carbon-lined vessel, in the interior of which a powerful arc is passing between carbon electrodes (usually between a vertical carbon and a carbon bottom). Part of the carbon reduces the lime, whilst a further portion combines with the liberated calcium to form the carbide, thus ($CaO + 3C = CaC_2 + CO$), and the carbide fuses and sinks to the bottom. The system of treatment may be either continuous or intermittent. In the continuous process a carbon-lined furnace is commonly used, with a massive carbon electrode (made up of several blocks of carbon clamped together) within it. Sufficiently high current-density is employed to ensure that the carbide formed remains fluid, and the passage of the (alternating) current through the fluid carbide, after the furnace is once in working order, is depended upon to generate the heat necessary both to keep it molten and to continue the action. A part of the carbide is tapped out of the furnace from time to time as it accumulates. In the intermittent process the current is stopped in about 12 to 18 hours when sufficient carbide is formed, and after cooling the solidified product is removed. In the King type of furnace a movable hearth is used, so that the action of the furnace is practically continuous, the current being broken only for the few minutes necessary to effect the exchange of hearths.

Although continuous processes appeared at one time to be growing in favour, there is in many places a tendency to revert to intermittent furnaces. Carlson, in a comparison of the two types (*Zeitschrift f. Elektrochem.*, 1900, vol. vi. pp. 413–429), has pointed out that the intermittent process is more economical, mainly on account of the higher temperature necessary in the continuous furnace to maintain the carbide fluid, but partly owing to the fact that the cooling carbide to some extent continues the reaction on portions of the surrounding charge still unconverted after the current has been diverted. The reaction between lime and carbon appears to begin at a temperature not greatly above 1500° C., but fusion does not occur until 2800° C. is reached, and the product only flows freely at temperatures between 3500° and 4000° C. In order that the carbide may be tapped from the furnace, it must attain a temperature, therefore, of at least 3500° C., whereas in the intermittent process 2800° to 3000° C. (3500° to 3800° F.) suffices. This leads to a saving in many directions, too numerous here to mention in detail. In the intermittent process, using an electrode of about 100 sq. in. in cross section, a current of about 2000 amperes at 70 to 100 volts (equal to about 250 E.H.P.) has been found to give in practice about 11 cwt. of a product containing, say, 80 per cent. of pure carbide for each ton of charge. This is equivalent to a production of about 0·4 ℔ of carbide per E.H.P.-hour.

Carborundum.

Carborundum, which on account of its great hardness has assumed an important place among abrasives used for polishing, and also has possible applications in the metallurgy of iron and steel, is a silicide of carbon (SiC) formed by the action of carbon on sand (silica) at high temperatures. Its name was derived from *carbon* and *corundum* (a form of alumina), from a mistaken view as to its composition. It was first obtained accidentally in 1891 by Acheson, in America, when he was experimenting with the electric furnace in the hope of producing artificial diamonds. The experiments were followed up in an incandescence furnace, which on a larger scale is now employed for the industrial manufacture of the product. A full description of the process has been given by Kohn (*Journ. Soc. Chem. Industry*, 1897, vol. xvi. p. 863). The furnace is rectangular, about 16 ft. long and 5 ft. wide by 5 ft. high, with massive brick end-walls 2 ft. thick, through which are built the carbon poles, consisting of bundles of 60 parallel 3-in. carbon rods, each 3 ft. in length, with a copper rod let into the outer end to connect it with a copper cap, which in turn is connected with one of the terminals of the generating dynamo. The spaces between the carbons of the electrode are packed tightly with graphite. In preparing the furnace for use, transverse iron screens are placed temporarily across each end, the space between these and the end walls being rammed with fine coke, and that in the interior is filled to the level of the centre of the carbon poles with the charge, consisting of 34 parts of coke, with 54 of sand, 10 of sawdust, and 2 of salt. A longitudinal trench is then formed in the middle, and in this is arranged a cylindrical pile of fragments of coke about $\frac{1}{2}$ in. or more in diameter, so that they form a core, about 21 in. in diameter, connecting the carbon poles in the end walls. Temporary side walls are then built up, the iron screens are removed, and a further quantity of charge is heaped up about 3 ft. above the top of the furnace. An alternating current of about 1700 amperes at 190 volts is now switched on; as the mass becomes heated by the passage of the current the resistance diminishes, and the current is regulated until after about 2 hours or less from starting it is maintained constant at about 6000 amperes and 125 volts. Carbon monoxide is given off and burns freely around the sides and top of the furnace, tinged yellow after a time by the sodium in the salt mixed with the charge. Meanwhile a shrinkage takes place, which is made good by the addition of a further quantity of charge until the operation is complete, usually in about 36 hours from the commencement. The current is then switched off, and the side walls, after cooling for a day, are taken down, the comparatively unaltered charge from the top is removed, and the products are carefully extracted. These consist of the inner carbon core, which at the temperature of the furnace will have been for the most part converted into graphite, then a thin black crust of graphite mixed with carborundum, next a layer of nearly pure crystallized carborundum about a foot in thickness, then grey amorphous carbide of silicon mixed with increasing proportions of unaltered charge, and lastly, on the outside, the portion of the charge which had never reached the temperature necessary for reaction, and which is altered only by the intrusion of salt from the inner part of the furnace. Special precautions are taken in making and breaking the intense current here used (amounting at the end to about 750 kilowatts, or 1000 E.H.P.), a water-regulator consisting of removable iron plates dipped in salt water being used for the purpose. In such a furnace as that above described the charge weighs about 14 tons, the yield of carborundum is about 3 tons, and the expenditure of energy about 3·9 kilowatt-hours (5·2 H.P.-hours) per pound of finished product. The carborundum thus produced is crystalline, greenish, bluish, or brownish in colour, sometimes opaque, but often translucent, resisting the action of even the strongest acids, and the action of air or of sulphur at high temperatures. The crude product can therefore be treated with hot sulphuric acid to purify it. In hardness it nearly equals the diamond, and it is used for tool grinding in the form of vitrified wheels (mixed with powdered porcelain and iron, pressed into shape and fired in a kiln). Carborundum paper, made like emery paper, is now largely used in place of garnet paper in American shoe factories, and is rapidly finding a market in other directions. The amorphous carbide, which was at first a waste product, has been tried, it is reported, with success as a lining for steel furnaces, as it is said not to be affected by iron or iron oxide at a white heat.

Graphite. The alteration of carbon at high temperatures into a material resembling graphite has long been known. In 1893, Girard and Street patented a furnace and a process by which this transformation could be effected. Carbon powder compressed into a rod was slowly passed through a tube in which it was subjected to the action of one or more electric arcs. In this way they converted into graphite about 85 per cent. of the carbon in a $\frac{1}{2}$-in. rod, the electric conductivity being increased fourfold, and the specific gravity being raised from 1·98 to 2·6. But Acheson, in 1896, patenting an application of his carborundum process to graphite manufacture, was apparently the first to undertake the production of graphite in large quantities. Powdered coke or other form of carbon is mixed with a small proportion of an oxide or silicate, and is moulded into the desired shape with the aid of water containing a little sugar. The moulded pieces are then embedded in carbon dust, surrounded with a bad conductor of heat, such as amorphous carbide of silicon, and subjected to the action of the current. The oxides present form carbides which, in turn, are probably dissociated, the metal being volatilized. In time the whole of the carbon could be converted into graphite, but it is preferred to leave a small proportion unchanged, as the product is then somewhat stronger than if it were pure graphite. Graphite so produced is widely used for electrodes in electro-chemical operations, as well as for dynamo brushes, lead pencils, and the like.

Phosphorus. During the last few years an electrothermal process has been largely employed for the manufacture of phosphorus. Calcium phosphate, mixed with sand and carbon, is fed into an electric furnace provided with a closely fitting cover with an outlet for the vapour and gases produced during the operation; these gases are then passed through a condenser to separate the condensible portion. The furnaces are smaller than those used in carborundum production, and commonly make about $1\frac{1}{2}$ cwt. of phosphorus each per diem. At the temperature of the furnace the silica (sand) attacks the calcium phosphate, forming silicate, and setting free phosphorus pentoxide, which is attacked by the carbon of the charge, forming phosphorus and carbon monoxide gas. As phosphorus boils at 290° C. (554° F.), it is produced in the form of vapour, which, mingled with the carbon monoxide, passes to the condenser, where it is condensed. It is then cast under water into the sticks in which it is known in commerce. The calcium silicate remains in the furnace in the form of a liquid slag, which may be run off to make room for a further charge, so that the action is practically continuous. Kaolin may with advantage be used in addition to or in part substitution for sand, because the double silicate thus formed is more fusible than the single silicate of lime. The alternating current is generally used, the action not being electrolytic. One of the special advantages of the electrical over the older process is that the distilling vessels have a longer life, owing to the fact that they are not externally heated, and so subjected to a relatively high temperature when in contact with the corrosive slag formed in the process. The Readman-Parker process (see *Journ. Soc. Chem. Industry*, 1891, vol. x. p. 445) appears to be very generally adopted. Readman, experimenting with a Cowles furnace in Staffordshire in 1888, patented his process, and in the same year Parker and Robinson, working independently, patented a similar one. The two inventors then co-operated, an experimental plant was run successfully, and the patents were taken over by the leading firm of phosphorus manufacturers. With the object of obtaining a valuable bye-product in place of the slag produced in this furnace, several patentees (*e.g.*, Hilbert and Frank, Billaudot, Bradley and Jacobs, and others) have sought to combine the manufacture of calcium carbide and phosphorus by using only calcium phosphate and carbon, effecting direct reduction by carbon at a high temperature. It remains to be seen whether the result will be satisfactory industrially.

Electrolytic Processes.—Bunsen and Deville, working independently, both produced metallic aluminium on a small scale in 1854 by the electrolysis of the fused double chloride of aluminium and sodium contained in a porcelain crucible, heated externally in a gas flame, and divided into two compartments, one containing a carbon anode, the other a carbon or platinum (Deville) cathode. This process could not well be used industrially, not only because at that time there was no cheap source of electric energy, but because the double chloride employed is very hygroscopic, and is therefore liable, unless stored in a perfectly dry place, to become converted into hydrated chloride which will not fuse, but is, on heating, decomposed into alumina and hydrochloric acid. The dry chloride, too, is volatile at comparatively low temperatures, so that it is practically impossible to avoid loss by vaporization, and moreover, the use of a chloride at all is objectionable, because of the difficulty in dealing with the corrosive and suffocating chlorine evolved at the anode. The actual system adopted in these experiments involves the use of external firing, which, as already pointed out, is usually to be avoided. Attempts to deposit aluminium from aqueous solution have been unsuccessful, and the reduction of alumina (aluminium oxide) by carbon in the electric furnace cannot well be used for the production of pure aluminium, on account of the readiness with which the metal at these high temperatures combines with carbon, and is thus rendered brittle. The use of the electric arc for the reduction of aluminium compounds other than the oxide has not met with success industrially. Speaking generally, the heat of the arc is too local and too intense for use except for the production of extremely high temperatures. From 1870 to the present time numerous patents have been granted for methods of reducing aluminium. The processes by which it is now for the most part made—the Héroult, the C. M. Hall, and the Minet—are in principle practically the same, and have entirely replaced the older, purely chemical method.

Aluminium reduction.

The furnace consists of an iron or other tank lined with stamped carbon dust, the whole of the lining acting as the cathode. A stout carbon rod, or a bundle of such rods, forms an anode, which may be lowered into the tank to any required depth. A cover to the tank is provided, with apertures for the anode and for introducing the charge. In some furnaces a tap-hole, fitted with a removable plug, is placed at one side, on a level with the bottom, so that a portion of the reduced aluminium may be run into a ladle from time to time; in others, the aluminium is removed from the tank by means of a ladle or a siphon. The bath consists usually of a mixture of the fluorides of aluminium, sodium and calcium, or of cryolite (a natural double fluoride of aluminium and sodium), with or without admixture with other fluorides. The mixture chosen must be one which melts readily at a bright red heat; it is either melted, little by little, in the furnace itself, with the aid of the current, a further quantity of charge being added as required until the tank is sufficiently full, or it is melted in an ordinary furnace outside, and then run into the electric furnace when ready for use. But it is not the fluoride that is electrolysed. The mixture of fluorides has the power, when melted at a red heat, of dissolving about one-fifth of its weight of aluminium oxide (alumina), just as water will dissolve copper sulphate. The electrolysis of this solution is comparable with that of copper sulphate—it is the dissolved substance (alumina), not the solvent (fluoride), which is dissociated by the electric current. The voltage theoretically required for the reduction is therefore that necessary for the decomposition of alumina, or about 2·8 volts. But since no external heat is applied, and during the whole period loss of heat by radiation is taking place, the mass would soon cool below its fusing point, and would therefore solidify, unless a current-density were used sufficiently high to ensure that the heat lost is made good by the conversion of electric into heat energy by the current in overcoming the resistance of the bath. For this reason a high electromotive force is necessary to drive the current through the mass, and of the total energy consumed a great part employed is expended to produce heat. In practice, the pressure applied is about 4 volts. The alumina is electrolysed into aluminium, which is deposited on the bottom and side walls of the tank, and oxygen, which, being liberated on the surface of the red-hot carbon anode, combines with it to form carbonic oxide (CO). The anode thus wears away, but in so doing contributes by its combustion towards the heat necessary to maintain the fluidity of the electrolyte. The expenditure of anode carbon is, however, somewhat in excess of the amount (2 ℔ of carbon : 3 ℔ of aluminium) theoretically necessary according to the equation $Al_2O_3 + 3C = Al_2 + 3CO$, partly owing to oxidation by air, partly, no doubt, to disintegration; and in practice the consumption of carbon is often equal in weight to the aluminium reduced. The aluminium is deposited at the temperature of the bath, which is commonly about 800° C. (1,500° F.), and therefore above the fusing-point of the metal (654° C. or 1200 F.), so that it is perfectly fluid and may readily be tapped or ladled out. Fresh alumina is introduced from time to time to dissolve into the bath and take the place of that which has been electrolysed. Thus the action of the furnace is continuous. The fluorides are practically unchanged, and may remain in use for a long period. The alumina and the carbon anode, both of which are used up in the process, must be as pure as possible. As aluminium stands very high in the list of electro-positive metals, nearly every other metal, and even certain metalloids, such as silicon, if present in the bath, would be deposited more readily than it, and would therefore be co-precipitated, rendering the product impure and less marketable. The fluorides, on the other hand, need not be absolutely pure initially, because they remain in use for a long time, and any impurity they may contain at first is removed in the first batch of aluminium deposited, the solvent then remaining fairly pure. Commercial aluminium now rarely contains more than from 1 to 1½ per cent. of impurities, which consist chiefly of iron, silicon, and carbon, and the best qualities are even purer.

In the early days of the electric smelting of aluminium an expenditure of 22 electrical horse-power hours (16½ kilowatt hours) was necessary for every pound of aluminium produced; this, at a later date, was reduced to 16 E.H.P. hours (or 12 K.W. hours), and at Foyers, in Scotland, the expenditure per pound has now been reduced to 12 E.H.P. hours (or 9 K.W. hours). It may be noted that at Foyers (see *Journ. Soc. Chem. Industry*, 1898, vol. xvii. p. 308) the total current employed in each furnace is 8000 amperes, and the current-density is 35 amperes per sq. in. of anode surface, and nearly 4·8 amperes per sq. in. of cathode surface, thus indicating that the areas of anode and cathode immersed are respectively about 228 sq. in. and 11½ sq. ft. It would appear that rather more than one-third of the energy consumed, and about three-fifths of the current volume applied, are usefully employed in depositing aluminium.

Many other processes have been proposed for cheapening the process of reducing aluminium. The direction in which many inventors have worked has been to find a suitable compound of aluminium with a lower heat of formation than the oxide, as such a substance would require a lower electromotive force to effect its decomposition, and would therefore entail a smaller expenditure of energy to produce a given weight of the metal. Aluminium sulphide is such a substance, requiring only 0·9 volt theoretically for decomposition, but one of the chief difficulties is to find a sufficiently economical method of preparing it. The Aluminium Industrie Aktiengesellschaft took out a patent in Germany in 1890 for the electrolysis of this substance. Peniakoff in 1896, Blackmore in 1897, and others have also worked at sulphide processes, but there is at present no indication that any of them will displace the oxide-electrolysis process already described.

Magnesium reduction.

The problem of magnesium reduction is in many respects similar to that of aluminium extraction, but the lightness of the metal as compared, bulk for bulk, with its fused salts (its specific gravity is only 1·75 in the solid state), and the readiness with which it burns when exposed to air at high temperatures, render the problem somewhat more difficult. Moissan found that the oxide resists reduction by carbon in the electric furnace, so that electrolysis of a fusible salt of the metal must be resorted to. Bunsen, in 1852, electrolysed fused magnesium chloride in a porcelain crucible, divided into two compartments by a porcelain partition which did not quite reach the bottom. The electrodes were shaped carbon rods passing through perforations in a fire-clay lid, the cathode having inverted steps cut on the side facing the anode, so that there should be three or four ledges to intercept and retain globules of molten magnesium accumulating on the cathode surface, and tending to float upwards to the top of the bath. The separation into two compartments was necessary to prevent the passage of chlorine to the cathode side, where it would recombine with magnesium. In later processes, carnallite (a natural double chloride of magnesium and potassium) has commonly, after careful dehydration, been substituted for the single chloride. Graetzel's process, which was at one time employed, consisted in electrolysing the chloride in a metal crucible heated externally, the crucible itself forming the cathode, and the magnesium being deposited upon its inner surface. Suspended within this was a fire-clay cell closed at the top and bottom, but with large perforations around the side walls near the bottom, and with a side tube near the top to conduct away the chlorine generated on the surface of the carbon anode, which is suspended within this cell through a hole in its cover. The outer crucible was also provided with an annular cover, so that the space above the melted charge could be filled with a reducing gas, such as coal gas, to prevent oxidation of the reduced magnesium by contact with air. The apertures at the bottom of the fire-clay cell allowed the passage of melted electrolyte, and therefore of the current, but, being near the bottom, prevented the escape of chlorine into the outer cell excepting by diffusion. Following a suggestion made by Deville in the case of aluminium reduction, an attempt was made to replenish the bath with magnesium by introducing into the anode cell a compressed rod of magnesia and carbon, in the expectation that, in the presence of chlorine, the magnesia would be reduced by the carbon. The rods, however, crumbled into the bath and were unsatisfactory. Borchers also uses an externally heated metal cathode vessel as the cathode; it is provided with a supporting collar or flange a little below the top, so that the upper part of the vessel is exposed to the cooling influence of the air, in order that a crust of solidified salt may there be formed, and so prevent the creeping of the electrolyte over the top. The carbon anode passes through the cover of a porcelain cylinder, open at the bottom, and provided with a side-tube at the top to remove the chlorine formed during electrolysis. The operation is conducted at a dull red heat (about 760° C. or 1400° F.), the current density being about 0·64 amperes per sq. in. of cathode surface, and the pressure about 7 volts. The fusing-point of the metal is about 730° C. (1350° F.), and the magnesium is therefore reduced in the form of melted globules which gradually accumulate. At intervals the current is interrupted, the cover removed, and the temperature of the vessel raised considerably above the melting-point of magnesium. The metal is then removed from the walls with the aid of an iron scraper, and the whole mass poured into a sheet-iron tray, where it solidifies. The solidified chloride is then broken up, the shots and fused masses of magnesium are picked out, run together in a plumbago crucible without flux, and poured into a suitable mould. Smaller pieces are thrown into a bath of melted carnallite and pressed together with an iron rod, the bath being then heated until the globules of metal float to the top, when they may be removed in perforated iron ladles, through the holes in which the fused chloride can drain away, but through which the melted magnesium cannot pass by reason of its high surface tension. The globules are then re-melted. For some years past practically the whole of the magnesium made has been obtained electrolytically.

The isolation of the alkali metals from caustic alkalis by Davy, in 1808, was one of the earliest triumphs of electrolysis. Until quite recently, however, the whole output of these metals was obtained by a metallurgical method; but now electrolytic processes alone are used. Since 1851, when Charles Watt patented his process for the reduction of the metals from fused chlorides, many inventors have worked at the subject, most of them electrolysing pure or mixed chlorides. Among the difficulties here to be contended with are the destructive action of fused chlorides and of the reduced alkali metals upon most non-metallic substances available for the containing vessel and its partition, and also of the anode chlorine upon metals; also the low fusing-point (95° C. or 203° F. for sodium, and 62° C. or 144° F. for potassium), and the low specific gravity of the metals, so that the separated metal floats as a fused layer upon the top of the melted salt. Again, pure sodium chloride melts at about 775° C. (1427° F.), while sodium boils at about 900° C., so that the margin of safety is but small if loss by vaporization is to be prevented. Borchers (*Zeitschrift f. angewandte Chem.*, 1893, vol. xvi. p. 486) endeavours to contend against the first difficulty by employing an iron cathode vessel and a chamotte (fire-clay) anode chamber united by a specially constructed water-cooled joint. The other difficulty is to some extent met by using mixed chlorides (*e.g.*, sodium, potassium, and strontium chlorides for sodium extraction), as these melt at a lower temperature than does the pure chloride. Castner, whose sodium process (as employed at Oldbury and Niagara and in Germany) has displaced not only the old metallurgical, but the chloride method, reverted to the electrolysis of fused caustic soda. The apparatus described in the patent specification is an iron cylinder heated by gas rings below, with a narrower cylinder beneath, through which passes upwards a stout iron cathode rod cemented in place by caustic soda solidified in the narrower vessel. Iron anodes are suspended around the cathode, and between the two is a cylinder of iron gauze at the bottom with a sheet-iron continuation above, the latter being provided with a movable cover. During electrolysis, oxygen is evolved at the anode and escapes from the outer vessel, while the sodium deposited in globules on the cathode floats upwards into the iron cylinder, within which it accumulates, and from which it may be removed at intervals by means of a perforated iron ladle, the fused salt, but not the metal, being able to pass freely through the perforations. The sodium is then cast into moulds. Sodium hydroxide has certain advantages compared with chloride, although it is more costly; its fusing-point is only 320° C. (600° F.), and no anode chlorine is produced, so that both containing vessel and anode may be of iron, and no porous partition is necessary. Alloys of sodium and lead have been prepared successfully from their fused chlorides, and in the article on ELECTRO-CHEMISTRY allusion is made to their use in the production of caustic alkalis.

Reduction of sodium and potassium.

Calcium, barium, and strontium have all been produced by electro-metallurgical methods, but the processes have only a laboratory interest at present. Lead, zinc, and other metals have also been reduced in this manner, but the industrial development of these processes has yet to come.

For further information the following books, in addition to those mentioned at the end of the article ELECTRO-CHEMISTRY, may be consulted:—BORCHERS. *Elektrometallurgie.* Halle, 1897. *Elektrische Oefen.* Halle, 1897.—MOISSAN. *Le Four Electrique.* Paris, 1897.—RICHARDS. *Aluminium: Its History, Occurrence, Property, Metallurgy, and Applications* (the chapters relating to Electro-Metallurgical Extraction), 3rd ed. Philadelphia, 1896.

(W. G. M.)

Elets (pronounced *Yelets*), a district town of Russia, government and 121 miles by rail east-south-east of Orel. It has grown rapidly since the development of the railway system, has gymnasia for boys and girls and other schools, and is now an important centre and depôt for trade in corn, live-stock, hides, tallow, wool, metals, and leather. The goods sent to it by rail during the year amount to an average of 171,500 tons. Population (1897), 37,455.

Eleusis.—The excavations at Eleusis have been carried on systematically by M. Philios for the Greek Archæological Society since 1882, and have laid bare the whole of the sacred precinct. It is now possible to trace its boundaries as extended at various periods, and also many successive stages in the history of the Telesterion, or Hall of Initiation. These complete excavations have shown the earlier and partial excavations to have been in some respects deceptive.

In front of the main entrance of the precinct is a large paved area, with the foundations of a temple in it, usually identified as that of Artemis Propylæa; in their present form both area and temple date from Roman times; and on each side of the Great Propylæa are the foundations of a Roman triumphal arch. Just below the steps of the Propylæa, on the left as one enters, there has been discovered, at a lower level than the Roman pavement, the curb surrounding an early well. This is almost certainly the *καλλίχορον φρέαρ* mentioned by Pausanias. The Great Propylæa is a structure of Roman Imperial date, in close imitation of the Propylæa on the Athenian Acropolis. It is, however, set in a wall of 6th-century work, though repaired in later times. This wall encloses a sort of outer court, of irregular triangular shape. The Small Propylæa is not set exactly opposite to the Great Propylæa, but at an angle to it; an inscription on the architrave records that it was built by Appius Claudius Pulcher, the contemporary of Cicero. It is also set in a later wall that occupies approximately the same position as two earlier ones, which date from the 6th and 5th centuries respectively, and must have indicated the boundary of the inner precinct. From the Small Propylæa a paved road of Roman date leads to one of the doors of the Telesterion. Above the Small Propylæa, partly set beneath the overhanging rock, is the precinct of Pluto; it has a curious natural cleft approached by rock-cut steps. Several inscriptions and other antiquities were found here, including the famous head, now in Athens, usually called Eubuleus, though the evidence for its identification is far from satisfactory. A little farther on is a rock-cut platform, with a well, approached by a broad flight of steps, which probably served for spectators of the sacred procession. Beyond this, close to the side of the Telesterion, are the foundations of a temple on higher ground; it has been conjectured that this was the temple of Demeter, but there is no evidence that such a building existed in historic times, apart from the Telesterion.

The Telesterion, or Hall of Initiation, was a large covered building, about 170 feet square. It was surrounded on all sides by steps, which must have served as seats for the mystæ, while the sacred dramas and processions took place on the floor of the hall: these seats were partly built up, partly cut in the solid rock; in later times they appear to have been cased with marble. There were two doors on each side of the hall, except the north-west, where it is cut out of the solid rock, and a rock terrace at a higher level adjoins it; this terrace may have been the station of those who were not yet admitted to the full initiation. The roof of the hall was carried by rows of columns, which were more than once renewed.

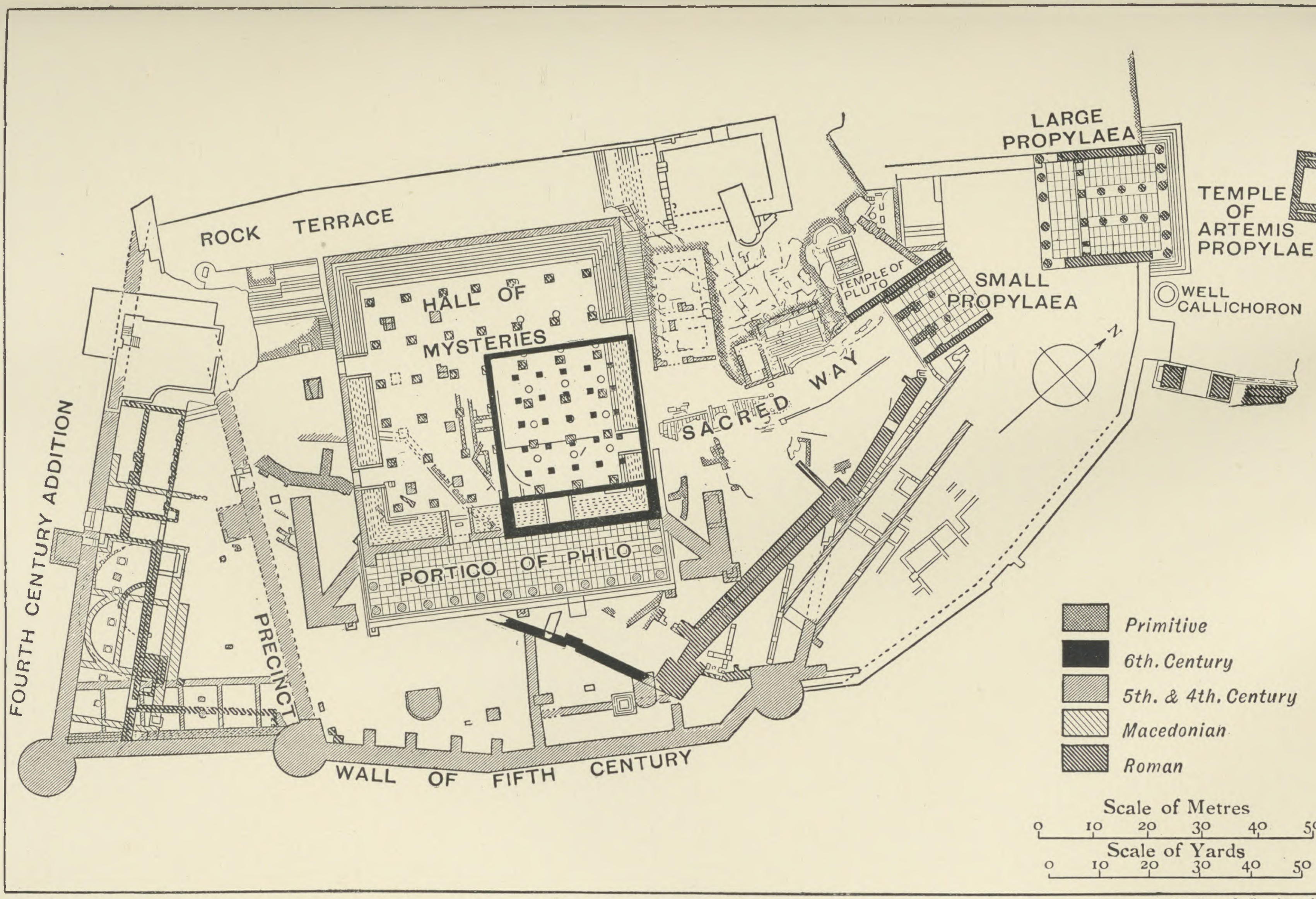
The architectural history of the hall has been traced by Professor Dörpfeld with the help of the various foundations that have been brought to light. The earliest building on the site is a small rectangular structure, with walls of polygonal masonry, built of the rock quarried on the spot. This was succeeded by a square hall, almost of the same plan as the later Telesterion, but about a quarter of the size; its eastern corner coincides with that of the later building, and it appears to have had a portico in front like that which, in the later hall, was a later addition. Its roof was carried by columns, of which the bases can still be seen. This building has with great probability been assigned to the time of Pisistratus; it was destroyed by the Persians. Between this event and the erection of the present hall, which must be substantially the one designed by Ictinus in the time of Pericles, there must have been a restoration, of which we may see the remains in a set of round sinkings to carry columns, which occur only in the north-east part of the hall; a set of bases arranged on a different system occur in the south-west part, and it is difficult to see how these two systems could be reconciled unless there were some sort of partition between the two parts of the hall. Both sets were removed to make way for the later columns, of which the bases and some of the drums still remain. These later columns are shown, by inscriptions and other fragments built into their bases, to belong to later Roman times. At the eastern and southern corners of the hall of Ictinus are projecting masses of masonry, which may be the foundation for a portico that was to be added; but perhaps they were only buttresses, intended to resist the thrust of the roof of this huge structure, which rested at its northern and western corners against the solid rock of the hill. On the south-east side the hall is faced with a portico, extending its whole width; the marble pavement of this portico is a most conspicuous feature of Eleusis at the present day. The portico was added to the hall by the architect Philo, under Demetrius Phalereus, about the end of the 4th century B.C. It was never completed, for the fluting of its columns still remains unfinished.

The Telesterion took up the greater part of the sacred precinct, which seems merely to have served to keep the profane away from the temple. The massive walls and towers of the time of Pericles, which resemble those of a fortress, are quite close in on the south and east; later, probably in the 4th century B.C., the precinct was extended farther to the south, and at its end was erected a building of considerable extent, including a curious apsidal chamber, for which a similar but larger curved structure was substituted in Roman times. This was probably the Buleuterium. The precinct was full of altars, dedications, and inscriptions; and many fragments of sculpture, pottery, and other antiquities, from the earliest to the latest days of Greece, have been discovered. It is to be noted that the subterranean passages, which some earlier explorers imagined to be connected with the celebration of the mysteries, have proved to be nothing but cisterns or water-courses.

The excavations of Eleusis, and the antiquities found in them, have been published from time to time in the Ἐφημερὶς Ἀρχαιολογική and in the Πρακτικά of the Greek Archæological Society, especially for 1887 and 1895. See also D. Philios, *Éleusis, ses mystères, ses ruines, et son Musée.* Inscriptions have also been published in the *Bulletin de Correspondance Hellénique.*

(E. GR.)

Elevators or **Lifts** are machines for raising or lowering loads, whether of people or material, from one level to another. They are operated by steam, hydraulic, or electric power, or, when small and light, by hand. Their construction varies with the magnitude of the work to be performed and the character of the motive power. In private houses, where only small weights, as coal, food, &c., have to be transferred from one floor to another, they usually consist simply of a small counter-balanced platform suspended from the roof or an upper floor by a tackle, the running part of which hangs from



Walker & Cockerell sc.

Eleusis; showing Excavations.

top to bottom and can be reached and operated at any level. If the platform is sufficiently large and strong to permit one or more persons to be carried, the hoisting is often performed by the person raised, or by an attendant, who manages the tackle from the "car" or cage. In hotels and warehouses, where great weights and numbers of people have to be lifted, or a high speed of elevation is demanded, some form of motor is necessary. This is usually, directly or indirectly, a steam engine or occasionally a gas engine; sometimes a water-pressure engine is adopted, and recently it has become more and more common to employ an electric motor deriving its energy from the general distribution of the city. Large establishments, hotels or business houses, commonly have their own source of energy, an electric or other power "plant," on the premises.

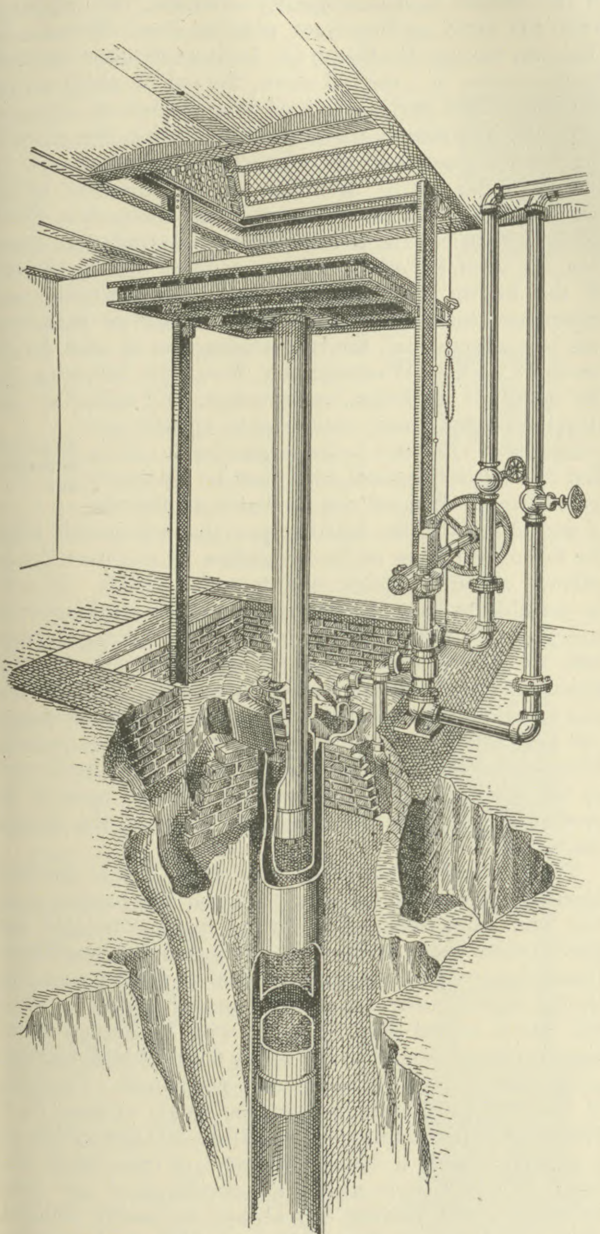


FIG. 1.—The Plunger, or Direct Lift Hydraulic Engine.

The Hydraulic Elevator is the simplest in construction of elevators proper, sometimes consisting merely of a long pipe set deeply in the ground under the cage and containing a correspondingly long plunger, which rises and falls as required and carries the elevator-cage on its upper end (Fig. 1). The "stroke" is thus necessarily equal to the height traversed by the cage, with some surplus to keep the plunger steady within its guiding-pipe. The pipe or pump chamber has a length exceeding the maximum rise and fall of the plunger, and must be strong enough to sustain safely the heavy hydraulic pressures needed to raise plunger and cage with load. The power is usually supplied by a steam pump (occasionally by a hydraulic motor), which forces water into the chamber of the great pipe as the elevator rises, a waste-cock drawing off the liquid in the process of lowering the cage. A single handle within the cage generally serves to apply the pressure when raising, and to reduce it when lowering the load. When an ample supply of water can be commanded at the top of the hoist, a still simpler mechanism is available. The cable is supported from a pulley, and the cage, which is attached to one of its ends, is nearly balanced by a water tank attached to the other. When it is desired to raise the cage and its load, the water tank, which is then at the top, is filled with water until it becomes sufficiently heavy to overbalance the weight of the cage, when it falls by the force of gravity. To reverse the motion, water is withdrawn from the tank until it becomes lighter than the cage, which then descends by virtue of its superior weight. A suitable brake regulates the speed of the cage, whether rising or falling. The most common form of this class of elevator, for important work and under usual conditions of operation, as in cities, consists of a suspended cage, carried by a tackle, the running part of which is connected with a set of pulleys at each end of a frame (Fig. 2). The rope is made fast at one end, and its intermediate part is carried round first one pulley at the farther end of the frame and then round another at the nearer end, and so on as often as is found advisable in the particular case. The two pulley shafts carrying these two sets of pulleys are made to traverse the frame in such a way as, by their separation, to haul in on the running part, or, by their approximation, to permit the weight of the cage to haul out the rope. By this alternate hauling and "rendering" of the rope the cage is raised and lowered. The use of a number of parallel and independent sets of pulleys and tackles assures safety in case of the breakage of any one, each being strong enough alone to hold the load. The movement of the pair of pulley shafts is effected by a water-pressure engine, actuating the plunger of a pump which is similar to that used in the preceding apparatus, but being relatively of short stroke and large diameter, is more satisfactory in design and construction as well as in operation. This form of construction is the usual one for elevators employed in commercial work. A steam engine, however, or electric motor, may be directly attached to the system of pulleys. The majority of the existing elevators are constructed on such a plan, being denominated steam, hydraulic, or electric, according to the form of energy employed as the primary source of power.

Hydraulic elevators.

An account of the older hydraulic elevators having been given in *Ency. Brit.* (9th ed., vol. xiv. p. 575), it is the intention here to describe the later forms in common use, especially in the United States, where, owing to the erection of tall buildings and the general adoption of such machines in great warehouses, there has been much more rapid and more extensive development than in other countries, and where enterprise, sharp competition, and exceptional ingenuity on the part of both manufacturer and artisan have combined to evolve most ingenious and most efficient systems of general construction and details. The electric elevator, particularly in the cities, has undergone remarkable development, and the commencement of the 20th century finds it in by far the most extensive use; the older

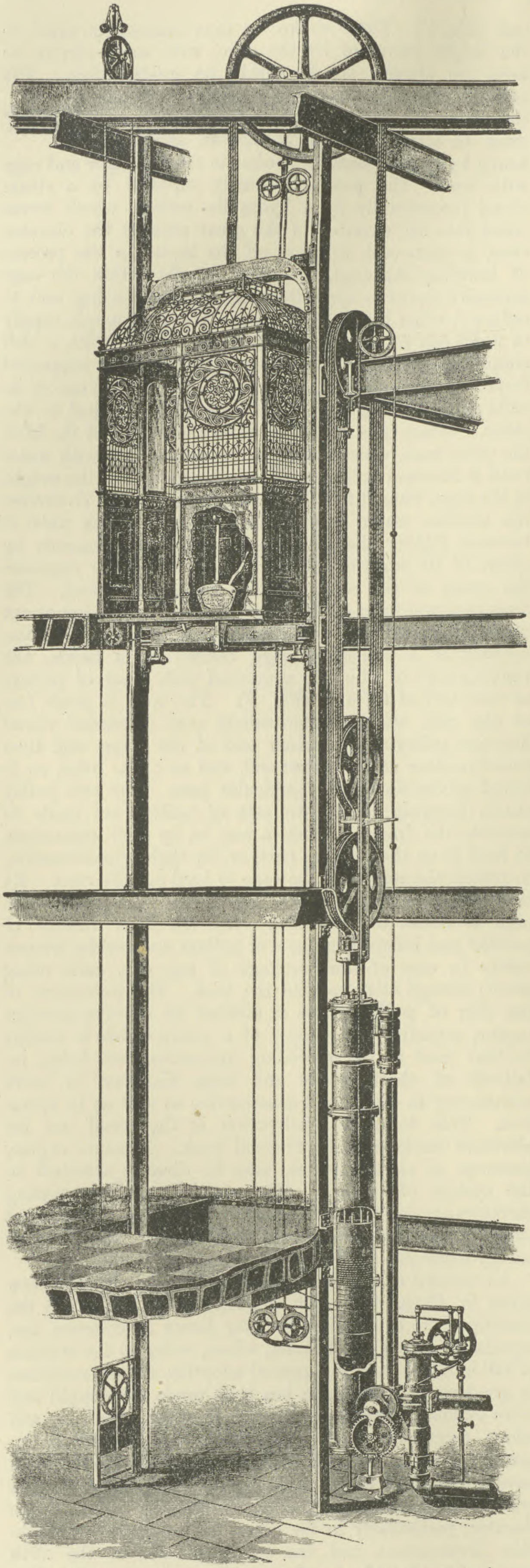


FIG. 2.—The Otis Standard Hydraulic Passenger Lift, with pilot valve and lever-operating device.

forms are rapidly disappearing, except in localities which offer special advantages for their employment. The history of the elevator is chronologically extensive, but only since 1850 has rapid or important progress been effected. In that year George H. Fox & Co. built an elevator operated by the motion of a vertical screw, the nut on which carried the cage. This device was used in a number of instances, especially in hotels in the large cities, during the succeeding twenty years, and was then generally supplanted by the hydraulic lift of the kind already described as the plunger-lift. With the increased demand for power, speed, safety, convenience of manipulation, and comfort in operation, the inventive ability of the engineer developed each of the known systems more and more perfectly, and experience gradually showed to what service each type was best adapted and the best construction of each for its peculiar work. Whatever the class, the following are the essentials of design, construction, and operation: the elevator must be safe, comfortable, speedy, and convenient; must not be too expensive in either first cost or maintenance, and must be absolutely trustworthy. It must not be liable to fracture of any element of the hoisting gear that will permit either the fall of the cage or its projection by an overweighted balance upwards against the top of its shaft. It must be possible to stop it, whether in regular working or in emergency, or when accident occurs, with sufficient promptness, yet without endangering life or property, or even very seriously inconveniencing the passengers. Acceleration and retardation in starting and stopping must be smooth and easy, the stop must be capable of being made precisely where and when intended, and no danger must be incurred by the passengers from contact with running parts of the mechanism or with the walls and doors of the elevator shaft.

Essentials of design, &c.

These requirements have been fully met in the later forms of elevator commonly employed for passenger service, and those designed for lifting heavy "freight" and merchandise have hardly less safety and trustworthiness. Usual sizes range from loads of 1000 to 5000 pounds, but special constructions are not infrequently called for which can take a loaded dray, weighing with its burden several tons, from the ground to the upper floors of high buildings at the rate of from 100 to 300 feet per minute. Capacities of 100,000 to 750,000 foot-pounds, speeds of from 80 to 250 feet a minute unloaded, and 75 to 200 feet loaded, are a standard, with a height of travel of from 50 to 200 feet. Where electric motors are employed, as now usual in cities where current can always be readily obtained, their speed ranges from 600 and 700 revolutions per minute in the larger to 1000 and 1200 in the smaller sizes, corresponding to from 20 down to 4 or 5 horse-power. Two or more counter-weights are employed, and from four to six suspension cables ensure as nearly as possible absolute safety. The electric elevators of the Central Electric Railway, London, are guaranteed to raise 17,000 pounds 65 feet, in some of its shafts, in 30 seconds from start to stop. Over 100,000 feet of $\frac{7}{8}$-inch and 17,000 feet of $\frac{3}{4}$-inch steel rope are required for its 24 shafts, and each rope carries from 16 to 22 tons without breaking. The steel used in the cables, of which there are four to six for each car and counter-weight, has a tenacity of 85 to 90 tons per square inch of section of wire. The maximum pull on each set of rope is assumed to be not over 9500 pounds, the remainder of the load being taken by the counter-balance. Oil "dash-pots" or buffers, into which enter plungers attached to the bottom of the cage, prevent too sudden a stop in case of accident, and safety-clutches with friction adjustments of ample power and fully tested before use give ample insurance against a fall even if all the cables should yield at once—an almost inconceivable contingency. The efficiency, *i.e.*, the ratio of work performed to power expended in the same time, was in these elevators found by test to be between 70 and 75 per cent.

Safety devices. Safety devices constitute perhaps the most important of the later improvements in elevator construction where passengers are carried. The simplest and, where practicable, most certain of them is the "air-cushion," a chamber into which the cage drops if detached or from any cause allowed to fall too rapidly to the bottom, compression of the air bringing it to rest without shock (Fig. 3). This chamber must be perfectly air-tight, except in so far as a purposely arranged clearance around the sides, diminishing downwards and in well-established proportion, is adjusted to permit a "dashpot" action and to prevent rebound. The air-cushion should be about one-tenth the depth of the elevator shaft; in high buildings it may be a well 20 or 30 feet deep. The Empire Building, in New York, is twenty storeys in height, and its air-cushion, at the bottom of 287 feet of travel of cage, is 50 feet deep, extending from the floor of the third storey to the bottom of the shaft. Sliding doors of great strength, and automatic in action, at the first and second floors, are the only openings. The shaft is tapered for some distance below the third floor, and then carried straight to the bottom. An inlet valve admits air freely as the cage rises, and an adjusted safety-valve provides against excess pressure. A "car," falling freely from the twentieth storey, was checked by this arrangement without injury to a basket of eggs placed on its floor, the weight being about 1 ton. The velocity of the fall attained a maximum at about 70 miles an hour, assuming retardation by friction to the extent of about 10 per cent. Other safety devices usually employed consist of catches under the floor of the cage, so arranged that they are held out of engagement by the pull on the cables. But if the strain is suddenly relieved, as by breakage of a cable or accident to the engine or motor, they instantly fly into place and, engaging strong side-struts in the shaft, hold the car until it can be once more lifted by its cables. These operate well when the cables part at or near the car, but they are apt to fail if the break occurs on the opposite side of the carrying sheaves at the top of the shaft, since the friction and inertia of the mass of the cables may in that case be sufficient to hold the pawls out of gear either entirely or until the headway is so great as to cause the smashing of all resistances when they do engage.

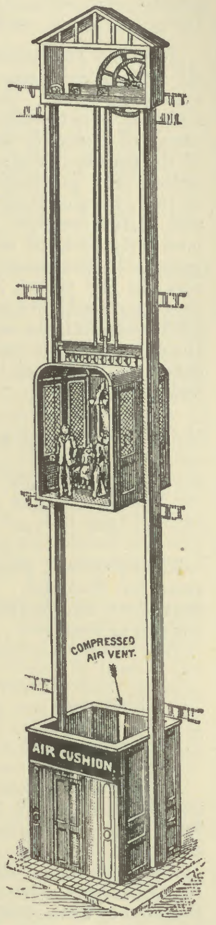


Fig. 3.—Safety Air-Cushion.

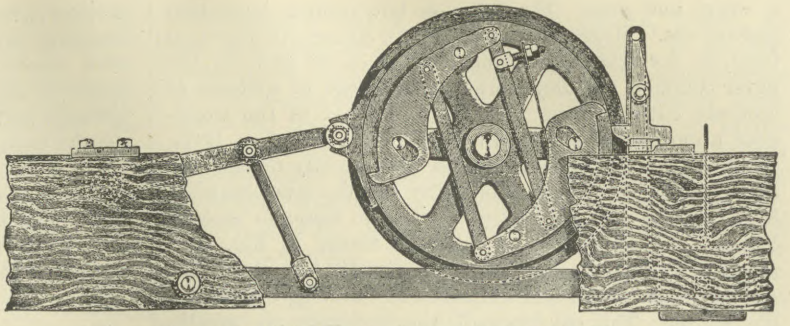


Fig. 4.—Centrifugal Elevator Governor (Stoke and Parish).

Another principle employed in safety arrangements is the action of inertia of parts properly formed and attached. Any dangerous acceleration of the cage causes the inertia of these parts to produce a retardation relative to the car which throws into action a brake or a catch, and thus controls the motion within safe limits or breaks the fall, entirely without injury. The hydraulic brake has been used in this apparatus, as have mechanical and pneumatic apparatus. This control of the speed of fall is most commonly secured by the employment of a centrifugal or other governor or regulator (Fig. 4). The governor may be on the top of the cage and driven by a stationary rope fixed between the upper and the lower ends of the shafts, or it may be placed at the top of the shaft and driven by a rope travelling with the car. Its action is usually to trip into service a set of spring grips or friction clutches, which, as a rule, grasp the guides of the cage and by their immense pressure and great resultant friction bring the cage to rest within a safe limit of speed, time, and distance. A coefficient of friction of about 15 per cent. is assumed in their design, and this estimate is confirmed by their operation. Pressures of 10 tons or more are sometimes provided in these grips to ensure the friction required. There are many different forms of safety device of these various classes, each maker having his own. The importance of absolute safety against a fall is so great that the best builders are not satisfied with any one form or principle, but combine provisions against every known danger, and often duplicate such precautions against the most common accidents.

The hoisting cables are handled by means of a winding drum driven by steam, electric, or other motor. Most commonly a system of gearing is arranged between the motor and the drum to accommodate the normal speeds of the two each to the other. This intermediate gearing consists of either a series of "spur" gears and pinions, or

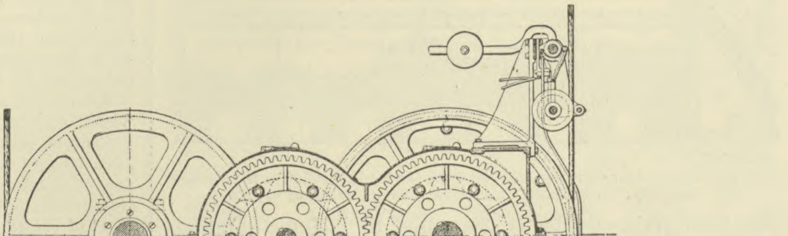


Fig. 5.—Sprague Worm-Gear.

a worm and gear. The latter is now coming more into general use. Recent improvements in construction and in form, as, for example, the introduction of the now old but never common Hindley worm, and the use of systems of accurate cutting, have made the efficiency of the worm-gear approximate closely to that of the spur-gear train, while the cost of construction has been greatly reduced by its employment, and the complexity and the space required have also been much lessened. In the Sprague electric elevator (the worm-gear of which is shown in Fig. 5) a motor of suitable design is coupled directly to a screw, the nut of which carries and displaces the moving sheaves of the cables. The efficiency of the apparatus is greatly

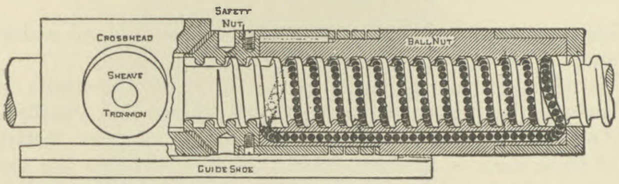


Fig. 6.—Multiple sheave type—hoisting nut at upper end of screw.

increased by the use of a ball-bearing system between the thread of the screw and that of the nut (Fig. 6).

The "Travelling Staircase" may be classed among the passenger elevators, as may be the "Travelling Platform or Sidewalk" among the "conveyors." It usually consists of a staircase so constructed that while the passenger is ascending it the whole structure is also ascending at a predetermined rate, so that the progress made is the sum of the two rates of motion. The system of "treads and risers" is carried on a long endless band of chain sustained by guides holding it in its desired line, and rendering at either end over cylinders or sprockets. The junctions between the stairway and the upper or lower floors are ingeniously arranged so as to avoid danger of injury to the passengers.

"Freight" elevators have the same general forms as the passenger elevators, but are often vastly larger and more powerful, and are not as a rule fitted up for such heights of lift, or constructed with such elaborate provision for safety or with any special finish. They are simple, strong, and durable, and should be economical in operation. Elevators raising grain, coal, earth, and similar materials, such as can be taken up by scooping into a bucket, or can be run into and out of the bucket by gravity, constitute a class by themselves, and entirely differ in construction from those just described. A set of buckets of suitable form and dimensions is fitted upon some kind of flexible carrying arrangement extending from the point of reception of the grain, fuel, or other material, to the point of delivery, with provisions for loading the bucket at the one end and discharging it at the other (Fig. 7).

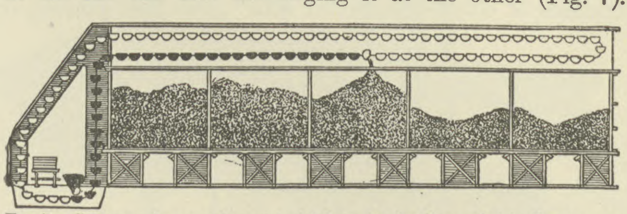


Fig. 7.—Conveyor for carrying material from the loading point to the storage bins, vertically, horizontally, or inclined, without shock or breakage.

The term grain elevator is often used to include buildings as well as machinery, and it is not unusual in Europe to hear a flour-mill, with its system of motor machinery, mills, elevator, and storage departments, spoken of as an "American elevator." The "conveyor" or bucket-chain elevator is very extensively employed where, as in transferring coal from point to point for the supply of large batteries of boilers or in excavating earthwork on large contracts, the path to be traversed has a variable direction in either a vertical or a horizontal plane, or in both. The flexibility of the system adapts it to such cases, and it often constitutes part, in this manner, of an extensive system of transportation of such materials. It is also the operative part of the apparatus often employed for dredging, the buckets acting also as scoops and taking the earth from the bottom of the channel and conveying it to the point of discharge. The bucket-and-chain dredge is sometimes built upon a large scale, as for the deepening of harbours or the cutting of canals, and somewhat similar mechanism is employed in the making of railway cuttings.

(R. H. T.)

Elgin, or Morayshire, a maritime county of North Scotland, bounded on the N. by the Moray Firth, on the E. and S.E. by Banffshire, on the S. and S.W. by Inverness-shire, and on the W. by Nairnshire.

Area and Population.—In 1891 the parish of Bellie and nearly all Rothes were placed in Elgin, and Boharm and Inveravon wholly in Banff; the Nairn portions of Dyke and Moy and Ardclach were transferred to Elgin; and the Elgin portion of the parish of Cromdale was constituted a parish of itself. The area of the county (foreshore excluded) is 308,499 acres, or 482 square miles. The population was, in 1881, 43,788; in 1891, 43,453; in 1891, on the above area, 43,471, of whom 20,368 were males and 23,103 females; in 1901, 44,808. On the old area, taking land only (304,606 acres or 475·9 square miles), the number of persons to the square mile in 1891 was 91, and the number of acres to the person 7·0. In the registration county the population decreased between 1881 and 1891 by 0·8 per cent. Between 1881 and 1891 the excess of births over deaths was 5925, and the decrease of the resident population 367. The following table gives particulars of births, deaths, and marriages in 1880, 1890, and 1899:—

Year.	Deaths.	Marriages.	Births.	Percentage of Illegitimate.
1880	812	274	1391	16·8
1890	818	233	1237	12·69
1899	760	270	1179	12·6

The birth-rate, death-rate, and marriage-rate are all below the rates for Scotland. The following table gives the birth-rate, death-rate, and marriage-rate per thousand of the population for a series of years:—

	1880.	1881–90.	1890.	1891–98.	1899.
Birth-rate . .	30·86	30·23	27·58	27·79	27·54
Death-rate . .	18·02	17·06	18·23	17·12	17·78
Marriage-rate .	6·08	5·52	5·19	6·02	6·31

In 1891 the number of Gaelic-speaking persons in the county was 2262, of whom 12 spoke Gaelic only; and there were 24 foreigners. The valuation in 1889–90 was £181,296; 1899–1900, £188,911.

Administration.—The county returns a member to Parliament in conjunction with Nairnshire. The royal burghs are Elgin, the county town (8407), and Forres (4313), the former belonging to the Elgin parliamentary group and the latter to the Inverness group. Lossiemouth (3889) is the largest police burgh. There are 19 civil parishes, 14 of which belong to the Morayshire Combination. The number of paupers and dependants in September 1899 was 1489. Elgin is included in one sheriffdom with Inverness and Nairn, and there is a resident sheriff-substitute at Elgin.

Education.—Twenty-one school boards manage 45 schools, which had in 1898–99 an average attendance of 6674; and 8 voluntary schools (one Episcopal and one Roman Catholic) had 766. There are academies at Elgin and Fochabers (Milne's Institution), and science and art and technical schools at Elgin and Grantown, and twelve other schools in the county earned grants in 1898 for giving higher education. The bulk of the "residue" grant is spent in subsidizing the agricultural department of Aberdeen University, the science schools at Elgin and Grantown, Milne's Institution, and science and art and technical classes elsewhere in the county.

Agriculture.—There has been a good deal of "improving" agriculture in Elgin of recent years, and the standard of farming is generally high. Of 1907 holdings in 1895, the average size was 53 acres. The percentage under 5 acres was 23·39, between 5 and 50 acres 44·05, and over 50 acres 32·56. The number of farms between 50 and 100 acres was 299; between 100 and

300, 282; between 300 and 500, 35; and over 500, 5. The percentage of cultivation was 32·9 in 1898. Heavy crops of barley are grown in the Laigh of Moray, and the barley acreage approximates more nearly to the oat acreage than in any other county except Haddington. In 1895 there were 46,688 acres under wood, 1936 having been planted since 1881. The following table gives the principal acreages at intervals of five years from 1880 :—

Year.	Area under Crops.	Corn Crops.	Green Crops.	Clover.	Permanent Pasture.	Fallow.
1880	104,992	40,192	20,410	39,264	4973	153
1885	106,004	40,551	19,738	39,709	5920	86
1890	102,738	39,034	18,786	39,257	5465	137
1895	101,758	36,922	17,996	37,343	9378	91
1899	101,689	36,497	17,793	38,964	8373	44

The following table gives particulars of the live-stock during the same years :—

Year.	Total Horses.	Total Cattle.	Cows or Heifers in Milk or Calf.	Sheep.	Pigs.
1880	5186	23,031	6832	52,202	2667
1885	5060	23,572	7285	60,364	3116
1890	4810	21,536	6571	55,957	3391
1895	5211	21,489	6197	61,802	2771
1899	4957	22,296	6895	72,514	2472

At the census of 1891, 4404 men and 450 women were returned as being engaged in agriculture.

Industries and Trade.—Distilling is the leading industry, there being as many as 15 distilleries in the county. There are woollen mills at Elgin and other places, and chemical works at Forres and Burghead. Extensions have been made in the harbours of Burghead (£60,000) and Hopeman (£20,000). Timber, fish, agricultural produce, and whisky are the principal articles of export, and coal and the raw materials for the chemical works are imported. Fishing is a considerable industry. To the four Morayshire ports there belonged, in 1899, 321 boats of 5429 tons, and 1004 resident fishermen and boys, and the value of the fish landed (about half herrings) was £32,575. The chief changes of recent years have been the decrease in the number of men and boys engaged, and the increase in the value of the boats and gear.

At the census of 1891, 4558 men and 1242 women were returned as being engaged in industrial pursuits. There are valuable sandstone quarries in the county; 28,348 tons of £5645 value were raised in 1895, and 37,124 tons of £8335 value in 1899. The average weight of the salmon despatched from the Spey, Lossie, and Findhorn district in the years 1894–98 was 485 tons. The railway mileage of the county was increased by 15 miles between 1875 and 1900, the longest of the new lines being one from Elgin to Garmouth (8⅝ miles).

AUTHORITIES.—R. YOUNG. *Annals of the Parish and Burgh of Elgin.* Elgin, 1879. *The Parish of Spynie.* Elgin, 1871.—LACHLAN SHAW. *History of the Province of Moray* (Gordon's edition). Glasgow, 1882.—E. DUNBAR DUNBAR. *Documents relating to the Province of Moray.* Edinburgh, 1895. *Social Life in Former Days.* Edinburgh, 1865 and 1866.—C. A. GORDON. *History of the House of Gordon.* Aberdeen, 1890.—*An Account of the Family of Innes.* (Spalding Club) 1864.—C. RAMPINI. *History of Moray and Nairn.* Edinburgh, 1897.—W. CRAMOND. *Life in Elgin 350 years ago.* Elgin, 1896.—C. INNES. *Elgin Past and Present.* Elgin, 1860.—J. COOPER. "Church and Convent of the Greyfriars" (*Trans. of the Aberdeen Eccles. Soc.*). 1890.—C. CORDIER. *Antiquities and Scenery of the North of Scotland.* Banff, 1880.—J. MACDONALD. "Burghead" (*Proceedings of Glasgow Archæo. Soc.*). 1891.—Sir T. DICK LAUDER. *The Wolf of Badenoch.* Glasgow, 1886.—M. MACDONALD. *Covenanters in Moray and Ross.* Inverness, 1892.—G. GORDON. *Flora of Moray.* Elgin, 1893. *Fauna of Moray.* Elgin, 1895.—HARVIE-BROWN and BUCKLEY. *Vertebrate Fauna of Scotland.* Edinburgh, 1896.—J. WATSON. *Some Local Wild Birds.* Elgin, 1889.

(W. WA.)

Elgin, a city, royal and parliamentary burgh (Elgin group), and county town of Elgin, Scotland, 71¼ miles by rail north-west by west of Aberdeen. Modern structures include a new town-hall, public baths, a new academy, and the Victoria School of Science and Art. Lossie Green recreation ground was extended in 1888. Population of royal burgh (1881), 6286; (1901), 8260.

Elgin, a city of Kane county, Illinois, U.S.A., on the Fox river, at an altitude of 716 feet. It has fine water-power in the river. Amongst its large manufacturing interests is the Elgin watch factory, the products of which are widely known. One of the state hospitals for insane is situated here. Elgin is on branches of the Chicago and North-Western and the Chicago, Milwaukee, and St Paul Railways. Population (1880), 8787; (1890), 17,823; (1900), 22,433, of whom 5419 were foreign-born and 187 were negroes.

Elgon Mount, also known as Masawa, an extinct volcano in British East Africa, cut by 1° N. and 34½° E., forming a vast isolated mass over 40 miles in diameter. The outer slopes are in great measure precipitous on the north, west, and south, but fall more gradually to the east. The southern cliffs are remarkable for extensive caves, which have the appearance of water-worn caves on a coast-line and have for ages served as habitations for the natives. The higher parts slope gradually upwards to the rim of an old crater, lying somewhat north of the centre of the mass, and measuring some 8 miles in diameter. The highest point of the rim is about 14,100 feet above the sea. Steep spurs separated by narrow ravines run out from the mountain, affording the most picturesque scenery. The ravines are traversed by a great number of streams, which flow north-west and west to the Nile (through Lake Choga), south and south-east to Victoria Nyanza, and north-east to Lake Rudolf by the Turkwell, the head-stream of which rises within the crater, breaking through a deep cleft in its rim. To the north-west of the mountain a grassy plain, swampy in the rains, falls towards the chain of lakes ending in Choga; towards the north-east the country becomes more arid, while towards the south it is well wooded. The outer slopes are clothed in their upper regions with dense forest formed in part of bamboos, especially towards the south and west, in which directions the rainfall is greater than elsewhere. The lower slopes are exceptionally fertile on the west, and produce bananas in abundance. On the north-west and north the region between 6000 and 7000 feet possesses a delightful climate, and is well watered by streams of icy-cold water. The district of Save on the north is a halting-place for Arab and Swahili caravans going north. On the west the slopes are densely inhabited by small Bantu tribes, who style their country Masawa (whence the alternative name for the mountain); but on the south and north there are tribes which seem akin to the Gallas. Of these, the best known are the El-gonyi, from whom the name Elgon has been derived. They formerly lived almost entirely in the caves, but with the establishment of order most of them have descended to villages at the foot of the mountain. Elgon was first visited in 1883 by Joseph Thomson, who brought to light the cave-dwellings on the southern face. It was crossed from north to south, and its crater reached, in 1890 by Messrs Jackson and Gedge, while the first journey round it was made by Mr C. W. Hobley in 1896.

See *Proceedings R. G. S. 1891*, p. 202; *Geog. Journ.* vol. ix. (1897), pp. 178–185; *Ibid.*, vol. xiv. p. 133. (E. HE.)

Eliot, Charles William (1834–——), president of Harvard University, U.S.A., was born in Boston, Mass., on the 20th of March 1834. He was the only son of Samuel Atkins Eliot, mayor of Boston, representative in Congress, and treasurer of Harvard College from 1842 to 1853. He attended the Latin School of Boston, and received the degree of B.A. from Harvard College in 1853. The next year he was made tutor in mathematics, and also studied chemistry. In 1857 he gave a course of lectures in chemistry in the medical college of the University, and in 1858 he was made assistant professor of mathematics and chemistry. In 1861 he was put in charge of the chemical department of Lawrence Scientific School. Two years later he went to Europe, where he spent two years in studying chemistry and the educational systems of England, France, and Germany. In 1865 he was appointed professor of analytical chemistry in the newly established Massachusetts Institute of Technology. This chair he held for four years, but in 1867–68 he was in Europe for fourteen months. In 1869 he was chosen president of Harvard University. President Eliot has laboured for increasing the unity of the educational system of the United States, for promoting the spirit of free inquiry on the part of teachers and of unrestricted choice of studies on the part of students, and for making available to the community, under wise conditions, all the resources of the university. The result has been the establishment at Harvard of a free optional system of studies, the advancement of professional and technical education, and other developments, which have given to Harvard a position in American education which it had not previously enjoyed. The university funds have increased from two and a quarter millions of dollars to twelve millions of dollars. A vast amount of money has been devoted to the erection of buildings and to the equipment of laboratories and libraries. The students have increased from about a thousand to about five thousand, and the tutorial staff from a hundred and fifty to five hundred. He has written two manuals of chemistry in collaboration with Professor F. H. Storer, and has published a few volumes of essays, largely upon educational or related subjects.

Eliot, George. See CROSS, M. A.

Elisabethgrad, or ELIZAVETGRAD, a fortress and district town of Russia, government and 152 miles north of Kherson, on Balta Kremenchug Railway, on the Ingul. It is a wealthy town, which has become an industrial centre for the region, especially on acount of its steam flour-mills, in which it is second only to Odessa, distilleries, mechanical works, &c., the aggregate annual produce of which exceeds £500,000. It is also a great centre for trade in corn and flour for export, and also in sheep, cattle, wool, leather, and timber. Five fairs are held annually. It has several gymnasia, a military school, a first-class meteorological station, and a spacious botanical garden. The population increased from 23,725 in 1860 to 61,841 in 1897.

Elisabethpol, a government of Russia, Transcaucasia, having Tiflis, Zakataly, and Daghestan on the N., Baku on the E., Persia on the S., and Erivan on the W. Area, 16,721 square miles. This vast government includes: (*a*) the southern slope of the main Caucasus range in the north-east, where the Tkhfan-dagh (13,764 ft.), Bazardyuz (14,722 ft.), and other peaks rise above the snowline; (*b*) the dry and unproductive steppes on the Kura, reaching 1000 ft. of altitude in the west and from 100 to 200 ft. only in the east, where irrigation is necessary for culture; and (*c*) the northern slopes of the Transcaucasian escarpment and portions of the Armenian plateau, which is intersected towards its western boundary, near Lake Gokcha, by chains of mountains consisting of trachytes and various crystalline rocks, and reaching from 11,000 to 12,856 ft. in Mount Kapudjikh. Elsewhere the country has the character of a plateau, 7000 to 8000 ft. high, deeply ravined by the tributaries of the Aras. All varieties of climate are found in this province, from the snowclad peaks, Alpine meadows, and stony deserts of the high levels, to the hill slopes, clothed with gardens and vineyards, and the dry Caspian steppes. Thus, at Shusha, on the plateau, at an altitude of 1368 ft., the average temperatures are: year 48°, January 26°, July 66°; yearly rainfall, 26·4 in.; while at Elisabethpol, in the valley of the Kura, they are: year 55°, January 32°·2, July 77°, and rainfall only 10·3 in. Nearly one-fifth of the surface is under forests.

The population, which was 871,557 in 1897 (only 392,124 women; 84,130 urban), consists chiefly of Azerbaijan Tatars (56 per cent.) and Armenians (35 per cent.). The remainder are Kurds (4·7 per cent.), Russians (a little over 1 per cent.), and a few Udines, Tates, &c. Peasants form the great bulk of the population, nearly two-thirds of them living on Crown lands, and the remainder on land belonging to landlords. Some of the Tatars and the Kurds still are nomadic. Wheat, Indian corn, barley, oats, and rye are grown, and the crops are estimated at 1,787,100 quarters of various cereals and 158,400 quarters of rice. Cultivation of the cotton tree has begun, but the rearing of silkworms is of old standing, especially at Nukha (32,700 cwts. of cocoons on the average are obtained every year). Nearly 8000 acres are under vine. Gardening reaches a high level of perfection. Liquorice root is obtained to the extent of about 700,000 cwts. The rearing of live-stock is largely carried on in the steppes, there being about 76,140 horses, 464,000 horned cattle, and 1,157,000 sheep. Copper (37,000 cwts.), some magnetic iron ore, cobalt ore, and a small quantity of naphtha are extracted, and nearly 9300 persons are employed in the 2200 factories and workshops. Carpet-weaving is widely spread. Owing to the Transcaucasian Railway, which crosses the province, trade, both in the interior and with Persia, is very brisk. The government is divided into 8 districts: Elisabethpol, Aresh, Jebrail, Jevanshir, Kazakh, Nukha, Shusha, and Zanglzur. The only towns, besides the capital, are Nukha (24,811 inhabitants) and Shusha (25,656).

Elisabethpol, formerly GANJA, capital of the above government, 120 miles by rail south-east of Tiflis and 3 miles from the railway. It is a very old town, which changed hands between Persians, Khozars, and Arabs even in the 7th century, and later fell into the possession of Mongols, Georgians, Persians, and Turks, until the Russians took it in 1796, and finally annexed it in 1813. It is situated in a very unhealthy locality, but has been much improved lately, a new European quarter having been built on the site of the old fortress. Population (1897), 20,706. Its inhabitants are chiefly Tatars and Armenians, famed for their excellent gardening, and also for silkworm breeding. It has a beautiful mosque, built in 1620, and a renowned "Green Mosque" amidst the ruins of old Ganja. The Persian poet Sheikh Nizam (Nizameddin) is said to have been buried close to the town.

Elizabeth, queen of Rumania ("Carmen Sylva"). See CHARLES I., king of Rumania.

Elizabeth, capital of Union county, New Jersey, U.S.A., in 40° 40′ N. lat. and 74° 13′ W. long., on Newark Bay. Its site is level, its plan regular, and it is divided into twelve wards. Its water supply is pumped from Ursine Lake. It is entered by the Pennsylvania, the Central of New Jersey, and the Lehigh Valley Railways. Though to a certain extent a residential city for business men in New York, it has commercial and manufacturing interests of its own. In 1890 the capital invested in manufactures was $7,785,553, employing 6561 persons, and turning out goods valued at $10,489,364. The principal productions were foundry and machine-shop articles, valued at about one-seventh of all the manufactures. In 1900 the assessed valuation of real and personal property was $17,492,021, the net debt $3,207,835, and the rate of taxation $29.60 per $1000. Population (1880), 28,229; (1890), 37,764; (1900), 52,130, of whom 14,770 were foreign-born and 1139 were negroes. The death-rate in 1900 was 17·5.

Elizabeth City, capital of Pasquotank county, North Carolina, U.S.A., situated on Pasquotank river and the Norfolk and Southern Railway. Being in a forest region, its industries consist largely of lumber trade and manufactures; it contains several saw and shingle mills. Population (1880), 2315; (1890), 3251; (1900), 6348, of whom 44 were foreign-born and 3164 were negroes.

Elkhart, a city of Elkhart county, Indiana, U.S.A., on the St Joseph river, at an altitude of 725 feet. It is on two railways, the Lake Shore and Michigan Southern, (the repair shops of which are here), and the Cleveland, Cincinnati, Chicago, and St Louis. It has varied manufactures. Population (1880), 6953; (1890), 11,360; (1900), 15,184, of whom 1353 were foreign-born and 35 were negroes.

Elland, a town and urban district in the Elland parliamentary division of Yorkshire, England, on the Calder, 2½ miles south of Halifax by rail. There are two endowed schools, a public recreation ground, a church house, and a town-hall and public baths. Cotton-mills, woollen factories, ironworks, flagstone quarries, and fire-clay works supply industries. Area of urban district, 1992 acres. Population (1901), 10,412.

Ellice, or LAGOON, a Polynesian archipelago, in about 9° S., nearly midway between Fiji and Gilbert, and some 700 miles north-west of Samoa. It comprises a large number of low coralline islands and atolls, which are disposed in nine clusters extending over a distance of 360 miles in the direction from north-west to south-east. Their total area is 14 square miles, and in 1900 the population was 2400. The chief groups, all yielding cocoanuts, pandanus fruit and yams, are Funafuti, Sophia (Rocky Island), Nui, Nukufetau, Vaitupu, Netherland, and Lynx. Nearly all the natives are Christians, Protestant missions having been long established in several of the islands. Those of Nui speak the language of the Gilbert Islanders, and have a tradition that they came some generations ago from that group. All the others are of Samoan speech, and their tradition that they came thirty generations back from Samoa is supported by recent research. The soundings taken at Funafuti in 1897 indicate almost beyond doubt that the whole of this Polynesian region is an area of comparatively recent subsidence.

Ellichpur, or ILICHPUR, a town and district of India, in Berar or the Haidarabad Assigned Districts. The town is on the left bank of the river Bichan. The population is about 36,000. The cantonment accommodates a battery of artillery and an infantry regiment, both of the Haidarabad Contingent. There are two steam factories for ginning cotton. The DISTRICT OF ELLICHPUR has an area of 2623 square miles, and had a population in 1881 of 313,805, and in 1901 of 295,392, the decrease being due to the famine of 1899–1900. The land revenue and rates were Rs.9,53,383, the incidence of assessment being R.1–10–4 per acre; the cultivated area in 1897–98 was 608,048 acres, of which 2971 were irrigated from wells; the number of police was 367; the death-rate in 1897 was 58·6 per 1000. There is no railway, but cotton is largely exported from Amraoti.

Ellis, Robinson (1834– ——), English classical scholar, was born at Barming, near Maidstone, on 5th September 1834. He was educated at Elizabeth College, Guernsey, Rugby, and Balliol. In 1858 he became fellow of Trinity College, Oxford. In 1870 he was appointed to the professorship of Latin at University College, London, but in 1876 he returned to Oxford, where from 1883 to 1893 he held the University readership in Latin. In 1893 he succeeded Henry Nettleship as professor. As early as 1859 he had turned his attention to Catullus, an author at that time much neglected by scholars both at home and abroad. His first *Commentary on Catullus* was published in 1876. It aroused great interest, and called forth a flood of Catullian literature and criticism. In 1889 appeared a second and enlarged edition, which summed up the results of thirty years' work and definitely placed its author in the first rank of authorities on Catullus. Professor Ellis quotes largely from the early Italian commentators, maintaining that the land where the Renaissance originated had done more for exact scholarship than was commonly recognized. He has supplemented his critical work by a translation of the poems in the metres of the originals. These were dedicated to Tennyson, whose alcaics and hendecasyllabics had paved the way for an experiment of this character. In the introduction he points out the necessity of observing the laws of position as well as accent in determining quantity. Another author to whom Robinson Ellis has devoted many years' study is Manilius, the astrological poet, whom Scaliger and Bentley edited and Goethe read and quoted, but who had fallen into complete neglect in an age which took a somewhat narrow view of the scope of classical scholarship. Manilius first engaged Mr Ellis's attention in 1862, but it was only in 1891 he published his *Noctes Manilianæ*, a series of dissertations on the *Astronomica*, with a number of happy emendations which will help to pave the way for a revised text of Manilius. Other less known writers with whom Robinson Ellis has dealt are Avianus, Velleius Paterculus, and the Christian poet Orientius, whom he edited for the Vienna Corpus Scriptorum Ecclesiasticorum. He has also edited the *Ibis* of Ovid, and contributed to the *Anecdota Oxoniensia* various unedited materials drawn from manuscripts in the Bodleian and other libraries.

Ellore, a town in British India, in the Godavari district of Madras, on the East Coast Railway, 303 miles from Madras. Population, about 28,000. The two canal systems of the Godavari and the Kistna deltas meet here. There are manufactures of cotton and saltpetre; a high school, with 214 pupils in 1896–97; and two printing-presses.

Elmira, capital of Chemung county, New York, U.S.A., in 42° 05′ N. lat. and 76° 50′ W. long., on the Chemung river, at an altitude of 863 feet. It is on four railways, the Delaware, Lackawanna, and Western, the Erie, the Lehigh Valley, and the Northern Central (a part of the Pennsylvania system). It contains the carriage works of the Erie Railway. Its manufactures had in 1890 an invested capital of $6,895,180, employed 5171 hands, and the products were valued at $8,844,936. These were varied, consisting in part of boots and shoes, flour, iron and steel goods, and lumber. Elmira College, which is situated here, is a Presbyterian institution, with, in 1900, 24 instructors and 237 students, all women, although the college is nominally for both sexes. The celebrated Elmira Reformatory for criminals is also here (see PRISON DISCIPLINE). The assessed valuation of real and personal property in 1900 was $17,615,158, the net debt of the city was $1,085,202, and the rate of taxation $24 per $1000. Population (1880), 20,541; (1890), 30,893; (1900), 35,672, of whom 5511 were foreign-born and 803 were negroes. The death-rate in 1900 was 15·4.

Elmshorn, a town of Prussia, province of Schleswig-Holstein, 19 miles by rail north-west from Altona. Amongst its chief industries are tanneries, breweries, linen and cotton mills, and shipbuilding yards. Population (1885), 8712; (1900), 13,640.

El Paso, capital of El Paso county, Texas, U.S.A., in 31° 45′ N. lat. and 106° 29′ W. long., on the east bank of the Rio Grande, at an altitude of 3710 feet. It is regularly laid out on the level bottom lands, stretching to the slopes on the east. Opposite, on the west bank of the river, is the Mexican town of Ciudad Juarez, with which El Paso is connected by bridges and by horse and steam trams. The city is entered by five railways, the Texas and Pacific, from the east; the Southern Pacific, which passes through it; the Atchison, Topeka, and Santa Fé, from the north; the Mexican Central, from Mexico; and the El Paso and North-Eastern. Its situation on the Mexican frontier gives it a large trade with that country. There are also extensive manufactures, including smelting works, to which are brought ores for treatment from Northern Mexico and Arizona. Population (1880), 736; (1890), 10,338; (1900), 15,906, of whom 6309 were foreign-born and 466 were negroes. A large proportion of the inhabitants are of Mexican descent.

Elreno, capital of Canadian county, Oklahoma, U.S.A., in 35° 32′ N. lat. and 97° 57′ W. long., on the north fork of Canadian river, at an altitude of 1372 feet. Its situation is on the level bottom lands, and the street plan is regular. It has two railways, a branch of the Chicago, Rock Island, and Pacific, and the Choctaw, Oklahoma, and Gulf. Near it is the military post of Fort Reno. Population (1890), 285; (1900), 3383, of whom 165 were foreign-born and 223 were negroes.

Elsinore (Danish, *Helsingör*), a seaport town of Denmark, co. Frederiksborg, on the west shore of the Sound, 28 miles by rail north from Copenhagen. Communication is maintained with Helsingborg by means of a steam ferry. Elsinore has shipbuilding yards, with foundry, engineering shops, &c.; it exports agricultural produce and imports iron, coal, cereals, and yarn. The port was entered by 899 vessels of 116,541 tons in 1899, and cleared by 918 of 127,040 tons. Population (1880), 8968; (1890), 11,076; (1900), 13,902.

Elssler, Fanny (1810–1884), the famous dancer, was born in Vienna on the 23rd of June 1810. From her earliest years she was trained for the ballet, and made her appearance at the Kärnther-Thor theatre in Vienna before she was seven. She almost invariably danced with her sister THERESA, who was two years her senior; and, after some years' experience together in Vienna, the two went in 1827 to Naples. Their success there (to which Fanny contributed more largely than her sister, who used to efface herself in order to heighten the effect of Fanny's more brilliant powers) led to an engagement in Berlin in 1830. This was the beginning of a series of triumphs for Fanny's personal beauty and skill in dancing. After captivating all hearts in Berlin and Vienna, she paid a visit to London, where she received much kindness at the hands of Mr and Mrs Grote, who practically adopted the little girl who was born three months after Fanny's arrival in England. This kind-hearted action subsequently cost them much distress of mind, but they eventually succeeded in removing the child from the atmosphere in which her mother lived. In September 1834 Fanny Elssler appeared at the Opera in Paris, a step to which she looked forward with much misgiving on account of Taglioni's supremacy on that stage. The result, however, was another triumph for Fanny Elssler, and the temporary eclipse of Taglioni, who, although the finer artist of the two, could not for the moment compete with the newcomer's personal fascination. It was conspicuously in her performance of the Spanish *cachuca* that Fanny Elssler outshone all rivals. In 1840 she sailed with her sister for New York, and after two years' unmixed success they returned to Europe, where during the following five years Fanny appeared in Germany, Austria, France, England, and Russia. In 1845, having amassed a large fortune, she retired from the stage and settled near Hamburg. A few years later her sister Theresa contracted a morganatic marriage with Prince Adalbert of Prussia, and was ennobled under the title of Baroness von Barnim. Fanny Elssler died at Vienna on the 27th of November 1884. Theresa was left a widow in 1873, and died at Meran, 19th November 1878. (R. F. S.)

Elster, the name of two rivers of Germany. 1. The Schwarze (Black) Elster rises in the Lausitz Mts., on the southern border of Saxony, flows north and north-west, and after a course of 112 miles enters the Elbe a little above Wittenberg. It is a sluggish stream, battling its way through sandy soil and frequently along a divided channel. 2. The Weisse (White) Elster rises in the north-western corner of Bohemia, a little north of Eger, cuts through the Vogtland in a deep and picturesque valley, passing Plauen, Greiz, Gera, and Zeitz on its way north to Leipzig, just below which city it receives its most important tributary, the Pleisse. At Leipzig it divides, the main stream turning north-west and entering the Saale from the right a little above Halle; the other arm, the Luppe, flowing parallel to the main stream and south of it, enters the Saale below Merseburg. Total length, 121 miles; total descent, 1286 feet.

Elswick. See NEWCASTLE-ON-TYNE.

Elvas, a city, episcopal see, and first-class fortress of Portugal, district Portalegre, 4½ miles from the right bank of the river Guadiana and 33 south-south-east from Portalegre. It is celebrated for its olives and its plums, the last named being exported, both fresh and dried, in large quantities. It also has distilleries and potteries. Population, about 13,000.

Elvey, Sir George Job (1816–1893), English organist and composer, was born at Canterbury on 27th March 1816. He was a chorister at Canterbury Cathedral under Highmore Skeats, the organist. Subsequently he became a pupil of his elder brother, Stephen, and then studied at the Royal Academy of Music under Cipriani Potter and Dr Crotch. In 1834 he gained the Gresham Prize Medal for an anthem, and in 1835 was appointed organist of St George's Chapel, Windsor, a post he filled for 47 years, retiring in 1882. He took the degree of Mus.B. at Oxford in 1838, and in 1840 that of Mus.D. Anthems of his were commissioned for the Three Choirs Festivals of 1853 and 1857, and in 1871 he received the honour of knighthood. He died at Windlesham in Surrey on 9th December 1893. His works, which are nearly all for the Church, include two oratorios, a great number of anthems and services, and some pieces for the organ. A memoir of him, by his widow, was published in 1894.

Elwood, a town of Madison county, Indiana, U.S.A., on Duck creek, at an altitude of 862 feet. It is on the Lake Erie and Western and the Pittsburg, Cincinnati, Chicago, and St Louis Railways. Population (1880), 751; (1890), 2284; (1900), 12,950, of whom 1386 were foreign-born.

Ely, a city and market-town in the Newmarket parliamentary division of Cambridgeshire, England, on the Ouse, 15 miles by rail north-north-east of Cambridge. The restoration of the cathedral was continued until 1884, when nearly £80,000 had been expended. Recent erections are two Established churches, a theological college, and a Roman Catholic chapel. The grammar school now occupies the room over the ancient archway to the monastery of which there are some remains; the chapel built by Prior John of Crandene has been restored and is used as a school chapel. Fruit growing and preserving are carried on. The water supply from the chalk is excellent. Area of urban district, 16,738 acres. Population (1881), 8177; (1891), 8017; (1901), 7713.

Elyria, capital of Lorain county, Ohio, U.S.A., on Black river, at an altitude of 720 feet. It is at the intersection of the Lake Shore and Michigan Southern and the Cleveland, Lorain, and Wheeling Railways. Population (1880), 4777; (1890), 5611; (1900), 8791, of whom 1397 were foreign-born and 201 were negroes.

Embroidery.—Embroidery is the enrichment of a stuff (generally woven) with the needle. It is mainly an affair of stitches, though the stitching on of other stuff (*appliqué*) or of gold thread or cord (*conching*) goes also by the name. The stitching, whether only, as it were, dipping into the stuff (*darning, chain stitch, &c.*), or distributed equally on both sides of it (*crewel stitch, satin stitch, &c.*), usually penetrates it at each ply of the needle. When it forms only a network upon the surface it belongs, strictly speaking, to lacework. Recent development of embroidery has been in the direction of domestic work. The Gothic Revival led to the study of old work, but chiefly of Church embroidery and in an antiquarian spirit. Greater attention is now being paid to the work itself and the way of doing it, than to its style and date. Moreover, we now know more about embroidery other than Gothic or Renaissance or Old English. There has been a discovery of early Coptic stuffs in Upper Egypt, which has found its way to the Victoria and Albert Museum in London, where also have been collected treasures of Persian, Indian, and other Oriental work. Much gorgeous Chinese and Japanese stitchery on silk, and more homely work from the Greek islands (Crete, &c.), has also been imported into England. Some of this is of a kind to appeal directly to the simple needlewoman, who, without pretending to be an artist, arrives by sincerity and thoroughness of work at artistic results. Schools of art needlework, patronized by royalty and assisted by artists, have done something to encourage the art of needlework. It is a mistake, however, to consider it too entirely as an art. It is essentially a handicraft. The needlework of to-day has long passed the stage of Berlin wool work; but it has yet to get over some of its high artistic pretensions, and settle down into the modest but beautiful needlework in which gentlewomen of earlier generations took honest pride. For embroidery begins and ends with the needle. In the simplest of work, where the stitch determines the character of the design, as in the most ambitious, where the design dictates the stitch, the one depends upon the other. Neatness or precision of stitch is a point of good workmanship; but its *direction* is of at least equal importance, for it is the means both of varying the shades of colour and of expressing form within the outlines of the design. A skilled worker gets accustomed to sort the varieties of sketches in her mind, according as they are available for outline, flat surfaces, shading, and so forth. Familiarity with the stitches is indispensable alike to the worker and to the designer, who must not ask of his interpreter more than needle and thread can do. A good design gives scope for the needle, and does justice to the material—to the gloss of lustrous silk, for instance. The term "Art Needlework" is commonly misused. Needlework is worthy of that title, not according to its pretensions, but as it is appropriately designed and cunningly worked, and beautiful accordingly. Good work does not mean only fine work. There is art in expressing form by the stepped outline which comes of accepting the square lines given by the mesh of a coarse canvas, no less than in following the subtle sweep of an easy brush stroke. Nor is one stitch or kind of embroidery intrinsically more artistic than another. There is no material so coarse it may not be embroidered, no stitch so mechanical it may not be employed to artistic purpose. All that is necessary is the artist, and he must understand his craft and work in sympathy with it. Great strides have been made in machine embroidery, and every year imitation is carried to further perfection. It is all the more incumbent, therefore, upon the needlewoman to avoid futile competition with loom or sewing-machine, and to do what sensitive hands alone can do. (L. F. D.)

Embryology.—The word embryo is derived from the Greek ἔμβρυον, which signified the fruit of the womb before birth. In its strict sense, therefore, embryology is the study of the intrauterine young or embryo, and can only be pursued in those animals in which the offspring are retained in the uterus of the mother until they have acquired, or nearly acquired, the form of the parent. As a matter of fact, however, the word has a much wider application than would be gathered from its derivation. All animals above the Protozoa undergo at the beginning of their existence rapid growth and considerable changes of form and structure. During these changes, which constitute the development of the animal, the young organism may be incapable of leading a free life and obtaining its own food. In such cases it is either contained in the body of the parent or it is protruded and lies quiescent within the egg membranes; or it may be capable of leading an independent life, possessing in a functional condition all the organs necessary for the maintenance of its existence. In the former case the young organism is called an *embryo*, in the latter a *larva*. It might thus be concluded that embryology would exclude the study of larvæ, in which the whole or the greater part of the development takes place outside the parent and outside the egg. But this is not the case; embryology includes not only a study of embryos as just defined, but also a study of larvæ. In this way the scope of the subject is still further widened. As long as embryology confines its attention to embryos, it is easy to fix its limits, at any rate in the higher animals. The domain of embryology ceases in the case of viviparous animals at birth, in the case of oviparous animals at hatching; it ceases as soon as the young form acquires the power of existing when separated from the parent or when removed from the protection of the egg membranes. But as soon as post-embryonic developmental changes are admitted within the scope of the subject, it becomes on close consideration difficult to limit its range. It must include all the developmental processes which take place as a result of sexual reproduction. A man at birth, when he ceases to be an embryo, has still many changes besides those of simple growth to pass through. The same remark applies to a young frog at the metamorphosis. A chick even, which can run about and feed almost immediately after hatching, possesses a plumage very different from that of the full-grown bird; a starfish at the metamorphosis is in many of its features quite different from the form with which we are familiar. It might be attempted to meet this difficulty by limiting embryology to a study of all those changes which occur in the organism before the attainment of the adult state. But this merely shifts the difficulty to another quarter, and makes it necessary to define what is meant by the adult state. At first sight this may seem easy, and no doubt it is not difficult when man and the higher animals alone are in question, for in these the adult state may be defined comparatively sharply as the stage of sexual maturity. After that period, though changes in the organism still continue, they are retrogressive changes, and as such might fairly be excluded from any account of development, which clearly implies progression, not retrogression. But, as so often happens in the study of organisms, formulæ which apply quite satisfactorily to one group require modification when others are considered.

Does sexual maturity always mark the attainment of the adult state? Is the Axolotl adult when it acquires its reproductive organs? Can a larval Ctenophore, which acquires functional reproductive glands and still possesses the power of passing into the form ordinarily described as adult in that group, be considered to have reached the end of its development? Or—to take the case of those animals, such as *Amphioxus*, *Balanoglossus*, and many segmented worms in which important developmental processes occur, *e.g.*, formation of new gill slits, of gonadial sacs, or even of whole segments of the body, long after the power of reproduction has been acquired—how is the attainment of the adult state to be defined, for it is clear that in them the attainment of sexual maturity does not correspond with the end of growth and development? If, then, embryology is to be regarded as including not only the study of embryos, but also that of larvæ, *i.e.*, if it includes the study of the whole developmental history of the individual—and it is impossible to treat the subject rationally unless it is so regarded—it becomes exceeding difficult to fix any definite limit to the period of life with which embryology concerns itself. The beginning of this period can be fixed, but not the end, unless it be the end of life itself, *i.e.*, death. The science of embryology, then, is the science of individual development, and includes within its purview all those changes of form and structure, whether embryonic, larval, or post-larval, which characterize the life of the individual. The beginning of this period is precise and definite—it is the completion of the fertilization of the ovum, in which the life of the individual has its start. The end, on the other hand, is vague and cannot be precisely defined, unless it be death, in which case the period of life with which embryology concerns itself is coincident with the life of the individual. To use the words of Huxley ("Cell Theory," *Collected Works*, vol. i. p. 267): "Development, therefore, and life are, strictly speaking, one thing, though we are accustomed to limit the former to the progressive half of life merely, and to speak of the retrogressive half as decay, considering an imaginary resting-point between the two as the adult or perfect state."

Reproduction.

There are two kinds of reproduction, the sexual and the asexual. The sexual method has for its results an increase of the number of kinds of individual or organism, whereas the asexual affords an increase in the number of individuals of the same kind. If the asexual method of reproduction alone existed, there would, so far as our knowledge at present extends, be no increase in the number of kinds of organism: no new individuality could arise. The first establishment of a new kind of individual by a sexual process is effected in a very similar manner in all Metazoa. The parent produces by a process of unequal fission, which takes place at a part of the body called the reproductive gland, a small living organism called the reproductive cell. There are always two kinds of reproductive cells, and these are generally produced by different animals called the male and female respectively (when they are produced by the same animal it is said to be hermaphrodite). The reproductive cell produced by the male is called the spermatozoon, and that produced by the female, the ovum. These two organisms agree in being small uninucleated masses of protoplasm, but differ considerably in form. They are without the organs of nutrition, &c., which characterize their parents, but the ovum nearly always possesses, stored up within its protoplasm, a greater or less quantity of vitelline matter or food-yolk, while the spermatozoon possesses in almost all cases the power of locomotion. The object with which these two minute and simple organisms are produced is to fuse with one another and give rise to one resultant uninucleated (for the nuclei fuse) organism or cell, which is called the *zygote*. This process of fusion between the two kinds of reproductive cells, which are termed *gametes*, is called conjugation: it is the process which is sometimes spoken of as the fertilization of the ovum, and its result is the establishment of a new individual. This new individual at first is simply a uninucleated mass of living matter, which always contains a certain amount of food-yolk, and is generally bounded by a delicate cuticular membrane called the vitelline membrane. In form the newly established zygote resembles the female gamete or ovum—so much so, indeed, that it is frequently called the ovum; but it must be clearly understood that although the bulk of its matter has been derived from the ovum, it consists of ovum and spermatozoon, and, as shown by its subsequent behaviour, the spermatozoon has quite as much to do with determining its vital properties as the ovum.

To the unaided eye the main difference between the newly formed zygotes of different species of animals is that of bulk, and this is due to the amount of food-yolk held in suspension in the protoplasm. The ovum of the fowl is 30 mm. in diameter, that of the frog 1·75 mm., while the ovum of the rabbit and *Amphioxus* have a diameter of ·1 mm. The food-yolk is deposited in the ovum as a result of the vital activity of its protoplasm, while the ovum is still a part of the ovary of the parent. It is an inert substance which is used as food later on by the developing embryo, and it acts as a dilutant of the living matter of the ovum. It has a profound influence on the subsequent developmental process. (For details as to what may be called the natural history of fertilization, see Reproduction.) The newly formed zygotes of different species of animals have undoubtedly, as stated above, a certain family resemblance to one another; but however great this resemblance may be, the differences must be most profound, and this fact becomes at once obvious when the properties of these remarkable masses of matter are closely investigated.

Causes of development.

As in the case of so many other forms of matter, the more important properties of the zygote do not become apparent until it is submitted to the action of external forces. These forces constitute the external conditions of existence, and the properties which are called forth by their action are called the acquired characters of the organism. The investigation of these properties, particularly of those which are called forth in the early stages of the process, constitutes the science of Embryology. With regard to the manifestation of these properties, certain points must be clearly understood at the outset:—(1) If the zygote is withheld from the appropriate external influences, *e.g.*, if a plant-seed be kept in a box free from moisture or at a low temperature, no properties are evolved, and the zygote remains unchanged and eventually dies; (2) the acquisition of the properties, which constitutes the growth and development of the organism, proceeds in a perfectly definite sequence, which, so far as is known, cannot be altered; (3) just as the features of the growing organism change under the continued action of the external conditions, so the external conditions themselves must change as the organism is progressively evolved. With regard to this last change, it may be said generally that it is usually, if not always, effected by the organism itself, making use of the properties which it has acquired at earlier stages of its growth, and acting in response to the external conditions. There is, to use a phrase of Mr Herbert Spencer, a continuous adjustment between the external and internal relations. For every organism a certain succession of conditions is necessary, if the complete and normal evolution of properties is to take place. Within certain limits these conditions may vary, without interfering with the normal evolution of the properties, though such variations are generally responded to by slight but unimportant variation of the properties (variation of acquired characters). But if the variation of the conditions is too great, the evolved properties become abnormal, and are of such a nature as to preclude the normal evolution of the organism; in other words, the action of the conditions upon the organism is injurious, causing abortions and, ultimately, death. For many organisms the conditions of existence are well known for all stages of life, and can be easily imitated, so that they can be reared artificially and kept alive and made to breed in confinement—*e.g.*, the common fowl. But in a large number of cases it is not possible, through ignorance of the proper conditions, or on account of the difficulty of imitating them, to make the organism evolve all its properties. For instance, there are many marine larvæ which have never been reared beyond a certain point, and there are some organisms which, even when nearly full-grown—a stage of life at which it is generally most easy to ascertain and imitate the natural conditions—will not live, or at any rate will not breed, in captivity. Of late years some naturalists have largely occupied themselves with experimental observation of the effects on certain organisms of marked and definite changes of the conditions, and the name of Developmental Mechanics (or *Physiology of Development*, under which title it is discussed below, p. 148) has been applied to this branch of study.

Gametogeny.

In normal fertilization, as a rule, only one spermatozoon fuses with the ovum. It has been observed in some eggs that a membrane, formed round the ovum immediately after the entrance of the spermatozoon, prevents the entrance of others. If more than one spermatozoon enters, a corresponding number of male pronuclei are formed, and the subsequent development, if it takes place at all, is abnormal and soon ceases. An egg by ill-treatment (influence of chloroform, carbonic acid, &c.) can be made to take more than one spermatozoon. In some animals it appears that several spermatozoa may normally enter the ovum (some Arthropods, Selachians, Amphibians, and Mammals), but of these only one forms a male pronucleus (see below), the rest being absorbed. Gametogeny is the name applied to the formation of the gametes, *i.e.*, of the ova and spermatozoa. The cells of the reproductive glands are the germ cells (*oögonia spermatogonia*). They undergo division and give rise to the progametes, which in the case of the female are sometimes called *oöcytes*, in the case of the male *spermatocytes*. The oöcytes are more familiarly called the ovarian ova. The nucleus of the oöcyte is called the germinal vesicle. The oöcyte (progamete) gives rise by division to the ovum or true gamete, the nucleus of which is called the *female pronucleus*. As a general rule the oöcyte divides unequally twice, giving rise to two small cells called polar bodies, and to the ovum. The first formed polar body frequently divides when the oöcyte undergoes its second and final division, so that there are three polar bodies as well as the ovum resulting from the division of the oöcyte or progamete. Sometimes the ovum arises from the oöcyte by one division only, and there is only one polar body (mouse, Sobotta, *Arch. f. mikr. Anat.*, 1895, p. 15). The polar bodies are ova, but as a rule they are so small as to be incapable of fertilization. They may therefore be regarded as abortive ova. In one case, however (see Francotte, *Bull. Acad. Belg.* (3), xxxiii., 1897, p. 278), the first formed polar body is nearly as large as the ovum, and is sometimes fertilized and develops. The spermatogonia are the cells of the testis; these produce by division the spermatocytes (progametes). These divide and produce the *spermatids*, which become the spermatozoa. The spermatocytes give rise to the young spermatozoa (spermatids) by division, but the number of divisions is more variable than in the case of the process by which the female gamete arises from the progamete. In *Ascaris* and some other forms there appear to be two binary divisions, giving rise to four equal spermatids, each of which becomes a functional spermatozoon; but in other cases, *e.g.*, *Lumbricus*, a much greater number of fissions follow each other, and many spermatids (young spermatozoa) result from one progamete (spermatocyte). The nucleus of the male gamete is not called the male pronucleus, as would be expected, that term being reserved for the second nucleus which appears in the ovum after fertilization. As this is in all probability derived entirely from the nucleus of the spermatozoon, we should be almost justified in calling the nucleus of the spermatozoon the male pronucleus. In *Ascaris* and some other forms in which the formation of the gametes from the progamete has been accurately followed, and in which the progamete of both sexes divides twice in forming the gametes, the division of the nucleus presents certain peculiarities. In the first place, between the first division and the second it does not enter into the resting state, but immediately proceeds to the second division. In the second place, the number of chromosomes which appear in the final divisions of the progametes and assist in constituting the nuclei of the gametes, is half the number which go to constitute the new nuclei in the ordinary nuclear divisions of the animal. The number of chromosomes of the nucleus of the gamete is therefore reduced, and the divisions by which the gametes arise from the progametes are called reducing divisions. It is not certain, however, that this phenomenon is of universal occurrence, or has the significance which is ordinarily attributed to it.

Fertilization.

As soon as the spermatozoon has conjugated with the ovum, a second nucleus appears in the ovum. This is undoubtedly derived from the spermatozoon, possibly from its nucleus only, and is called the male pronucleus. It possesses in the adjacent protoplasm a well-marked centrosome. The general rule appears to be that the female pronucleus is without a centrosome, and that no centrosome appears in the female in the divisions by which the gamete arises from the progamete. If this is true, the centrosome of the zygote nucleus must be entirely derived from that of the male pronucleus. This accounts for the fact, which has been often observed, that the female pronucleus is not surrounded by protoplasmic radiations, whereas such radiations are present round the male pronucleus in its approach to the female. In the mouse the subsequent events are as follow:—Both pronuclei assume the resting form, the chromatin being distributed over the nuclear network, and the nuclei come to lie side by side in the centre of the egg. A long loop of chromatin then appears in each nucleus and divides up into twelve pieces, the chromosomes. The centrosome now divides, the membranes of both nuclei disappear, and a spindle is formed. The twenty-four chromosomes arrange themselves at the centre of this spindle and split longitudinally, so that forty-eight chromosomes are formed. Twenty-four of these, twelve male and twelve female, as it is supposed, travel to each pole of the spindle and assist in giving rise to the two nuclei. At the next nuclear division twenty-four chromosomes appear in each nucleus, each of which divides longitudinally; and so in all subsequent divisions. The fusion of the two pronuclei is sometimes effected in a manner slightly different to that described for the mouse. In *Echinus*, for instance, the two pronuclei fuse, and the spindle and chromosomes are formed from the zygote nucleus, whereas in the mouse the two pronuclei retain their distinctness during the formation of the chromosomes. There appears, however, to be some variation in this respect: cases have been observed in the mouse in which fusion of the pronuclei occurs before the separation of the chromosomes.

Parthenogenesis.

Parthenogenesis, or development of the female gamete without fertilization, is known to occur in many groups of the animal kingdom. Attempts have been made to connect this phenomenon with peculiarities in the gametogeny. For instance, it has been said that parthenogenetic ova form only one polar body. But, as we have seen, this is sometimes the case in eggs which are fertilized, and parthenogenetic ova are known which form two polar bodies, *e.g.*, ova, of the honey-bee which produce drones (*Morph. Jahrb.* xv., 1889, p. 85), ova of *Rotifera* which produce males (*Zool. Anzeiger*, xx., 1897, p. 455). It is quite probable that parthenogenesis is more common than has been supposed, and it appears that there is some evidence to show that ova, which in normal conditions are incapable of developing without fertilization, may yet develop if subjected to an altered environment. For instance, it has been asserted that the addition of a certain quantity of chloride of magnesium and other substances to sea-water will cause the unfertilized ova of certain marine animals (*Arbacia, Chætopterus*) to develop (J. Loeb, *American Journal of Physiology*, ix., 1901, p. 423); but it is not known whether in such cases a previous formation of polar bodies has occurred. This experiment, if authenticated, suggests that ova have the power of development, but are not able to exercise it in their normal surroundings. There is reason to believe that the same assertion may be made of spermatozoa. Phenomena of the nature of parthenogenesis have never been observed in the male gamete, but it has been suggested by Giard (*Cinquantenaire de la Soc. de Biol.*, 1900) that the phenomenon of the so-called fertilization of an enucleated ovum which has been described by Boveri and Delage in various eggs, and which results in development up to the larval form, is in reality a case in which the male gamete, unable to undergo development in ordinary circumstances on account of its small size and specialization of structure, has obtained a nutritive environment which enables it to display its latent power of development. Moreover, Giard suggests that in some cases of apparently normal fertilization, one of the pronuclei may degenerate, the resultant embryo being the product of one pronucleus only. In this way he explains certain cases of hybridization in which the paternal (rarely the maternal) type is exclusively reproduced. For instance, in the batrachiate Amphibia, Héron Royer succeeded in 1883 in rearing, out of a vast number of attempts, a few hybrids between a female *Pelobates fuscus* and a male *Rana fusca*; the product was a *Rana fusca*. He also crossed a female *Bufo vulgaris* with a male *Bufo calamita*; in the few cases which reached maturity the product was obviously a *Bufo calamita*. Finally, Ziegler (*Arch. f. Ent.-Mech.*, 1898,

p. 249) divided the just fertilized ovum of a sea-urchin in such a way that each half had one pronucleus; the half with the male pronucleus segmented and formed a blastula, the other degenerated. It is said that in a few species of animals males do not occur, and that parthenogenesis is the sole means of reproduction (a species of *Ostracoda* among Crustacea; species of *Tenthredinidæ*, *Cynipidæ*, and *Coccidæ* among Insecta); this is the thelytoky of Siebold. The number of species in which males are unknown is constantly decreasing, and it is quite probable that the phenomenon does not exist. Parthenogenesis, however, is undoubtedly of frequent occurrence, and is of three kinds, namely, (1) that (arrhenotoky) in which males alone are produced, *e.g.*, honey-bees; (2) that in which the product is generally a female, but males occasionally occur, *e.g.*, some *Aphidæ*, Phyllopod Crustacea; (3) that in which there is an alternation of a sexual generation with a parthenogenetic generation (many *Cynipidæ*). It would appear that "parthenogenesis does not favour the production of one sex more than another, but it is clear that it decidedly favours the production of a brood that is entirely of one sex, but which sex that is differs according to circumstances" (Sharp, *Cambridge Natural History*, "Insects," pt. i. p. 498). In some Insecta and Crustacea exceptional parthenogenesis occurs: a certain proportion of the eggs laid are capable of undergoing either the whole or a part of development parthenogenetically, *e.g.*, *Bombyx mori*, &c. (Brauer, *Arch. f. mikr. Anat.*, 1893; consult also Maupas on parthenogenesis of Rotifera, *Comp. Rend.*, 1889–91, and Lauterborn, *Biol. Centralblatt*, xviii., 1898, p. 173).

Determination of sex.

The question of the determination of sex may be alluded to here. Is sex determined at the act of conjugation of the two gametes? Is it, in other words, an unalterable property of the zygote, a genetic character? Or does it depend upon the conditions to which the zygote is subjected in its development? In other words, is it an acquired character? It is impossible in the present state of knowledge to answer these questions satisfactorily, but the balance of evidence appears to favour the view that in most cases sex is an unalterable, inborn character, though in a few it may be an acquired character. Thus those twins which are believed to come from a split zygote are always of the same sex, members of the same litter which have been submitted to exactly similar conditions are of different sexes, and all attempts to determine the sex of offspring in the higher animals by treatment have failed. On the other hand, the male bee is a portion of a female zygote—the queen-bee. The same remark applies to the male Rotifer, in which the zygote always gives rise to a female, from which the male arises parthenogenetically, and parthenogenetic eggs which would ordinarily give rise to females may be made by certain treatment to become males. It is said that in human societies the number of males born increases after wars and famines, but this, if true, is probably due to an affection of the gametes and not of the young zygote. For a review of the whole subject, see Cuénot, *Bull. Sci. France et Belgique*, xxxii., 1899, pp. 462–535.

Cleavage.

The first change the zygote undergoes in all animals is what is generally called the segmentation or cleavage of the ovum. This consists essentially of the division of the nucleus into a number of nuclei, around which the protoplasm sooner or later becomes arranged in the manner ordinarily spoken of as cellular. This division of the nucleus is effected by the process called binary fission; that is to say, it first divides into two, then each of these divides simultaneously again into two, giving four nuclei; each of these after a pause again simultaneously divides into two. So the process continues for some time until the ovum becomes possessed of a large number of nuclei, all of which have proceeded from the original nucleus by a series of binary fissions. This division of the nucleus, which constitutes the essential part of the cleavage of the ovum, continues through the whole of life, but it is only in the earliest period that it is distinguished by a distinct name and used to characterize a stage of development. The nuclear division of cleavage is usually at first a rhythmical process; all the nuclei divide simultaneously, and periods of nuclear activity alternate with periods of rest. Nuclear divisions may be said to be of three kinds, according to the accompanying changes in the surrounding protoplasm: (1) accompanied by no visible change, *e.g.*, the multinucleated Protozoon *Actinosphærium;* (2) accompanied by a rearrangement of the protoplasm around each nucleus, but not by its division into two separate masses, *e.g.*, the division which results in the formation of a colony of Protozoa; (3) accompanied by the division of the protoplasm into two parts, so that two distinct cells result, *e.g.*, the divisions by which the free wandering leucocytes are produced, the reproduction of uninuclear Protozoa, &c. In the cleavage of the ovum the first two of these methods of division are found, but probably not the third. At one time it was thought that the nuclear divisions of cleavage were always of the third kind, and the result of cleavage was supposed to be a mass of isolated cells, which became reunited in the subsequent development to give rise to the later connexions between the tissues which were known to exist. But in 1885 it was noticed that in the ovum of *Peripatus capensis* (Sedgwick, *Q.J.M.S.*, xxv., 1885, p. 449) the extranuclear protoplasm did not divide in the cleavage of the ovum, but merely became rearranged round the increasing nuclei: the continuity of the protoplasm was not broken, but persisted into the later stages of growth, and gave rise to the tissue connexions which undoubtedly exist in the adult. This discovery was of some importance, because it rendered intelligible the unity of the embryo so far as its developmental processes are concerned, the maintenance of this unity being somewhat surprising on the previous view. On further inquiry and examination it was found that the ova of many other animals presented a cleavage essentially similar to that of *Peripatus.* Indeed, it was found that the nuclear divisions of cleavage were of the first two kinds just described. In some eggs, *e.g.*, the Alcyonaria, the first nuclear divisions are effected on the first plan, *i.e.*, they take place without at first producing any visible effect upon the protoplasm of the egg. But in the later stages of cleavage the protoplasm becomes arranged around each nucleus and related to it as to a centre. In the majority of eggs, however, the protoplasm, though not undergoing complete cleavage, becomes rearranged round each nucleus as it is formed. The best and clearest instance of this is afforded by many Arthropodan eggs, in which the nucleus of the just-formed zygote takes up a central position, where it undergoes its first division, subsequent divisions taking place entirely within the egg and not in any way affecting its exterior. The result is to give rise to a nucleated network or foam-work of protoplasm, ramifying through the yolk particles and containing these in its meshes.

In other Arthropodan eggs the cleavage is on the so-called centrolecithal type, in which the dividing nuclei pass to the cortex of the ovum, and the surface of the ovum becomes indented with grooves corresponding to each nucleus. In this kind of cleavage all the so-called segments are continuous with the central undivided yolk-mass. It sometimes happens that in Arthropods the egg breaks up into masses, which cannot be said to have the value of cells, as they are frequently without nuclei. In other eggs, characterized by a considerable amount of yolk, *e.g.*, the ova of Cephalopoda, and of the Vertebrata with much yolk, the first nucleus takes up an eccentric position in a small patch of protoplasm which is comparatively free from yolk particles. This patch is the germinal disc, and the nuclear divisions are confined to it and to the transitional region, where it merges into the denser yolk which makes up the bulk of the egg. At the close of segmentation the germinal disc consists of a number of nuclei, each surrounded by its own mass of protoplasm, which is, however, not separated from the protoplasm round the neighbouring nuclei, as was formerly supposed, but is continuous at the points of contact. In this manner the germinal disc has become converted into the blastoderm, which consists of a small watch-glass-shaped mass of so-called cells resting on, but continuous with, the large yolk-mass. It is characteristic of this kind of ovum that there is always a row of nuclei, called the yolk nuclei, placed in the denser yolk immediately adjacent to the blastoderm. These nuclei are continually undergoing division, one of the products of division, together with a little of the sparse yolk protoplasm, passing into the blastoderm to reinforce it. The other product of the dividing yolk nuclei remains in the yolk, in readiness for the next division. In this manner nucleated masses of protoplasm are continually being added to the periphery of the blastoderm and assisting in its growth. But it must be borne in mind that all the nucleated masses of which the blastoderm consists are in continuity with each other and with the sparse protoplasmic reticulum of the subjacent yolk.

In the great majority of eggs, then, the nuclear division of cleavage is not accompanied by a complete division of the ovum into separate cells, but only by a rearrangement of the protoplasm, which produces, indeed, the so-called cellular arrangement, and an appearance only of separate cells. But there still remain to be mentioned those small eggs in which the amount of yolk is inconsiderable, and in which the division of the nuclei does appear to be accompanied by a complete division of the surrounding protoplasm into separate unconnected cells—ova of many Annelida, Mollusca, Echinoderma, &c., and of Mammalia amongst Vertebrata. In the case of these (Andrews, *Zool. Bulletin*, ii., 1898) also, it has been shown that the apparently separate spheres are connected by a number of fine anastomosing threads of a hyaline protoplasm, which are not easy to detect and are readily destroyed by the action of reagents. It is therefore probable that the divisions of the nuclei in cleavage are in no case accompanied by complete division of the surrounding protoplasm, and the organism in the cleavage stage is a continuous whole, as it is in all the other stages of its existence.

Division of embryo.

Of late years a great number of experiments have been made to discover the effects of dividing the embryo during its cleavage, and of destroying certain portions of it. These experiments have been made with the object of testing the view, held by some authorities, that certain segments are already set apart in cleavage to give rise to certain adult organs, so that if they were destroyed the organs in question could not be developed. The results obtained have not borne out this view. Speaking generally, it may be said that they have been different according to the stage at which the separation was effected and the conditions under which the experiment was carried out. If the experiment be made at a sufficiently early stage, each part, if not too small, will develop into a normal, though small, embryo. In some cases the embryo remained imperfect for a certain time after the experiment, but the loss is eventually made good by regeneration. (For a summary of the work done on this subject, see Berg, *Zool. Centralblatt*, vii., 1900, p. 1.)

The layer-theory.

The end of cleavage is marked by the commencement of the differentiation of the organs. The first differentiation is the formation of the layers. These are three in number, being called respectively the ectoderm, endoderm, and mesoderm, or, in embryos in which at their first appearance they lie like sheets one above the other, the epiblast, hypoblast, and mesoblast. The layers are sometimes spoken of as the primary organs, and their importance lies in the fact that they are supposed to be generally homologous throughout the series of the Metazoa. This view, which is based partly on their origin and partly on their fate, had great influence on the science of comparative anatomy during the last thirty years of the 19th century, for the homology of the layers being admitted, they afforded a kind of final court of appeal in determining questions of doubtful homologies between adult organs. Great importance was therefore attached to them by embryologists, and both their mode of development and the part which they play in forming the adult organs were examined with the greatest care. It is very unusual for all the layers to be established at the same time. As a general rule the ectoderm and endoderm, which may be called the primary layers, come first, and later the mesoderm is developed from one or other of them. There are two main methods in which the first two are differentiated—invagination and delamination. The former is generally found in small eggs, in which the embryo at the close of cleavage assumes the form of a sphere, having a fluid or gelatinous material in its centre, and bounded externally by a thin layer of protoplasm, in which all the nuclei are contained. Such a sphere is called a blastosphere, and may be regarded as a spherical mass of protoplasm, of which the central portion is so much vacuolated that it seems to consist entirely of fluid. The central part of the blastosphere is called the segmentation cavity or blastocœl. The blastosphere soon gives rise, by the invagination of one part of its wall upon the other, and a consequent obliteration of the segmentation cavity, to a double-walled cup with a wide opening, which, however, soon becomes narrowed to a small pore. This cup stage is called the gastrula stage; the outer wall of the gastrula is the ectoderm, and its inner the endoderm; while its cavity is the enteron, and the opening to the exterior the blastopore. Origin of the primary layers by delamination occurs universally in eggs with large yolks (Cephalopoda and many Vertebrata), and occasionally in others. In it cleavage gives rise to a solid mass, which divides by delamination into two layers, the ectoderm and endoderm. The main difference between the two methods of development lies in the fact that in the first of them the endoderm at its first origin shows the relations which it possesses in the adult, namely, of forming the epithelial wall of the enteric space, whereas in the second method the endoderm is at first a solid mass, in which the enteric space makes its appearance later by excavation. In the delaminate method the enteric space is at first without a blastopore, and sometimes it never acquires this opening, but a blastopore is frequently formed, and the two-layered gastrula stage is reached, though by a very different route to that taken in the formation of the invaginate gastrula. According to the layer-theory, these two layers are homologous throughout the series of Metazoa; their limits can always be accurately defined, they give rise to the same organs in all cases, and the adult organs (excluding the mesodermal organs) can be traced back to one or other of them with absolute precision. Thus the ectoderm gives rise to the epidermis, to the nervous system, and to the lining of the stomodæum and proctodæum, if such parts of the alimentary canal are present. The endoderm, on the other hand, gives rise to the lining of the enteron, and of the glands which open into it.

So far as these two layers are concerned, and excluding the mesoderm, it would appear that the layer-theory does apply in a very remarkable manner to the whole of the Metazoa. But even here, when the actual facts are closely scanned, there are found to be difficulties, which appear to indicate that the theory may not perhaps be such an infallible guide as it seems at first sight. Leaving out of consideration the case of the Mammalia, in which the differentiation of the segmented ovum is not into ectoderm and endoderm, and the case of the sponges, the most important of these difficulties concern the stomodæum and proctodæum. The best case to examine is that of *Peripatus capensis*, in which the blastopore is at first a long slit, and gives rise to both the mouth and the anus of the adult, Here there is always found at the lips of the blastopore, and extending for a short distance inwards as enteric lining, a certain amount of tissue, which by its characters must be regarded as ectoderm. Now, in the closure of the blastopore between the mouth and anus, this tissue, which at the mouth and anus develops into the lining of the stomodæum and proctodæum, is left inside, and actually gives rise to the median ventral epithelium of the alimentary canal. Hence the development of *Peripatus capensis* suggests the conclusion, if we strictly apply the layer-theory, that a considerable portion of the true mesenteron is lined by ectoderm, and is not homologous with the corresponding portion of the mesenteron of other animals —a conclusion which will on all hands be admitted to be absurd. The difficulties in the application of the layer-theory become vastly greater when the origin and fate of the mesoderm is considered. The mesoderm is, if we may judge from the number of organs which are derived from it, much the most important of the three layers. It generally arises later than the others, and in its very origin presents difficulties to the theory, which are much increased when we consider its history. It is generally, though not always, developed from the endoderm, either as hollow outgrowths containing prolongations of the enteric cavity, which become the cœlom, or as solid proliferations. But in some groups the mesoderm is actually laid down in cleavage, and is present at the end of that process. In others it is entirely derived from the ectoderm (*Peripatus capensis*). In yet others it is partly derived from endoderm and partly from ectoderm (primitive streak of amniotic Vertebrates). Finally, in whatever manner the first rudiments are developed, it frequently receives considerable reinforcements from one of the primary layers. For instance, the structure known as the nerve crest of the vertebrate embryo is not, as was formerly supposed, exclusively concerned with the formation of the spinal nerves and ganglia, but contributes largely to the mesoderm of the axial region of the body. This is particularly clearly seen in the case of the anterior part of the head of Elasmobranch and probably of other vertebrate embryos, where all the mesoderm present is derived from the anterior part of the neural crest (*Q.J.M.S.* xxxvii. p. 92).

Mesoderm.

The layer-theory, then, will not bear critical examination. It is clear, both from their origin and history, that the layers or masses of cells called ectoderm, endoderm, and mesoderm have not the same value in different animals; indeed, it is misleading to speak of three layers. At the most we can only speak of two, for the mesoderm is formed after the others, has a composite origin, and has no more claim to be considered an embryonic layer than has the rudiment of the central nervous system, which in some animals, indeed, appears as soon as the mesoderm. Arguments as to homology, based on derivation or non-derivation from the same embryonic layer, have therefore in themselves but little value.

It has frequently been asserted that the reproductive cells are marked off at a very early stage of the development (*Sagitta*, certain Crustacea, *Scorpio*). Recently it has been asserted that in *Ascaris* (Boveri, *Kuppfer's Festschrift*, 1899, p. 383) the reproductive cells are set apart after the first cleavage, and that they can be traced by certain peculiarities of their nuclei into the adult reproductive glands.

Mesenchyme.

It has been already stated that the mesoderm is a composite tissue. This fact is frequently conspicuous at its first establishment. In many Cœlomata it is present under two forms from the beginning. One of these is epithelial in character, while the other has the form of a network of protoplasm, with nuclei at the nodes. The former is called simply epithelial mesoderm, the latter mesenchyme. Sometimes the epithelial mesoderm is the first formed, and what little mesenchyme there is is developed from it (*Amphioxus*, *Balanoglossus*, &c.). Sometimes the mesenchyme is the first to arise, the epithelial mesoderm developing from it (most, if not all, Vertebrates). Finally, it sometimes happens that these two kinds of tissue arise separately from one or other of the primary layers (Echinodermata). As already hinted, in *Balanoglossus* and *Amphioxus* the whole of the mesoderm of the body is at first in an epithelial condition, being developed as an outgrowth of the gut wall. In *Peripatus capensis* also, and possibly in other Arthropods, it has at first an intermediate form, being derived from a primitive streak and not from the gut wall, but it rapidly assumes an epithelial structure, from which all the mesodermal tissues are developed. In Annelids the bulk of the mesoderm has at first a modified epithelial form similar to that of Arthropods, but it is formed, not from a primitive streak, but from some peculiar cells produced in cleavage, called pole-cells. In Annelids with trochosphere larvæ a certain amount of mesenchyme is formed at an earlier stage and gives rise to the muscular bands of the young larva. In Echinodermata a certain amount of mesenchyme appears before the epithelial mesoderm, which is formed later as gut diverticula. In these forms the mesenchyme is said to arise as wandering amœboid cells, which are budded into the blastocœl by the endoderm just before and during its invagination, but the writer has reason to believe that this account of it does not quite describe what happens. It would seem to be more probable that the mesenchyme arises in these forms, as it certainly does in the case of the later-formed mesenchyme of the Vertebrate embryo, as a protoplasmic outflow from its tissue of origin, passing at first along the line of pre-existent protoplasmic strands which traverse the blastocœl, and sending out at the same time processes which branch and anastomose with neighbouring processes (see MacBride, *Proc. Camb. Phil. Soc.*, 1896, p. 153). In the Vertebrata the whole of the mesoderm has at first the mesenchyme form. Afterwards, when the body-cavity split appears, the bulk of it assumes a kind of modified epithelial condition, which later on yields, by a process of outflow very similar in its character to what has been supposed to occur in the Echinoderm blastula, a considerable mesenchyme of the reticulate character. Mesenchyme is the tissue which in Vertebrate embryology has frequently been called embryonic connective tissue. This name is no doubt due to the fact that it was supposed to consist of isolated stellate cells. It is, however, in no sense of the word connective tissue, because it gives rise to many organs having nothing whatever to do with connective tissue. For instance, in Vertebrata this tissue gives rise to nervous tissue, blood-vessels, renal tubules, smooth muscular fibres, and other structures, as well as to connective and skeletal tissues. The Vertebrata, indeed, are remarkable for the fact that the epithelial tissues of the so-called mesoderm, *e.g.*, the epithelial lining of the body-cavity, and of the renal tubules and urogenital tracts, all pass through the mesenchymatous condition, whereas in *Amphioxus*, *Balanoglossus*, and presumably *Sagitta* and the Brachiopoda, all the mesodermal tissues pass through the epithelial condition, the epithelial mesodermal tissues of the adult retaining this condition permanently. As has been implied in the above account, mesenchyme is usually formed from epithelial mesoderm or from endoderm, or from tissue destined to form endoderm. It is also sometimes formed from ectoderm, as in the Vertebrata at the nerve crest and other places. In some Cœlenterata also it appears certain that the ectoderm does furnish tissue of a mesenchymatous nature which passes into the jelly, but this phenomenon takes place comparatively late in life, at any rate after the embryonic period. In this connexion it may be interesting to point out that in many Cœlenterates all the tissues of the body retain throughout life the epithelial condition, nothing comparable to mesenchyme ever being formed.

Continuity of the layers.

Finally, before leaving this branch of the subject, the fact that the three germinal layers are continuous with one another, and not isolated masses of tissue, may be emphasized. Indeed, an embryo may be defined as a multinucleated protoplasmic mass, in which the protoplasm at any surface—whether internal or external—is in the form of a relatively dense layer, while that in the interior is much vacuolated and reduced to a more or less sparse reticulum, the nuclei either being exclusively found in the surface protoplasm, or if the embryo has any bulk and the internal reticulum is at all well developed, at the nodes of the internal reticulum as well.

The origin of some of the more important organs may now be considered. It is a remarkable fact that the mouth and anus develop in the most diverse ways in different groups, but as a rule either one or both of them can be traced into relation with the blastopore, the history of which must therefore be examined. In most, if not all, the great groups of the animal kingdom, *e.g.*, in Cœlenterata, Annelida, Mollusca, Vertebrata, and in Arthropoda, the blastopore or its representative is placed on the neural surface of the body, and, as will be shown later on, within the limits of the central nerve rudiment. Here it undergoes the most diverse fate, even in members of the same group. For instance, in *Peripatus capensis* it extends as a slit along the ventral surface, which closes up in the middle, but remains open at the two ends as the permanent mouth and anus. In other Arthropods, though full details have not yet in all cases been worked out, the following general statement may be made:—A blastopore (certain Crustacea) or its representative is formed on the neural surface of the embryo and always becomes closed, the mouth and anus arising as independent perforations later. Here no one would doubt the homology of the mouth and anus throughout the group; yet within the limits of a single genus—*Peripatus*—they show the most diverse modes of development. In Annelids the blastopore sometimes becomes the mouth (most *Chætopoda*); sometimes it becomes the anus (*Serpula*); sometimes it closes up, giving rise to neither, though in this case it may assume the form of a long slit along the ventral surface before disappearing. In Mollusca its fate presents the same variations as in Annelida. Now in these groups no zoologist would deny the homology of the mouth and anus in the different forms, and yet how very different is their history even in closely allied animals. How are these apparently diverse facts to be reconciled? The only satisfactory explanation which has been offered (Sedgwick, *Q.J.M.S.* xxiv., 1884, p. 43) is that the blastopore is homologous in all the groups mentioned, and is the representative of the original single opening into the enteric cavity, such as at present characterizes the Cœlenterata. From it the mouth and anus have been derived, as is indicated by its history in *Peripatus capensis*, and by the variability in its behaviour in closely allied forms; such variability in its subsequent history is due to its specialization as a larval organ, as a result of which it has lost its capacity to give rise to both mouth and anus, and sometimes to either.

Mouth and anus.

That the blastopore does become specialized as a larval organ is obvious in those cases in which it becomes transformed into the single opening with which some larvæ are, for a time at least, alone provided, *e.g.*, *Pilidium*, Echinoderm larvæ, &c., and that larval characters have been the principal causes of the form of embryonic characters, strong reason to believe will be adduced later on. In the Vertebrata the behaviour of the blastopore (anus of Rusconi) is also variable in a very remarkable manner. As a rule it is slit-like in form and closes completely, but in most cases one portion of it remains open longer than the rest, as the neurenteric canal. In a few forms (*e.g.*, Newt, *Lepidosiren*, &c.) the very hindermost portion of the slit-like blastopore remains permanently open as the anus, and from such cases it can be shown that the neurenteric aperture (when present) is derived from a portion of the blastopore just anterior to its hindermost end. The words "hindermost" and "anterior" are used on the assumption that the whole blastopore has retained its dorsal position; as a matter of fact the hindermost part of it—the part which persists or reopens as the anus—loses this position in the course of development and becomes shifted on to the ventral surface. This is clearly seen in *Lepidosiren* (Kerr, *Phil. Trans.* cxcii., 1900), in *Elasmobranchii*, and in *Amniota* (primitive streak). Moreover, in *Lepidosiren*, and possibly in some other forms, the anus, *i.e.*, the hind end of the blastopore, is at first contained within the medullary plate and bounded behind by the medullary folds. Later the portions of the medullary plate in the neighbourhood of the anus completely atrophy, and this relation is lost. This extension of the hind end of the blastopore on to the ventral surface, and atrophy of the portion of the medullary plate in relation with it, is a highly important phenomenon, and one to which attention will be again called when the relation of the mouth to the blastopore is being considered. The remarkable fact about the Vertebrata, a feature which that group shares in common with all other Chordata (*Amphioxus*, *Tunicata*, *Enteropneusta*) and with the Echinodermata, is that the mouth has never been traced into relation with the blastopore. For this reason, among others, it has been held by some zoologists that the mouth of the Vertebrata is not homologous with the mouth of such groups as the Annelida, Arthropoda, and Mollusca. But, as has been explained above, in face of the extraordinary variability in the history of the mouth and anus in these groups, this view cannot be regarded as in any way established. On the contrary, there are distinct reasons for thinking that the Vertebrate mouth is a derivate of the blastopore. In the first place, in *Elasmobranchii* (Sedgwick, *Q.J.M.S.* xxxiii., 1892, p. 559), and in a less conspicuous form in other groups, the mouth has at first a slit-like form, extending from the anterior end of the central nerve tube backwards along the ventral surface of the anterior part of the embryo. This slit-like rudiment, recalling as it does the form which the blastopore assumes in so many groups and in many Vertebrata, does suggest the view that possibly the mouth of the Vertebrata may in reality be derived from a portion of an originally long slit-like neural blastopore, which has become extended anteriorly on to the ventral surface and has lost its original relation to the nerve rudiment, as has undoubtedly happened with the posterior part, which persists as the anus.

Of the other organs which develop from the two primary layers, it is only possible to notice here the central nervous system. This in almost all animals develops from the ectoderm. In Cephalopods among Mollusca—the development of which is remarkable from the almost complete absence of features which, for want of a better name, we must call vestigial-ancestral—and in one or two other forms, it has been said to develop from the mesoderm; but apart from these exceptional and perhaps doubtful cases, the central nervous system of all embryos arises as thickenings of the ectoderm, and in the groups above mentioned, namely, Annelida, Mollusca, Arthropoda, and Vertebrata, and probably others, from the ectoderm of the blastoporal surface of the body. This surface generally becomes the ventral surface, but in Vertebrata it becomes the dorsal. These thickened tracts of ectoderm in *Peripatus* and a few other forms can be clearly seen to surround the blastopore. This relation is retained in the adult in *Peripatus*, some Mollusca, and some Nemertines, in which the main lateral nerve cords are united behind the anus as well as in front of the mouth; in other forms it cannot always be demonstrated, but it can, as in the case of the Vertebrata just referred to, always be inferred; only, in the Invertebrate groups the part of the nerve rudiment which has to be inferred is the posterior part behind the blastopore, whereas in Vertebrata it is the anterior part, namely, that in front of the blastopore, assuming that the mouth is a blastoporal derivate.

Central nervous system.

In the Echinodermata, Enteropneusta, and one or two other groups, it is not possible, in the present state of knowledge, to bring the mouth into relation with the blastopore, nor can the blastopore be shown to be a perforation of the neural surface. For the Echinoderms, at any rate, this fact loses some of the importance which might at first sight be attributed to it when the remarkable organization of the adult and the sharp contrast which exists between it and the larva is remembered. In some Annelids the central nervous system remains throughout life as part of the outer epidermis, but as a general rule it becomes separated from the epidermis and embedded in the mesodermal tissues. The mode in which this separation is effected varies according to the form and structure of the central nervous system. In the Vertebrata, in which this organ has the form of a tube extending along the dorsal surface of the body, it arises as a groove of the medullary plate, which becomes constricted into a canal. The lining of this canal consists of ectoderm, which at an earlier stage formed part of the outer surface of the body, and which now thickens, to give rise to the epithelial lining of the canal and to the nervous tissue which forms the bulk of the canal wall. The fact that the blastopore remains open at the hind end of the medullary plate explains to a certain extent the peculiar relation which always exists in the embryo between the hind end of the neural and alimentary canals. This communication between the hind end of the neural tube and the gut is one of the most remarkable and constant features of the Vertebrate embryo. As has been pointed out, it is not altogether unintelligible when we remember the relation of the blastopore to the medullary plate of the earlier stage, but to give a complete explanation of it is, and probably always will be, impossible. It is no doubt the impress of some remarkable larval condition of the blastopore of a stage of evolution now long past.

In *Ceratodus* the open part of the blastopore is enclosed by the medullary folds, and probably persists as the anus, the portion of the folds around the anus undergoing atrophy (Semon, *Zool. Forschungsreisen in Australien*, 1893, Bd. i. p. 39). In Urodeles the blastopore persists as anus, so far as is known, but the relation to the medullary folds has not been noticed. The same may be said of *Petromyzon* (Shipley, *Q.J.M.S.* xxviii., 1887).

Cranial flexure.

The nerve tube of the Vertebrata at a certain early stage of the embryo becomes bent ventralwards in its anterior portion, in such a manner that the anterior end, which is represented in the adult by the infundibulum, comes to project backwards beneath the mid-brain. This bend, which is called the cranial flexure, takes place through the mid-brain, so that the hind-brain is unaffected by it. The cranial flexure is not, however, confined to the brain: the anterior end of the notochord, which at first extends almost to the front end of the nerve tube (this extension, which is quite obvious in the young embryo of Elasmobranchs, becomes masked in the later stages by the extraordinary modifications which the parts undergo), is also affected by it. Moreover, it affects even other parts, as may be seen by the oblique, almost antero-posterior, direction of the anterior gill slits as compared with the transverse direction of those behind. No satisfactory explanation has ever been offered of the cranial flexure. It is found in all Vertebrates, and is effected at an early stage of the development. In the later stages and in the adult it ceases to be noticeable, on account of an alteration of the relative sizes of parts of the brain. This is due almost entirely to the enormous growth of the cerebral vesicle, which is an outgrowth of the dorsal wall of the fore-brain just short of its anterior end. The anterior end of the fore-brain remains relatively small throughout life as the infundibulum, and the junction of this part of the fore-brain with the part which is so largely developed, as the rudiment of the cerebrum, is marked by the attachment of the optic chiasma. The optic nerve, indeed, is morphologically the first cranial nerve, the olfactory being the second; both are attached to what is morphologically the dorsal side of the nerve tube. The morphological anterior end of the central nerve tube is the point of the infundibulum which is in contact with the pituitary body. While on the subject of the cranial flexure, it may be pointed out that there is a similar downward curve of the hind end of the nervous axis, which leads into the hind end of the enteron. If it be supposed that originally there was a communication between the infundibulum and pituitary body, then the ventral flexure found at both ends of the nerve axis would originally have had the same result, namely, of placing the neural and alimentary canals in communication. Moreover, the mouth would have had much the same relation to this imaginary anterior neurenteric canal that the anus has to the actual posterior one.

In *Amphioxus* and the Tunicata the early development of the central nervous system is very much like that of the Vertebrata, but the later stages are simpler, being without the cranial flexure. The Tunicata are remarkable for the fact that the nervous system, though at first hollow, becomes quite solid in the adult. In *Balanoglossus* the central nervous system is in part tubular, the canal being open at each end. It arises, however, by delamination from the ectoderm, the tube being a secondary acquisition. This is probably due to a shortening of development, for the same feature is found in some Vertebrata (*Teleosteans, Lepidosteus*, &c.), where the central canal is secondarily hollowed out in the solid keel-like mass which is separated from the ectoderm. Parts of the central nervous system arise by invagination in other groups; for instance, the cerebral ganglia of *Dentalium* are formed from the walls of two invaginations of ectoderm, which eventually disappear at the anterior end of the body (Kowalevsky, *Ann. Mus. Hist. Nat. Marseilles*, "Zoology," vol. i.). In *Peripatus* the cerebral ganglia arise in a similar way, but in this case the cavities of the invagination become separated from the skin and persist as two hollow appendages on the lower side of the cerebral ganglia. In other Arthropods the cerebral ganglia arise in a similar way, but the invaginations disappear in the adult. In Nemertines the cerebral ganglia contain a cavity which communicates with the exterior by a narrow canal.

Peripheral nervous system.

Although the central nervous system is almost always developed from the ectoderm of the embryo, the same cannot be said of the peripheral nerve trunks. These structures arise from the mesoblastic reticulum already described (Sedgwick, *Q.J.M.S.* xxxvii. p. 92). Inasmuch as this reticulum is perfectly continuous with the precisely similar though denser tissue in the ectoderm and endoderm, it may well be that a portion of the nerve trunks should be described as being ectodermal and endodermal in origin, though the bulk of them are undoubtedly formed from that portion of the reticulum commonly described as mesoblastic. But, however that may be, the tissue from which the great nerve trunks are developed is continuous on all sides with a similar tissue which pervades all the organs of the body, and in which the nuclei of these organs are contained.

In the early stages of development this tissue is very sparse and not easily seen. It would appear, indeed, that it is of a very delicate texture and readily destroyed by reagents. It is for this reason that the layers of the Vertebrate embryo are commonly represented as being quite isolated from one another, and that the medullary canal is nearly always represented as being completely isolated at certain stages from the surrounding tissues. In reality the layers are all connected together by this delicate tissue—in a sparse form, it is true—which not only extends between them, but also in a denser and more distinct form pervades them. In the germinal layers themselves, and in the organs developing from them, this tissue is in the young stages almost entirely obscured by the densely packed nuclei which it contains. For instance, in the wall of the medullary canal in the Vertebrate embryo, in the splanchnic and somatic layers of mesoderm of the same embryo, and in the developing nerve cords of the *Peripatus* embryo, the nuclei are at first so densely crowded together that it is almost impossible to see the protoplasmic framework in which they rest, but as development proceeds this extra-nuclear tissue becomes more largely developed, and the nuclei are forced apart, so that it becomes visible and receives various names according to its position. In the wall of the medullary canal of the Vertebrate embryo, on the outside of which it becomes especially conspicuous in certain places, and on the dorsal side of the developing nerve cords of the *Peripatus* embryo, it constitutes the white matter of the developing nerve cord; in the mesoblastic tissue outside, where it at the same time becomes more conspicuous (Sedgwick, "Monograph of the Development of *Peripatus capensis*," *Studies from the Morph. Lab. of the University of Cambridge*, iv., 1889, p. 131), it forms the looser network of the mesoblastic reticulum; and connecting the two, in place of the few and delicate strands of this tissue of the former stage, there are at certain places well-marked cords of a relatively dense texture, with the meshes of the reticulum elongated in the direction of the cord. This latter structure is an incipient nerve trunk. It can be traced outwards into the mesoblastic reticulum, from the strands of which it is indeed developed, and with which it is continuous not only at its free end, but also along its whole course. In this way the nerve trunks are developed—by a gathering up, so to speak, of the fibres of the reticulum into bundles. These bundles are generally marked by the possession of nuclei, especially in their cortical parts, which become no doubt the nuclei of the nerve sheath, and, in the neighbourhood of the ganglia, of nerve cells. In some parts of the body of Vertebrata (particularly in the case of the cranial nerves of *Elasmobranchii*) the course of the future nerve is at first marked by a tract of densely packed nuclei extending through a portion of the reticulum, in which the nuclei have become less closely packed. Such nerve tracts soon reveal themselves by the loosening of their nuclei, and become transformed into cords containing a core of the pale fibrous substance with a cortex of nuclei. From this account of the early development of the nerves, it is apparent that they are in their origin continuous with all the other tissues of the body, with that of the central nervous system and with that which becomes transformed into muscular tissue and connective and epithelial tissues. All these tissues are developed from the general reticulum, which in the young embryo can be seen to pervade the whole body, not being confined to the mesoderm, but extending between the nuclei of the ectoderm and endoderm, and forming the extra-nuclear, so-called cellular, protoplasm of those layers. Moreover, it must be remarked that in the stages of the embryo with which we are here concerned the so-called cellular constitution of the tissues, which is such a marked feature of the older embryo and adult, has not been arrived at. It is true, indications of it may be seen in some of the earlier-formed epithelia, but of nerve cells, muscular cells, and many kinds of gland cells no distinct signs are yet visible. This remark particularly applies to nerve cells, which do not make their appearance until a much later stage—not, indeed, until some time after the principal nerve trunks and ganglia are indicated as tracts of pale fibrous substance and aggregations of nuclei respectively. The neuroblasts of His and other authors have no existence, at any rate until long after the stages are passed in which they are described as taking part in the formation of nerves by the extension of their cell-bodies.

The embryos of Elasmobranchs—particularly of *Scyllium*—are the best objects in which to study the development of nerves. In many embryos it is difficult to make out what happens, because the various parts of the body remain so close together that the process is obscured, and the loosening of the mesoblastic nuclei is deferred until after the nerves have begun to be differentiated. The process may also be traced in the embryos of *Peripatus*, where the main features are essentially similar to those above described (*op. cit.* p. 131).

To sum up, the development of nerves is not, as has been recently urged, an outgrowth of cell processes from certain cells, but is a differentiation of a substance which was already in position, and from which all other organs of the body have been and are developed. It frequently happens that the young nerve tracts can be seen sooner near the central organ than elsewhere, but it is doubtful if any importance can be attached to this fact, since it is not constantly observed. For instance, in the case of the third nerve of *Scyllium* the differentiation appears to take place earliest near the ciliary ganglion, and to proceed from that point to the base of the mid-brain.

Cœlom. There are two main methods in which new organs are developed. In the one, which indicates the possibility of physiological continuity, the organ arises by the direct modification of a portion of a pre-existing organ; the development of the central nervous system of the Vertebrata from a groove in the embryonic ectoderm may be taken as an example of this method. In the other method there is no continuity which can be in any way interpreted as physiological; a centre of growth appears in one of the parts of the embryo, and gives rise to a mass of tissue which gradually shapes itself into the required organ. The development of the central nervous system in Teleosteans and in other similar exceptional cases may be mentioned as an example of the second plan. Such a centre of growth is frequently called a blastema, and consists of a mass of closely packed nuclei which have arisen by the growth-activity of the nuclei in the neighbourhood. The cœlom, an organ which is found in the so-called cœlomate animals, and which in the adult is usually divided up more or less completely into three parts, namely, body-cavity, renal organs, generative glands, presents in different animals both these methods of development. In certain animals it develops by the direct modification of a part of the primitive enteron, while in others it arises by the gradual shaping of a mass of tissue which consists of a compact mass of nuclei derived by nuclear proliferation from one or more of the pre-existing tissues of the body. Inasmuch as the first rudiment of the cœlom nearly always makes its appearance at an early stage, when the ectoderm and endoderm are almost the only tissues present, and as it then bulks relatively very large and frequently contains within itself the potential centres of growth of other, not allied, organs, it has come to be regarded by embryologists as being the forerunner of all the so-called mesodermal organs of the body, and has been dignified with the somewhat mysterious rank which attaches to the conception of a germinal layer. Its prominence and importance at an early stage led embryologists, as has already been explained, to overlook the fact that although some of the centres of growth for the formation of other non-cœlomic organs and tissues may be contained within it, all are not so contained; that there are centres of growth still left in the ectoderm and endoderm after its establishment; and, finally, that there are some animals in which probably no potential centres of growth, other than those connected with the formation of cœlomic organs, are contained in the cœlomic rudiment. If these considerations, and others like them, are correct, it would seem to follow that the conception implied by the word mesoderm has no objective existence, that the tissue of the embryo, called mesoderm, is mainly, sometimes exclusively, the rudiment of the cœlom, and that though this rudiment may contain within itself the potential centres of growth of other organs and tissues which are commonly ranked as mesodermal, it is not different in this respect from the rudiments of the two other organs already formed, namely, the ectoderm and endoderm; for these contain within themselves centres of growth for the production of the so-called mesodermal tissues, as witness the nerve-crest of Vertebrata, the growing-point of the pronephric duct, and the formation of blood-vessels from the hypoblast described for some members of the same group. In Echinodermata, *Amphioxus*, Enteropneusta, and a few other groups, the cœlom develops from a portion or portions of the primitive enteron, which eventually becomes separated from the rest and forms a variable number of closed sacs lying between the gut and the ectoderm. The number of these sacs varies in different animals, but the evidence at present available seems to show that the maximum number is five—an unpaired one in front and two pairs behind—and, further, that if a less number of sacs is actually separated from the enteron, the rule is for these sacs so to divide up that they give rise to five sacs arranged in the manner indicated. The Enteropneusta present us with the clearest case of the separation of five sacs from the primitive enteron (Bateson, *Q.J.M.S.* xxiv. 1884).

In *Amphioxus*, according to the important researches of MacBride (*Q.J.M.S.* xl. p. 589), it appears that a similar process occurs, though it is complicated by the fact that the sacs of the posterior pair become divided up at an early stage into many pairs. In *Phoronis* there are indications of the same phenomenon (Masterman, *Q.M.J.S.* xliii. p. 375). In the Chætognatha a single sac only is separated from the enteron, but soon becomes divided up. The exact method of this division is not known, but the facts so far observed suggest that a renewed investigation may show that the division is into five sacs arranged as in the Enteropneust embryo. In the Brachiopoda one pair of sacs is separated from the enteron, but our knowledge of their later history is not sufficient to enable us to say whether they divide up into the typically arranged five sacs. (The embryology of the Chætognatha and Brachiopoda would well repay investigation by modern methods with regard to this point.) In Echinodermata the number of sacs separated from the enteron varies from one to three; but though the history of these shows considerable differences, there are reasons to believe that the typical final arrangement is one unpaired and two paired sacs. But however many sacs may arise from the primitive enteron, and however these sacs may ultimately divide up and arrange themselves, the important point of development common to all these animals, about which there can be no dispute, is that the cœlom is a direct differentiation of a portion of the enteron.

In the majority of the Cœlomata the cœlomic rudiment does not arise by the simple differentiation of a pre-existing organ, and there is considerable variation in its method of formation. Speaking generally, it may be said to consist at first of a blastema (see above), which arises at an early stage as a nuclear proliferation from one or more growth-centres in one or both of the primary layers. When the cœlomic rudiment arises in this way, and not by the direct differentiation of a portion of a pre-existing organ, its later history always shows that it contains within itself the growth centres of a large number of non-cœlomic organs. In some cases, it is true, it receives later such important reinforcements, which become indistinguishably mingled with it, that it is possible that the number of those originally present in it may be less than is supposed (Vertebrata); but making all allowances for this, it must be admitted that there are some embryos, *e.g.*, *Peripatus capensis*, in which the cœlomic rudiment is not appreciably reinforced after its first establishment, but contains within itself the germs of practically all the organs which are not developed from the original ectoderm and endoderm. Apart from the Mollusca, in which the history of the mesoderm can only be followed with great difficulty, and is not in all cases known or understood, the mesoderm of Cœlomate animals, when once established, immediately proceeds to show its real nature by assuming the form and relations of the cœlom. In the first place it acquires a cavity or series of cœlomic cavities, which become transformed into the body-cavity (except in the Arthropoda), into the renal organs (with the possible exception, again, of some Arthropoda), and into the reproductive glands. In metamerically segmented animals the appearance of these cavities is synchronous with, and indeed determines, the appearance of metameric segmentation. In all segmented animals in which the cœlomic rudiment appears as a continuous sheet or band of tissue on each side of the body, the cœlomic cavity makes its first appearance not as a continuous space on each side, which later becomes divided up into the structures called mesoblastic somites, but as a series of paired spaces round which the cœlomic tissue arranges itself in an epithelial manner. In the Vertebrata, it is true, the ventral portion of the cœlom appears at first as a continuous space, at any rate behind the region of the two anterior pairs of somites, but in the dorsal portion the cœlomic cavity is developed in the usual way, the cœlomic tissue becoming transformed into the muscle plates and rudimentary renal tubules of the later stages. With regard to this ventral portion of the cœlom in Vertebrata, it is to be noticed that the cavity in it never becomes divided up, but always remains continuous, forming the perivisceral portion of the cœlom. The probable explanation of this peculiarity in the development of the Vertebrate cœlom, as compared with that of *Amphioxus* and other segmented animals, is that the segmented stage of the ventral portion of the cœlom is omitted. This explanation derives some support from the fact that even in animals in which the cœlom is at its first appearance wholly segmented, it frequently happens that in the adult the perivisceral portion of it is unsegmented, *i.e.*, it loses during development the segmentation which it at first possesses. This happens in many Annelida and in *Amphioxus*. The lesson, then, which the early history of the cœlom in segmented animals teaches, is that however the cœlomic cavity first makes its appearance, whether by evaginations from the primitive enteron, or by the hollowing out of a solid blastema-like tissue which has developed from one or both of the primary layers, it is in its first origin segmented, and forms the basis on which the segments of the adult are moulded. In Arthropoda the origin of the cœlom is similar to that of Annelids, but its history is not completely known in any group, with the exception of *Peripatus*. In this genus it develops no perivisceral portion, as in other groups, but gives rise solely to the nephridia and to the reproductive organs. It is probable, though not certainly proved, that the history of the cœlom in other Arthropods is essentially similar to that of *Peripatus*, allowance being made for the fact that the nephridial portion does not attain full development in those forms which are without nephridia in the adult.

With regard to the development of the vascular system, little can be said here, except that it appears to arise in all cases from the spaces of the mesoblastic reticulum. These acquire special epithelial walls, and form the main trunks and network of smaller vessels found in animals with a canalicular vascular system, or the large sinus-like spaces characteristic of animals with a hæmocœlic body-cavity.

Transient embryonic organs.

The existence of a phase at the beginning of life during which a young animal acquires its equipment by a process of growth of the germ is of course intelligible enough; such a phase is seen in the formation of buds, and in the sexual reproduction of both animals and plants. The remarkable point is that while in most cases this embryonic growth is a direct and simple process—*e.g.*, animal and plant buds, embryonic development of plant seeds—in many cases of sexual reproduction of animals it is not direct, and the embryonic phase shows stages of structure which seem to possess a meaning other than that of being merely phases of growth. The fact that these stages of structure through which the embryo passes sometimes present for a short time features which are permanent in other members of the same group, adds very largely to the interest of the phenomenon and necessitates its careful examination. This may be divided into two heads: (1) in relation to embryos, (2) in relation to larvæ. So far as embryos are concerned, we shall limit ourselves mainly to a consideration of the Vertebrata, because in them are found most instances of that remarkable phenomenon, the temporary assumption by certain organs of the embryo of stages of structure which are permanent in other members of the same group. As is well known, the embryos of the higher Vertebrata possess in the structure of the pharynx and of the heart and vascular system certain features—namely, paired pharyngeal apertures, a simple tubular heart, and a single ventral aorta giving off right and left a number of branches which pass between the pharyngeal apertures—which permanently characterize those organs in fishes. The skeleton, largely bony in the adult, passes through a stage in which it is entirely without bone, and consists mainly of cartilage—the form which it permanently possesses in certain fishes. Further, the Vertebrate embryo possesses for a time a notochord, a segmented muscular system, a continuity between the pericardium and the posterior part of the perivisceral cavity—all features which characterize certain groups of Pisces in the adult state. Instances of this kind might be multiplied, for the work of anatomists and embryologists has of late years been largely devoted to adding to them. Examples of embryonic characters which are not found in the adults of other Vertebrates, are the following:—At a certain stage of development the central nervous system has the form of a groove in the skin, there is a communication at the hind end of the body between the neural and alimentary canals, the mouth aperture has at first the form of an elongated slit, the growing end of the Wolffian duct is in some groups continuous with the ectoderm, and the retina is at one stage a portion of the wall of the medullary canal. In the embryos of the lower Vertebrates many other instances of the same interesting character might be mentioned; for instance, the presence of a cœlomic sac close to the eye, of another in the jaw, and of a third near the ear (Elasmobranchs), the opening of the Müllerian duct into the front end of the Wolffian duct, and the presence of an aperture of communication between the muscle-plate cœlom and the nephridial cœlom.

The interest attaching to these remarkable facts is much increased by the explanation which has been given of them. That explanation, which is a deduction from the theory of evolution, is to the effect that the peculiar embryonic structures and relations just mentioned are due to the retention by the embryo of features which, once possessed by the ancestor, have been lost in the course of evolution.

This explanation, which at once suggests itself when we are dealing with structures actually present in adult members of other groups, does not so obviously apply to those features which are found in no adult animal whatsoever. Nevertheless it has been extended to them, because they are of a nature which it is not impossible to suppose might have existed in a working animal. Now this explanation, which, it will be observed, can only be entertained on the assumption that the evolution theory is true, has been still further extended by embryologists in a remarkable and frequently unjustifiable manner, and has been applied to all embryonic processes, finally leading to the so-called recapitulation theory, which asserts that embryonic history is a shortened recapitulation of ancestral history, or, to use the language of modern zoology, that the ontogeny or development of the individual contains an abbreviated record of the phylogeny or development of the race. A theory so important and far-reaching as this requires very careful examination. When we come to look for the facts upon which it is based, we find that they are non-existent, for the ancestors of all living animals are dead, and we have no means of knowing what they were like. It is true there are fossil remains of animals which have lived, but these are so imperfect as to be practically useless for the present requirements. Moreover, if they were perfectly preserved, there would be no evidence to show that they were ancestors of the animals now living. They might have been animals which have become extinct and left no descendants. Thus the explanation ordinarily given of the embryonic structures referred to is purely a deduction from the evolution theory. Indeed, it is even less than this, for all that can be said is something of this kind:—if the evolution theory is true, then it is conceivable that the reason why the embryo of a bird passes through a stage in which its pharynx presents some resemblance to that of a fish is that a remote ancestor of the bird possessed a pharynx with lateral apertures such as are at present found in fishes.

Recapitulation theory.

But the explanation is sometimes pushed even farther, and it is said that these pharyngeal apertures of the ancestral bird had the same respiratory function as the corresponding structures in modern fishes. That this is going too far a little reflection will show. For if it be admitted that all so-called vestigial structures had once the same function as the homologous structures when fully developed in other animals, it becomes necessary to admit that male mammals must once have had fully developed mammary glands and suckled the young, that female mammals formerly were provided with a functional penis, and that in species in which the females have a trace of the secondary sexual characters of the male the latter were once common to both sexes. The second and more extended form of the explanation plainly introduces a considerable amount of contentious matter, and it will be advisable, in the first instance, at any rate, to confine ourselves to a critical examination of the less ambitious conception. This explanation obviously implies the view that in the course of evolution the tendency has been for structures to persist in the embryo after they have been lost in the adult. Is there any justification for this view? It is clearly impossible to get any direct evidence, because, as explained above, we have no knowledge of the ancestors of living animals; but if we assume the evolution theory to be true, there is a certain amount of indirect evidence which is distinctly opposed to the view. As is well known, living birds are without teeth, but it is generally assumed that their edentulous condition has been comparatively recently acquired, and that they are descended from animals which, at a time not very remote from the present, possessed teeth. Considering the resemblance of birds to other terrestrial vertebrates, and the fact that extinct birds, not greatly differing from birds now living, are known to have had teeth, it must be allowed that there is some warrant for the assumption. Yet in no single case has it been certainly shown that any trace of teeth has been developed in the embryo. The same remark applies to a large number of similar cases; for instance, the reduced digits of the bird's hand and foot, and the limbs of snakes. Moreover, organs which are supposed to have become recently reduced and functionless in the adult are also reduced in the embryo; for instance, digits 3 and 4 of the horse's foot, the hind limbs of whales (Guldberg and Nansen, "On the Development and Structure of Whales," *Bergen Museum*, 1894), the spiracle of Elasmobranchii. In fact, considerations of this kind distinctly point to the view that any tendency to the reduction or enlargement of an organ in the adult is shared approximately to the same extent by the embryo. But there are undoubtedly some, though not many, cases in which organs which were presumably present in an ancestral adult have persisted in the embryo of the modern form. As an instance may be mentioned the presence in whalebone whales of imperfectly formed teeth, which are absorbed comparatively early in fœtal life (Julin, *Arch. Biologie*, i., 1880, p. 75).

It therefore becomes necessary to inquire why in some cases an organ is retained by the embryo after its loss by the adult, whereas in other cases it dwindles and presumably disappears simultaneously in the embryo and the adult. The whole question is examined and discussed by the present writer in the *Q.J.M.S.* xxxvi., 1894, p. 35, and the conclusions there reached are as follow:—A disappearing adult organ is not retained in a relatively greater development by an organism in the earlier stages of its individual growth unless it is of functional importance to the young form. In cases in which the whole development is embryonic this rarely happens, because the conditions of embryonic life are so different from free life that functional embryonic organs are usually organs *sui generis*, which cannot be traced to a modification of organs previously present in the adult. It does, however, appear to have happened sometimes, and as an instance of it may be mentioned the *ductus arteriosus* of the Sauropsidan and Mammalian embryo. On the other hand, when there is a considerable period of larval life, it does appear that there is a strong case for thinking that organs which have been lost by the adult may be retained and made use of by the larva. The best-known example that can be given of this is the tadpole of the frog. Here we find organs, viz., gills and gill-slits, which are universally regarded as having been attributes of all terrestrial Vertebrata in an earlier and aquatic condition, and we also notice that their retention is due to their being useful on account of the supposed ancient conditions of life having been retained. Many other instances, more or less plausible, of a like retention of ancestral features by larvæ might be mentioned, and it must be conceded that there are strong reasons for supposing that larvæ often retain traces, more or less complete, of ancestral stages of structure. But this admission does not carry with it any obligation to accept the widely prevalent view that larval history can in any way be regarded as a recapitulation of ancestral history. Far from it, for larvæ in retaining some ancestral features are in no way different from adults; they only differ from adults in the features which they have retained. Both larvæ and adults retain ancestral features, and both have been modified by an adaptation to their respective conditions of life which has ever been becoming more perfect.

The conclusion, then, has been reached, that whereas larvæ frequently retain traces of ancestral stages of adult structure, embryos will rarely do so; and we are confronted again with the question, How are we to account for the presence in the embryo of numerous functionless organs which cannot be explained otherwise than as having been inherited from a previous condition in which they were functional? The answer is that the only organs of this kind which have been retained are organs which have been retained by the larvæ of the ancestors after they have been lost by the adult, and have become in this way impressed upon the development. As an illustration taken from current natural history of the manner in which larval characters are in actual process of becoming embryonic may be mentioned the case of the viviparous salamander (*Salamander atra*), in which the gills, &c., are all developed but never used, the animal being born without them. In other and closely allied species of salamander there is a considerable period of larval life in which the gills and gill-slits are functional, but in this species the larval stage, for the existence of which there was a distinct reason, viz., the entirely aquatic habits of life in the young state, has become at one stroke embryonic by its simple absorption into the embryonic period. The view, then, that embryonic development is essentially a recapitulation of ancestral history must be given up; it contains only a few references to ancestral history, namely, those which have been preserved probably in a much modified form by previous larvæ.

We must now pass to the consideration of another supposed law of embryology—the so-called law of v. Baer. This generalization is usually stated as follows:—

Law of v. Baer.

Embryos of different species of the same group are more alike than adults, and the resemblances are greater the younger the embryo examined. Great importance has been attached to this generalization by embryologists and naturalists, and it is very widely accepted. Nevertheless, it is open to serious criticism. If it were true, we should expect to find that embryos of closely similar species would be indistinguishable, but this is notoriously not the case. On the contrary, they often differ more than do the adults, in support of which statement the embryos of the different species of *Peripatus* may be referred to. The generalization undoubtedly had its origin in the fact that there is what may be called a family resemblance between embryos, but this resemblance, which is by no means exact, is purely superficial, and does not extend to anatomical detail. On the contrary, it may be fairly argued that in some cases embryos of widely dissimilar members of the same group present anatomical differences of a higher morphological value than do the adults (see Sedgwick, *loc. cit.*), and, as stated above, the embryos of closely allied animals are distinguishable at all stages of development, though the distinguishing features are not the same as those which distinguish the adults. To say that the development of the organism and of its component parts is a progress from the simple to the complex is to state a truism, but to state that it is also a progress from the general to the special is to go altogether beyond the facts. The bipinnaria larva of an echinoderm, the trochosphere larva of an annelid, the blastodermic vesicle of a mammal are all as highly specialized as their respective adults, but the specialization is for a different purpose, and of a different kind to that which characterizes the adult.

For an account of the history of the subject the reader is referred to the article EMBRYOLOGY in the 9th edition of this *Encyclopædia*, where he will also find under the heading REPRODUCTION information respecting the menstruation, fertilization, gestation, parental care, formation of ovum, and spermatozoon. The following books contain fuller information:—K. E. VON BAER. *Ueber Entwicklungsgeschichte der Thiere.* Königsberg, 1828, 1837.—F. M. BALFOUR. *A Monograph of the Development of Elasmobranch Fishes.* London, 1878. *A Treatise on Comparative Embryology*, vols. i. and ii. London, 1885 (still the most important work on Vertebrate Embryology).—M. DUVAL. *Atlas d'Embryologie.* Paris, 1889. —M. FOSTER and F. M. BALFOUR. *Elements of Embryology.* London, 1883.—O. HERTWIG. *Lehrbuch der Entwicklungsgeschichte des Menschen u. der Wirbelthiere*, 6th edition. Jena, 1898.—A. KÖLLIKER. *Entwicklungsgeschichte des Menschen u. der höheren Thiere.* Leipzig, 1879.—E. KORSCHELT and K. HEIDER. *Lehrbuch der vergleich. Entwicklungsgeschichte der wirbellosen Thiere.* Jena, 1890 (English translation, London, 1895–1900).—A. M. MARSHALL. *Vertebrate Embryology.* London, 1893.—C. S. MINOT. *Human Embryology.* New York, 1892.

(A. SE*.)

PHYSIOLOGY OF DEVELOPMENT.

Physiology of Development [in German, *Entwicklungsmechanik* (Roux), *Entwicklungsphysiologie* (Driesch), *Physiologische Morphologie* (Loeb)] is, in the broadest meaning of the word, the experimental science of morphogenesis, *i.e.*, of the laws that govern morphological differentiation. In this sense it embraces the study of regeneration and variation, and would, as a whole, best be called rational morphology. Here we shall treat of the Physiology of Development in a narrower sense, as the study of the laws that govern the development of the adult organism from the egg, REGENERATION and VARIATION forming the subjects of special articles.

After the work done by His, Goette, and Pflüger, who gave a sort of general outline and orientation of the subject, the first to study developmental problems properly in a systematical way, and with full conviction of their great importance, was Wilhelm Roux. This observer, having found by a full analysis of the facts of "development" that the first special problem to be worked out was the question when and where the first differentiation appeared, got as his main result that, when one of the two first blastomeres (cleavage cells) of the frog's egg was killed, the living one developed into a typical half-embryo, *i.e.*, an embryo that was either the right or the left part of a whole one. From that Roux concluded that the first cleavage plane determined already the median plane of the adult; and that the basis of all differentiation was given by an unequal division of the nuclear substances during karyokinesis, a result that was also attained on a purely theoretical basis by Weismann. Hans Driesch repeated Roux's fundamental experiment with a different method on the sea-urchin's egg, with a result that was absolutely contrary to that of Roux: the isolated blastomere cleaved like half the egg, but it resulted in a whole blastula and a whole embryo, which differed from a normal one only in its small size. Driesch's result was obtained in somewhat the same manner by Wilson with the egg of Amphioxus, by Zoja with the egg of Medusæ, &c. It thus became very probable that an inequality of nuclear division could not be the basis of differentiation. The following experiments were still more fatal to the theories of Roux and of Weismann. Driesch found that, even when the first eight or sixteen cells of the cleaving egg of the sea-urchin were brought into quite abnormal positions with regard to one another, still a quite normal embryo was developed; Driesch and Morgan discovered jointly that in the Ctenophore egg one isolated blastomere developed into a half-embryo, but that the same was the case if a portion of protoplasm was cut off from the fertilized egg not yet in cleavage; last, but not of least importance, in the case of the frog's egg which had been Roux's actual subject of experiment, conditions were discovered by O. Schultze and O. Hertwig under which one of the two first blastomeres of this egg developed into a whole embryo of half size. This result was made still more decisive by

Morgan, who showed that it was quite in the power of the experimenter to get either a half-embryo or a whole one of half size, the latter dependent only upon giving to the blastomere the opportunity for a rearrangement of its matter by turning it over.

Thus we may say that the general result of the introductory series of experiments in the physiology of development is the following:—In many forms, *e.g.*, Echinoderms, Amphioxus, Ascidians, Fishes, and Medusæ, the potentiality (*prospective Potenz*—Driesch) of all the blastomeres of the segmented egg is the same, *i.e.*, each of them may play any or every part in the future development; the prospective value (*prosp. Bedeutung*—D.) of each blastomere depends upon, or is a function of, its position in the whole of the segmented egg; we can term the "whole" of the egg after cleavage an "aequipotential system" (Driesch). But though aequipotential, the whole of the segmented egg is nevertheless not devoid of orientation or direction; the general law of causality compels us to assume a general orientation of the smallest parts of the egg, even in cases where we are not able to see it. It has been experimentally proved that external stimuli (light, heat, pressure, &c.) are not responsible for the first differentiation of organs in the embryo; thus, should the segmented egg be absolutely equal in itself, it would be incomprehensible that the first organs should be formed at one special point of it, and not at another. Besides this general argument, we see a sort of orientation in the typical forms of the polar or bilateral cleavage stages.

Differentiation, therefore, depends on a primary, *i.e.*, innate, orientation of the egg's plasma in those forms, the segmented eggs of which represent aequipotential systems; this orientation is capable of a sort of regulation or restoration after disturbances of any sort; in the egg of the Ctenophora such a regulation is not possible, and in the frog's egg it is facultative, *i.e.*, possible under certain conditions, but impossible under others. Should this interpretation be right, the differences between the eggs of different animals would not be so great as it seemed at first: differences with regard to the potentialities of the blastomeres would only be differences with regard to the capability of regulation or restoration of the egg's protoplasm.

The foundation of physiological embryology being laid, we now can shortly deal with the whole series of special problems offered to us by a general analysis of that science, but at present worked out only to a very small extent.

We may ask the following questions:—What are the general conditions of development? On what general factors does it depend? How do the different organs of the partly developed embryo stand with regard to their future fate? What are the stimuli (*Reize*) effecting differentiation? What is to be said about the specific character of the different formative effects? And as the most important question of all: Are all the problems offered to us in the physiology of development to be solved with the aid of the laws known hitherto in science, or do we want specifically new "vitalistic" factors?

Conditions of differentiation.

Energy in different forms is required for development, and is provided by the surrounding medium. Light, though of no influence on the cleavage (Driesch), has a great effect on the later stages of development (Young), and is also necessary for the formation of polyps in Eudendrium (Loeb). That a certain temperature is necessary for ontogeny has long been known; this was carefully studied by O. Hertwig, as was also the influence of heat on the rate of development. Oxygen is also wanted, either from a certain stage of development or from the very beginning of it, though very nearly related forms differ in this respect (Loeb). The great influence of osmotic pressure on growth was studied by Loeb, Herbst, and Davenport. In all these cases energy may be necessary for development in general, or a specific form of energy may be necessary for the formation of a specific organ; it is clear that, especially in the latter case, energy is shown to be a proper factor for morphogenesis. Besides energy, a certain chemical condition of the medium, whether offered by the water in which the egg lives or (especially in later stages) by the food, is of great importance for normal ontogeny; the only careful study in this respect was carried out by Herbst for the development of the egg of Echinids. This investigator has shown that all salts of the sea water are of great importance for development, and most of them specifically and typically; for instance, calcium is absolutely necessary for holding together the embryonic cells, and without calcium all cells will fall apart, though they do not die, but live to develop farther.

What we have dealt with may be called external factors of development; as to their complement, the internal factors, it is clear that every elementary factor of general physiology may be regarded as one of them. Chemical metamorphosis plays, of course, a great part in differentiation, especially in the form of secretions; but very little has been carefully studied in this respect. Movement of living matter, whether of cells or of intracellular substance, is another important factor (Bütschli, Dreyer, Rhumbler). Cell-division is another, its differences in direction, rate, and quantity being of great importance for differentiation. We know very little about it; a so-called law of O. Hertwig, that a cell would divide at right angles to its longest diameter, though experimentally stated in some cases, does not hold for all, and the only thing we can say is, that the unknown primary organization of the egg is here responsible. (Compare the papers on "cell-lineage" of Wilson, Lillie, Jennings, Zurstrassen, and others.) Of the inner factors of ontogeny there is another category that may be called physical, that already spoken of being physiological. The most important of these is the capillarity of the cell surfaces. Berthold was the first to call attention to its rôle in the arrangement of cell composites, and afterwards the matter was more carefully studied by Dreyer, Driesch, and especially Roux, with the result that the arrangement of cells follows the principle of surfaces *minimæ areæ* (Plateau) as much as is reconcilable with the conditions of the system.

Potentialities of embryonic cells.

It has already been shown that in many cases the embryo after cleavage, *i.e.*, the blastula, is an "aequipotential system." It was shown that in the egg of Echinids there existed such an absolute lack of determination of the cleavage cells that (*a*) the cells may be put in quite abnormal positions with reference to one another without disturbing development; (*b*) a quarter blastomere gives a quite normal little pluteus, even a sixteenth yields a gastrula; (*c*) two eggs may fuse in the early blastula stage, giving one single normal embryo of double size. Our next question concerns the distribution of potentiality, when the embryo is developed farther than the blastula stage. In this case it has been shown that the potentialities of the different embryonic organs are different: that, for instance, in Echinoderms or Amphibians the ectoderm, when isolated, is not able to form endoderm, and so on (Driesch, Barfurth); but it has been shown at the same time that the ectoderm in itself, the intestine in itself of Echinoderms (Driesch), the medullary plate in itself of Triton (Spemann), is as aequipotential as was the blastula: that any part whatever of these organs may be taken away without disturbing the development of the rest into a normal and proportional embryonic part, except for its smaller size.

If the single phases of differentiation are to be regarded as effects, we must ask for the causes, or stimuli, of these effects. For a full account of the subject we refer to Herbst, by whom also the whole botanical literature, much more important than the zoological, is critically reviewed. We have already seen that when the blastula represents an aequipotential system, there must be some sort of primary organization of the egg, recoverable after disturbances, that directs and localizes the formation of the first embryonic organs; we do not know much about this organization. Directive stimuli (*Richtungsreize*) play a great rôle in ontogeny; Herbst has analysed many cases where their existence is probable. They have been experimentally proved in two cases. The chromatic cells of the yolk sac of Fundulus are attracted by the oxygen of the arteriæ (Loeb); the mesenchyme cells of Echinus are attracted by some specific parts of the ectoderm, for they move towards them also when removed from their original positions to any point of the blastocœl by shaking (Driesch). Many directive stimuli might be discovered by a careful study of grafting experiments, such as have been made by Born, Joest, Harrison, and others, but at present these experiments have not been carried out far enough to get exact results.

Formative stimuli.

Formative stimuli in a narrower meaning of the word, *i.e.*, stimuli affecting the origin of embryonic organs, have long been known in botany; in zoology we know (especially from Loeb) a good deal about the influence of light, gravitation, contact, &c., on the formation of organs in hydroids, but these forms are very plant-like in many respects; as to free-living animals, Herbst proved that the formation of the arms of the pluteus larva depends on the existence of the calcareous tetrahedra, and made in other cases (lens of vertebrate eye, nerves and muscles, &c.) the existence of formative stimuli very probable. Many of the facts generally known as functional adaptations (*functionelle Anpassung*—Roux) in botany and zoology may also belong to this category, *i.e.*, be the effects of some external stimulus, but they are far from having been analysed in a satisfactory manner. That the structure of parts of the vertebrate skeleton is always in relation to their function, even under abnormal conditions, is well known; what is the real "cause" of differentiation in this case is difficult to say.

Specific characters.

It is obvious that we cannot answer the question why the different ontogenetic effects are just what they are. Developmental physiology takes the specific nature of form for granted, and it may be left for a really rational theory of the evolution of species in the future to answer the problem of species, as far as it is answerable at all. What we intend to do here is only to say in a few words wherein consists the specific character of embryonic organs. That embryonic parts are specific or typical in regard to their protoplasm is obvious, and is well proved by the fact that the different parts of the embryo react differently to the same chemical or other reagents (Herbst, Loeb). That they may be typical also in regard to their nuclei was shown by Boveri for the generative cells of Ascaris; we are not able at present to say anything definite about the importance of this fact. The specific nature of an embryonic organ consists to a high degree in the number of cells composing it; it was shown for many cases that this number, and also the size of cells, is constant under constant conditions, and that under inconstant conditions the number is variable, the size constant; for instance, embryos which have developed from one of the two first blastomeres show only half the normal number of cells in their organs (Morgan, Driesch).

We have learnt that the successive steps of embryonic development are to be regarded as effects, caused by stimuli, which partly exist in the embryo itself. But it must be noted that not every part of the embryo is dependent on every other one, but that there exists a great independence of the parts, to a varying degree in every case. This partial independence has been called self-differentiation (*Selbstdifferenzierung*) by Roux, and is certainly a characteristic feature of ontogeny. At the same time it must not be forgotten that the word is only relative, and that it only expresses our recognition of a negation.

Self-differentiation.

For instance, we know that the ectoderm of Echinus may develop farther if the endoderm is taken away; in other words, that it develops by self-differentiation in regard to the endoderm, that its differentiation is not dependent on the endoderm; but it would be obviously more important to know the factors on which this differentiation is actually dependent than to know one factor on which it is not. The same is true for all other experiments on "self-differentiation," whether analytical (Loeb, Schaper, Driesch) or not (grafting experiments, Born, Joest, &c.).

Vitalism.

Can we understand differentiation by means of the laws of natural phenomena offered to us by physics and chemistry? Most people would say yes, though not yet. Driesch has tried to show that we are absolutely not able to understand development, at any rate one part of it, *i.e.*, the localization of the various successive steps of differentiation. But it is impossible to give any idea of this argument in a few words, and we can only say here that it is based on the experiments upon isolated blastomeres, &c., and on an analysis of the character of aequipotential systems. In this way physiology of development would lead us straight on into Vitalism.

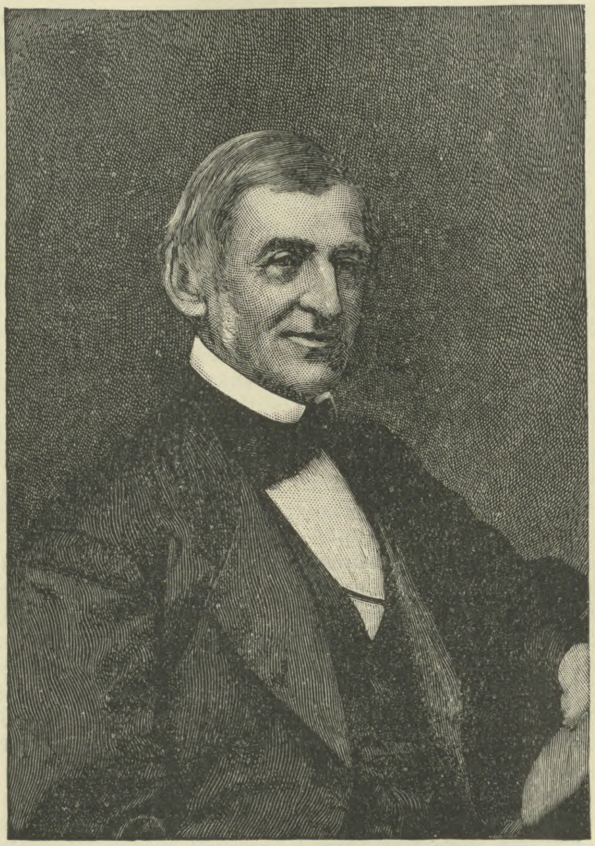
REFERENCES.—An account of the subject, with full literature, is given by DRIESCH, *Resultate und Probleme der Entwicklungsphysiologie der Thiere in Ergebnisse der Anat. u. Entw. gesch.*, 1899. Other works are:—DAVENPORT. *Experimental Morphology.* New York, 1897–99.—DELAGE. *La structure du protoplasm*, &c. 1895. —DRIESCH. *Mathem. mech. Betrachtung morpholog. Probleme.* Jena, 1891. *Entwicklungsmechan. Studien.*, 1891–93. *Analytische Theorie d. organ. Entw.* Leipzig, 1894. *Studien über d. Regulationsvermögen*, 1897–1900, &c.—HERBST. *Ueber die Bedeutung d. Reizphysiologie für die kausale Auffassung von Vorgängen i. d. thier. Ontogenese. Biolog. Centralblatt*, vols. xiv. u. xv. Leipzig, 1901.—Many papers on influence of salts on development in *Arch. f. Entw. Mech.*—O. HERTWIG. Papers in *Arch. f. mikr. Anat. Die Zelle und die Gewebe*, ii. Jena, 1897.—HIS. *Unsere Körperform.* Leipzig, 1875.—J. LOEB. *Untersuch. z. physiol. Morph.* Würzburg, 1891–92. Papers in *Arch. f. Entw. Mech.* and Pflüger's *Archiv.*—MORGAN. *The Development of the Frog's Egg.* New York, 1897. Papers in *Arch. f. Entw. Mech.*—ROUX. *Gesammelte Abhandlungen.* Leipzig, 1895. Papers in *Arch. f. Entw. Mech.*—WEISMANN. *Das Keimplasma.* Jena, 1892.—WILSON. Papers in *Journ. Morph. The Cell in Development and Inheritance.* New York, 1896.

(H. A. E. D.)

Emden, a town of Prussia, province of Hanover, near the mouth of the Ems, 49 miles north-west from Oldenburg by rail. The town-hall (1574–76) possesses an exceptionally interesting collection of weapons of war. There are two other museums, one of art, coins, and Frisian antiquities, the other containing specimens of natural history. It has a school of navigation. Emden is the seat of an active trade in agricultural produce and live-stock, timber, coal, tea, wine, and fish. Cement, wire ropes, sugar, tobacco, woollens, and leather are manufactured. The harbour has been greatly improved in consequence of the construction of the Ems–Jade and the Ems–Dortmund canals; and in 1900 the Prussian Government resolved to enlarge the outer harbour and deepen it to 37 ft. 8½ in., as well as deepen the lower Ems to 32 ft. 9 in., the total cost being estimated at close upon £400,000. Population (1885), 14,019; (1900), 16,453.

Emerson, Ralph Waldo (1803–1882), American poet and essayist, was born in Boston, Massachusetts, 25th May 1803. Seven of his ancestors were ministers of New England churches. Among them were some of those men of mark who made the backbone of the American character: the sturdy Puritan, Peter Bulkeley, sometime rector of Odell in Bedfordshire, and afterward pastor of the church in the wilderness at Concord, New Hampshire; the zealous evangelist, Father Samuel Moody of Agamenticus in Maine, who pursued graceless sinners even into the alehouse; Joseph Emerson of Malden, "a heroic scholar," who prayed every night that no descendant of his might ever be rich; and William Emerson of Concord, Mass., the patriot preacher, who died while serving in the army of the Revolution. Sprung from such stock, Emerson inherited qualities of self-reliance, love of liberty, strenuous virtue, sincerity, sobriety, and fearless loyalty to ideals. The form of his ideals was modified by the metamorphic glow of Transcendentalism which passed through the region of Boston in the second quarter of the 19th century. But the spirit in which Emerson conceived the laws of life, reverenced them, and lived them out, was the Puritan spirit, elevated, enlarged, and beautified by the poetic temperament.

His father was the Rev. William Emerson, minister of the First Church (Unitarian) in Boston. Ralph Waldo was the fourth child in a family of eight, of whom at least three gave evidence of extraordinary mental powers. He was brought up in an atmosphere of hard work, of moral discipline, and (after his father's death in 1811) of that wholesome self-sacrifice which is a condition of life for those who are poor in money and rich in spirit. His aunt, Miss Mary Moody Emerson, a brilliant old maid, an eccentric saint, was a potent factor in his education. Loving him, believing in his powers, passionately desiring for him a successful career, but clinging with both hands to the old forms of faith from which he floated away, this solitary, intense woman did as much as any one to form, by action and reaction, the mind and character of the young Emerson. In 1817 he entered Harvard College, and graduated in 1821. In scholarship he ranked about the middle of his class. In literature and oratory he was more distinguished, receiving a Boylston prize for declamation, and two Bowdoin prizes for dissertations, the first essay being on "The Character of Socrates" and the second on "The Present State of Ethical Philosophy"—both rather dull, formal, didactic productions. He was fond of reading and of writing verse, and was chosen as the poet for class-day. His cheerful serenity of manner, his tranquil mirthfulness, and the steady charm of his personality, made him a favourite with his fellows, in spite of a certain reserve. His literary taste was conventional, including the standard British writers, with a preference for Shakespeare among the poets, Berkeley among the philosophers, and Montaigne (in Cotton's translation) among the essayists. His particular admiration among the college professors was the stately rhetorician, Edward Everett; and this predilection had much to do with his early ambition to be a professor of rhetoric and elocution.



RALPH WALDO EMERSON.
(From a photograph by Elliott & Fry, London.)

Immediately after graduation he became an assistant in his brother William's school for young ladies in Boston, and continued teaching, with much inward reluctance and discomfort, for three years. The routine was distasteful; he despised the superficial details which claimed so much of his time. The bonds of conventionalism were silently dissolving in the rising glow of his poetic nature. Independence, sincerity, reality, grew more and more necessary to him. His aunt urged him to seek retirement, self-reliance, friendship with nature; to be no longer "the nurseling of surrounding circumstances," but to prepare a celestial abode for the muse. The passion for spiritual leadership stirred within him. The ministry seemed to offer the fairest field for its satisfaction. In 1825 he entered the divinity school at Cambridge, to prepare himself for the Unitarian pulpit. His course was much interrupted by ill-health. His studies were irregular, and far more philosophical and literary than theological. In October 1826 he was "approbated to preach" by the Middlesex Association of Ministers. The same year a threatened consumption compelled him to take a long journey in the south. Returning in 1827, he continued his studies, preached as a candidate in various churches, and improved in health. In 1829 he married a beautiful but delicate young woman, Miss Ellen Tucker of Concord, and was installed as associate minister of the Second Church (Unitarian) in Boston. The retirement of his senior colleague soon left him the sole pastor. Emerson's early sermons were simple, direct, unconventional. He dealt freely with the things of the spirit. There was a homely elevation in his discourses, a natural freshness in his piety, a quiet enthusiasm in his manner, that charmed thoughtful hearers. In 1831 he lost his wife, a sorrow that deeply depressed him in health and spirits. In 1832, following his passion for independence and sincerity, he arrived at the conviction that the Lord's Supper was not intended by Christ to be a permanent sacrament. To him, at least, it had become an outgrown form. He was willing to continue the service only if the use of the elements should be dropped and the rite made simply an act of spiritual remembrance. Setting forth these views, candidly and calmly, in a sermon, he found his congregation, not unnaturally, reluctant to agree with him, and therefore retired, not without some disappointment, from the pastoral office. He never again took charge of a parish; but he continued to preach, as opportunity offered, until 1847. In fact, he was always a preacher, though of a singular order. His supreme task was to befriend and guide the inner life of man.

The strongest influences in his development about this time were the liberating philosophy of Coleridge, the mystical visions of Swedenborg, the intimate poetry of Wordsworth, and the stimulating essays of Carlyle. On Christmas Day 1832 he took passage in a sailing vessel for the Mediterranean. He travelled through Italy, visited Paris, spent two months in Scotland and England, and saw the four men whom he most desired to see—Landor, Coleridge, Carlyle, and Wordsworth. "The comfort of meeting such men of genius as these," he wrote, "is that they talk sincerely." But he adds that he found all four of them, in different degrees, deficient in insight into religious truth. His visit to Carlyle, in the lonely farm-house at Craigenputtock, was the memorable beginning of a lifelong friendship. Emerson published Carlyle's first books in America. Carlyle introduced Emerson's Essays into England. The two men were bound together by a mutual respect deeper than a sympathy of tastes, and a community of spirit stronger than a similarity of opinions. Emerson was a sweet-tempered Carlyle, living in the sunshine. Carlyle was a militant Emerson, moving amid thunderclouds. The things that each most admired in the other were self-reliance, directness, moral courage. A passage in Emerson's Diary, written on his homeward voyage, strikes the keynote of his remaining life. "A man contains all that is needful to his government within himself. . . . All real good or evil that can befall him must be from himself. . . . There is a correspondence between the human soul and everything that exists in the world; more properly, everything that is known to man. Instead of studying things without, the principles of them all may be penetrated into within him. . . . The purpose of life seems to be to acquaint man with himself. . . . The highest revelation is that God is in every man." Here is the essence of that intuitional philosophy, commonly called Transcendentalism. Emerson disclaimed allegiance to that philosophy. He called it "the saturnalia, or excess of faith." His practical common sense recoiled from the amazing conclusions which were drawn from it by many of its more eccentric advocates. His independence revolted against being bound to any scheme or system of doctrine, however nebulous. He said: "I wish to say what I feel and think to-day, with the proviso that to-morrow perhaps I shall contradict it all." But this very wish commits him to the doctrine of the inner light. All through his life he navigated the Transcendental sea, piloted by a clear moral sense, warned off the rocks by the saving grace of humour, and kept from capsizing by a good ballast of New England prudence.

After his return from England in 1833 he went to live with his mother at the old manse in Concord, Mass., and began his career as a lecturer in Boston. His first discourses were delivered before the Society of Natural History and the Mechanics' Institute. They were chiefly on scientific subjects, approached in a poetic spirit. In the autumn of 1835 he married Miss Lydia Jackson of Plymouth, having previously purchased a spacious old house and garden at Concord. There he spent the remainder of his life, a devoted husband, a wise and tender father, a careful householder, a virtuous villager, a friendly neighbour, and, spite of all his disclaimers, the central and luminous figure among the Transcendentalists. The doctrine which in others seemed to produce all sorts of extravagances—communistic experiments at Brook Farm and Fruitlands, weird schemes of political reform, long hair on men and short hair on women—in his sane, well-balanced nature served only to lend an ideal charm to the familiar outline of a plain, orderly New England life. Some mild departures from established routine he tranquilly tested and as tranquilly abandoned. He tried vegetarianism for a while, but gave it up when he found that it did him no particular good. An attempt to illustrate household equality by having the servants sit at table with the rest of the family was frustrated by the dislike of his two sensible domestics for such an inconvenient arrangement. His theory that manual labour should form part of the scholar's life was checked by the personal discovery that hard labour in the fields meant poor work in the study. "The writer shall not dig," was his practical conclusion. Intellectual independence was what he chiefly desired; and this, he found, could be attained in a manner of living not outwardly different from that of the average college professor or country minister. And yet it was to this property-holding, debt-paying, law-abiding, well-dressed, courteous-mannered citizen of Concord that the ardent and enthusiastic turned as the prophet of the new idealism. The influence of other Transcendental teachers, Dr Hedge, Dr Ripley, Bronson Alcott, Orestes Brownson, Theodore Parker, Margaret Fuller, Henry Thoreau, Jones Very, was narrow and parochial compared with that of Emerson. Something in his imperturbable, kindly presence, his angelic look, his musical voice, his commanding style of thought and speech, announced him as the possessor of the great secret which many were seeking—the secret of a freer, deeper, more harmonious life. More and more, as his fame spread, those who "would live in the spirit" came to listen to the voice, and to sit at the feet, of the Sage of Concord.

It was on the lecture-platform that he found his power and won his fame. The courses of lectures that he delivered at the Masonic Temple in Boston, during the winters of 1835 and 1836, on "Great Men," "English Literature," and "The Philosophy of History," were well attended and admired. They were followed by two discourses which commanded for him immediate recognition, part friendly and part hostile, as a new and potent personality. His Phi Beta Kappa oration at Harvard College in August 1837, on "The American Scholars," was an eloquent appeal for independence, sincerity, realism, in the intellectual life of America. His address before the graduating class of the divinity school at Cambridge, in 1838, was an impassioned protest against what he called "the defects of historical Christianity" (its undue reliance upon the personal authority of Jesus, and its failure to explore the moral nature of man as the fountain of established teaching), and a daring plea for absolute self-reliance and a new inspiration of religion. "In the soul," he said, "let redemption be sought. Wherever a man comes, there comes revolution. The old is for slaves. Go alone. Refuse the good models, even those which are sacred in the imagination of men. Cast conformity behind you, and acquaint men at first hand with Deity." In this address Emerson laid his hand on the sensitive point of Unitarianism, which rejected the divinity of Jesus but held fast to his supreme authority. A blaze of controversy sprang up at once. Conservatives attacked him; Radicals defended him. Emerson made no reply. But amid this somewhat fierce illumination he went forward steadily as a public lecturer. It was not his negations that made him popular; it was the eloquence with which he presented the positive side of his doctrine. Whatever the titles of his discourses, "Literary Ethics," "Man the Reformer," "The Present Age," "The Method of Nature," "Representative Men," "The Conduct of Life," their theme was always the same, namely, "the infinitude of the private man." Those who thought him astray on the subject of religion listened to him with delight when he poetized the commonplaces of art, politics, literature, or the household. His utterance was Delphic, inspirational.

There was magic in his elocution. The simplicity and symmetry of his sentences, the modulations of his thrilling voice, the radiance of his fine face, even his slight hesitations and pauses over his manuscript, lent a strange charm to his speech. For more than a generation he went about the country lecturing in cities, towns, and villages, before learned societies, rustic lyceums, and colleges; and there was no man on the platform in America who excelled him in distinction, in authority, or in stimulating eloquence.

In 1847 Emerson visited Great Britain for the second time, was welcomed by Carlyle, lectured to appreciative audiences in Manchester, Liverpool, Edinburgh, and London, made many new friends among the best English people, paid a brief visit to Paris, and returned home in July 1848. "I leave England," he wrote, "with increased respect for the Englishman. His stuff or substance seems to be the best in the world. I forgive him all his pride. My respect is the more generous that I have no sympathy with him, only an admiration." The impressions of this journey were embodied in a book called *English Traits*, published in 1856. It might be called "English Traits and American Confessions," for nowhere does Emerson's Americanism come out more strongly. But the America that he loved and admired was the ideal, the potential America. For the actual conditions of social and political life in his own time he had a fine scorn. He was an intellectual Brahmin. His principles were democratic, his tastes aristocratic. He did not like crowds, streets, hotels—"the people who fill them oppress me with their excessive civility." Humanity was his hero. He loved man, but he was not fond of men. He had grave doubts about universal suffrage. He took a sincere interest in social and political reform, but towards specific "reforms" his attitude was somewhat remote and visionary. On the subject of temperance he held aloof from the intemperate methods of the violent prohibitionists. He was a believer in woman's rights, but he was lukewarm towards conventions in favour of woman suffrage. Even in regard to slavery he had serious hesitations about the ways of the abolitionists, and for a long time refused to be identified with them. But as the irrepressible conflict drew to a head Emerson's hesitation vanished. He said in 1856, "I think we must get rid of slavery, or we must get rid of freedom." With the outbreak of the Civil War he became an ardent and powerful advocate of the cause of the Union. James Russell Lowell said, "To him more than to all other causes did the young martyrs of our Civil War owe the sustaining strength of thoughtful heroism that is so touching in every record of their lives."

Emerson the essayist was a condensation of Emerson the lecturer. His prose works, with the exception of the slender volume entitled *Nature* (1836), were collected and arranged from the manuscripts of his lectures. His method of writing was characteristic. He planted a subject in his mind, and waited for thoughts and illustrations to come to it, as birds or insects to a plant or flower. When an idea appeared, he followed it, "as a boy might hunt a butterfly"; when it was captured he pinned it in his "Thought-book." The writings of other men he used more for stimulus than for guidance. He said that books were for the scholar's idle times. "I value them," he said, "to make my top spin." His favourite reading was poetry and mystical philosophy: Shakespeare, Dante, George Herbert, Goethe, Berkeley, Coleridge, Swedenborg, Jacob Boehmen, Plato, the new Platonists, and the religious books of the East (in translation). Next to these he valued books of biography and anecdote: Plutarch, Grimm, St Simon, Varnhagen von Ense. He had some odd dislikes, and could find nothing in Aristophanes, Cervantes, Shelley, Scott, Miss Austen, Dickens. Novels he seldom read. He was a follower of none, an original borrower from all. His illustrations were drawn from near and far. The zodiac of Denderah; the Savoyards who carved their pine-forests into toys; the naked Derar, horsed on an idea, charging a troop of Roman cavalry; the long, austere Pythagorean lustrum of silence; Napoleon on the deck of the *Bellerophon*, observing the drill of the English soldiers; the Egyptian doctrine that every man has two pairs of eyes; Empedocles and his shoe; the horizontal stratification of the earth; a soft mushroom pushing its way through the hard ground;—all these allusions and a thousand more are found in the same volume. On his pages, close beside the Parthenon, the Sphinx, St Paul's, Ætna, and Vesuvius, you will find the White Mountains, Monadnock, Agiocochook, Katahdin, the pickerel-weed in bloom, the wild geese honking through the sky, the chick-a-dee braving the snow, Wall Street and State Street, cotton-mills, railroads, and Quincy granite. For an abstract thinker he was strangely in love with the concrete facts of life. Idealism, in him, assumed the form of a vivid illumination of the real. From the pages of his teeming note-books he took the material for his lectures, arranging and rearranging it under such titles as Nature, School, Home, Genius, Beauty and Manners, Self-Possession, Duty, The Superlative, Truth, The Anglo-Saxon, The Young American. When the lectures had served their purpose he rearranged the material in essays and published them. Thus appeared in succession the following volumes: *Essays* (First Series), 1841; *Essays* (Second Series), 1844; *Representative Men*, 1850; *English Traits*, 1856; *The Conduct of Life*, 1860; *Society and Solitude*, 1870; *Letters and Social Aims*, 1876. Besides these, many other lectures were printed in separate form and in various combinations.

Emerson's style is brilliant, epigrammatic, gem-like; clear in sentences, obscure in paragraphs. He was a sporadic observer. He saw by flashes. He said, "I do not know what arguments mean in reference to any expression of a thought." The coherence of his writing lies in his personality. His work is fused by a steady glow of optimism. Yet he states this optimism moderately. "The genius which preserves and guides the human race indicates itself by a small excess of good, a small balance in brute facts always favourable to the side of reason."

His verse, though in form inferior to his prose, was perhaps a truer expression of his genius. He said, "I am born a poet"; and again, writing to Carlyle, he called himself "half a bard." He had "the vision," but not "the faculty divine" which translates the vision into music. In his two volumes of verse (*Poems*, 1846; *May Day and other Pieces*, 1867) there are many passages of beautiful insight and profound feeling, some lines of surprising splendour, and a few poems, like "The Rhodora," "The Snowstorm," "Ode to Beauty," "Terminus," "The Concord Ode," and the marvellous "Threnody" on the death of his first-born boy, of beauty unmarred and penetrating truth. But the total value of his poetical work is discounted by the imperfection of metrical form, the presence of incongruous images, the predominance of the intellectual over the emotional element, and the lack of flow. It is the material of poetry not thoroughly worked out. But the genius from which it came—the swift faculty of perception, the lofty imagination, the idealizing spirit enamoured of reality—was the secret source of all Emerson's greatness as a speaker and as a writer. Whatever verdict time may pass upon the bulk of his poetry, Emerson himself must be recognized as an original and true poet of a high order.

His latter years were passed in peaceful honour at

Concord. In 1866 Harvard College conferred upon him the degree of LL.D., and in 1867 he was elected an overseer. In 1870 he delivered a course of lectures before the university on "The Natural History of the Intellect." In 1872 his house was burned down, and was rebuilt by popular subscription. In the same year he went on his third foreign journey, going as far as Egypt. About this time began a failure in his powers, especially in his memory. But his character remained serene and unshaken in dignity. Steadily, tranquilly, cheerfully, he finished the voyage of life.

I trim myself to the storm of time,
I man the rudder, reef the sail,
Obey the voice at eve obeyed at prime:
"Lowly faithful, banish fear,
Right onward drive unharmed;
The port, well worth the cruise, is near,
And every wave is charmed."

Emerson died on 27th April 1882, and his body was laid to rest in the peaceful cemetery of Sleepy Hollow, in a grove on the edge of the village of Concord.

AUTHORITIES.—*Emerson's Complete Works*, Riverside edition (edited by J. E. Cabot), 11 vols. Boston, 1883–84.—*The Correspondence of Thomas Carlyle and Ralph Waldo Emerson* (edited by Charles Eliot Norton). Boston, 1883.—GEORGE WILLIS COOKE. *Ralph Waldo Emerson: His Life, Writings, and Philosophy.* Boston, 1881.—ALEXANDER IRELAND. *Ralph Waldo Emerson: His Life, Genius, and Writings.* London, 1882.—A. BRONSON ALCOTT. *Ralph Waldo Emerson, Philosopher and Seer.* Boston, 1882.—MONCURE DANIEL CONWAY. *Emerson at Home and Abroad.* Boston, 1882.—JOEL BENTON. *Emerson as a Poet.* New York, 1883.—F. B. SANBORN (editor). *The Genius and Character of Emerson: Lectures at the Concord School of Philosophy.* Boston, 1885.—OLIVER WENDELL HOLMES. *Ralph Waldo Emerson* ("American Men of Letters" Series). Boston, 1885.—JAMES ELLIOTT CABOT. *A Memoir of Ralph Waldo Emerson*, 2 vols. (the authorized biography). Boston, 1887.—EDWARD WALDO EMERSON. *Emerson in Concord.* Boston, 1889.—RICHARD GARNETT. *Life of Ralph Waldo Emerson.* London, 1888. (H. VAN D.)

Emery Grinding Machinery.—Emery wheels, being cleaner, safer, and more efficient than the old grindstone, have become a necessity in all iron, steel, and other metal works. An emery wheel, properly mounted, runs at a peripheral speed of 6000 feet per minute, whereas a file in the hands of the best mechanic can only travel, and that with far less cutting power, at the rate of 60 feet per minute. Moreover, the efficiency of a file lessens every hour as its teeth become duller, but the emery wheel continually presents a fresh cutting surface, and remains the same until worn down to the wrought- or cast-iron washers which generally form the mount. Emery grinding operations may be divided into four classes: (1) tool and cutter grinding, for sharpening tools which would otherwise require to be softened, filed, and then hardened again; (2) cylindrical grinding, as in a grinding lathe; (3) surface grinding, where the emery wheel does the work of a shaping or planing machine, or of files; (4) surface edge grinding, where the emery wheel takes the place of the ordinary steel tools, such as the cold chisel and files. The qualities required in an emery wheel are: (1) sufficient tenacity to withstand the centrifugal strain caused by the high speed at which it revolves; (2) ability to resist heat, inasmuch as the friction of grinding rapidly increases the temperature of the metal being operated on; and (3) uniformity of strength, density, and texture. The wheel must not be so hard as to allow the compound to project above the surface of the emery; in other words, the binding material must wear away about as fast as the emery, and also be of such a nature that it will not put a glaze on the surface of the wheel, or combine with the object operated upon. This glazing is in fact one of the most serious difficulties to be encountered in the use of emery wheels.

The fineness or coarseness of the emery used is determined by passing the crushed rock or stone through sieves or wire cloths having from 6 to 100 wires to the inch; thus emery that will pass through a sieve of 6 wires to the inch is called No. 6 grade or grit. The numbers representing the various grades run from No. 6 to No. 100, and the smoothness of surface which the wheel leaves on the article ground may be compared with that left by files as follows:—

No. 6 to 10	represents	the cut	of a	wood rasp.
,, 16 ,, 20	,,	,,	,,	coarse rough file.
,, 24 ,, 35	,,	,,	,,	bastard file.
,, 40 ,, 60	,,	,,	,,	second cut file.
,, 70 ,, 80	,,	,,	,,	smooth file.
,, 90 ,, 100	,,	,,	,,	superfine.

To obtain the best result from an emery wheel it must be perfectly true, run at a high speed, and free itself from disengaged particles of metal, so as to allow of continuous contact between itself and the work. With equal speed and proportional pressure, a wheel six inches wide ought to grind off six times as much metal from a steel or iron bar six inches wide as a wheel one inch wide would from a steel or iron bar one inch wide. Experiments show that, taking the moderate price of one shilling per pound for the emery wheel, the maximum cost of grinding one pound of cast-iron is about sixpence, whereas the cost per pound of filing cast-iron is at least one shilling and sixpence. In the case of grinding a tempered saw, where the steel resists the file, an emery wheel will remove fifty-five times more than a file in the same time.

The speed at which the wheel may be run without danger of bursting varies with its size, as well as with the quality of the binding material and the general excellence of the manufacture. The centrifugal force evolved varies as the square of the velocity; hence a wheel of any given size is subjected to four times the bursting strain at 2000 revolutions that it is at 1000. Hence a comparatively small increase in the number of revolutions adds 100 per cent. to the breaking strain. It is practically impossible for one standard speed to be maintained in the workshop, since to do so would entail the continual alteration of driving pulleys to increase the speed so as to compensate for the wear in the diameter of the emery wheel. It is a common practice, therefore, to use wheels of a certain diameter upon machines running at the appropriate speed, and to transfer them to faster ones as their size is diminished by use.

Corundum wheels are manufactured from the mineral corundum, which resembles emery, and they are made and used in the same manner as emery wheels. They are superior to the latter, both in cutting more freely and in being more durable, with less liability to glaze, but corundum is only found in limited quantities, and is consequently too expensive for the general uses for which emery wheels are equally well suited.

Emilia, a territorial division of Italy, enclosed generally between the lower Po, the Apennines, and the Adriatic, and comprising the provinces of Bologna, Ferrara, Forli, Modena, Parma, Piacenza, Ravenna, and Reggio, with an area of 7967 sq. miles, and a population (1881) of 2,183,391, and (1901) of 2,451,752. Alongside the Po and the Adriatic there are extensive marshy tracts. The principal crops are maize, wheat, vine, hemp, fruit, tobacco, flax, rice, and chestnuts. Salt and sulphur are extracted, and granite is quarried. The greatest number of people are engaged in making strawplait and chip hats in their own homes. The industries which claim the next largest numbers of workpeople are the making of mats and baskets, furniture, and cheese and butter, the manufacture of silks, tobacco, and fireworks, the production of cocoons, and ironworks. The region gets its name from the old Roman road, the Via Emilia, which traversed it from north-west to south-east. The most important towns are Bologna, Ferrara, Ravenna, Modena, Reggio, Parma, Forlì, Piacenza, Rimini, Faenza, Correggio, and Guastalla. Rimini is the only seaport. The history of Emilia is coincident with the history of the duchies of Modena, Parma, and Massa-Carrara, and of the States of the Church.

Emin Pasha [EDUARD SCHNITZER] (1840–1892), German traveller and naturalist, was the son of Ludwig Schnitzer, a merchant of Oppeln in Silesia, and was born in Oppeln, 28th March 1840. He was educated at the universities of Breslau, Berlin, and Königsberg, and took the degree of M.D. at Berlin. He displayed an early predilection for zoology and ornithology, and in later life became a skilled and enthusiastic collector, particularly of African plants and birds. When he was four and twenty he determined to seek his fortunes abroad, and made his way to Turkey, where, after practising medicine on his own account for a short time, he was appointed (in 1865) Quarantine Medical Officer at Antivari. The duties of the post were not heavy, and allowed him leisure for a diligent study of Turkish, Arabic, and Persian. From 1870 to 1874 he was in the service of the Governor of Northern Albania, had adopted a Turkish name (though not that by which he afterwards became so widely known), and was practically naturalized as a Turk. After a visit home in 1875, he went to Cairo, and then to Khartum, in the hope of an opportunity for travelling in the interior of Africa. This came to him in the following year, when General Gordon, who had recently succeeded Sir Samuel Baker as Governor of Equatorial Africa, invited Schnitzer, who was now known as "Emin Effendi," to join him at Lado. Although nominally Gordon's medical officer, Emin was soon entrusted with political missions of some importance to Uganda and Unyoro. In these he acquitted himself so well that when, in 1878, Gordon's successor in the governorship was deprived of his office on account of malpractices (Gordon himself having been made Governor-General of the Sudan), Emin was chosen to fill the post, with the title of "Bey." He proved an energetic and enterprising governor; indeed, his enterprise on more than one occasion brought him into conflict with Gordon, who eventually decided to remove Emin to Suakin. Before the change could be effected, however, Gordon resigned his post in the Sudan, and his successor revoked the order. The next three or four years were employed by Emin in various journeys through his provinces, and in the initiation of various schemes for their development, until in 1882, on his return from a visit to Khartum, he became aware that the Mahdist rebellion, which had originated in the Sudan, was spreading to Equatoria. The effect of the rebellion was, of course, more markedly felt in Emin's province after the abandonment of the Sudan by the Egyptian Government in 1884. He was obliged to give up several of his stations in face of the rebel advance, and ultimately to retire from Lado, which had been his capital, to Wadelai. This last step followed upon his receipt of a letter from Nubar Pasha, informing him that it was impossible for the Egyptian Government to send him help, and that he must stay in his province or retire towards the coast as best he could. Emin (who about this time was raised to the rank of Pasha) had some thoughts of a retreat to Zanzibar, but decided to remain where he was and endeavour to hold his own. To this end he carried on protracted negotiations with neighbouring native potentates. When, in 1887, Stanley's expedition was on its way to relieve him, it is clear from Emin's diary that he had no wish to leave his province, even if relieved. He had done good work there, and established a position which he believed himself able to maintain. He hoped, however, that the presence of Stanley's force, when it arrived, would strengthen his position; but the condition of the relieving party, when it arrived in April 1888, did not seem to Emin to promise this. Stanley's proposal to Emin, as stated in the latter's diary, was that Emin should either remain as Governor-General on behalf of the King of the Belgians, or establish himself on Victoria Nyanza on behalf of a group of English merchants who wished to start an enterprise in Africa on the model of the East India Company. After much hesitation, and prompted by a growing disaffection amongst the natives (owing, as he maintained, to his loss of prestige after the arrival of Stanley's force), Emin decided to accompany Stanley to the coast, where the expedition arrived in December 1889. Unfortunately, on the evening of a reception dinner given in his honour, Emin met with an accident which resulted in fracture of the skull. Careful nursing gradually restored him to health, and on his convalescence he resolutely maintained his decision to remain in Africa, and, if possible, to work there in future on behalf of the German Government. The seal was definitely set upon this decision by his formal engagement on behalf of his native country, early in 1890. Preparations for a new expedition into the interior were set on foot, and meanwhile Emin was honoured in various ways by learned societies in Germany and elsewhere. The object of the new expedition was (to quote Emin's instructions) "to secure on behalf of Germany the territories situated south of and along Victoria Nyanza up to Albert Nyanza," and to "make known to the population there that they were placed under German supremacy and protection, and to break or undermine Arab influence as far as possible." The force, which was well equipped, started at the end of April 1890. For a time things went well enough with the expedition, but by degrees ill-fortune clouded its prospects. Difficulties on the route; dissensions between Emin and the authorities in German East Africa, and misunderstandings on the part of both; epidemics of disease in Emin's force, followed by a growing spirit of mutiny among his native followers; an illness of a painful nature which attacked himself;—all this gradually undermined Emin's courage, and his diaries at the close of 1891 reflect a gloomy and almost hopeless spirit. The only pleasurable incident of the expedition had been his unexpected meeting with Dr Peters, who since the spring of 1888 had been at the head of a German expedition which had been sent to attempt the relief of Emin at the time when it was thought improbable that Stanley's expedition would ever reach its goal, and had itself in turn been completely lost sight of and reported annihilated. At last the hatred with which Emin had inspired the African Arabs found its vent in his treacherous murder by order of a native chief at the instigation of an Arab slave dealer, on 23rd or 24th October 1892, at Kinena in the Congo State. His journals and biography have been published since his death. (R. F. S.)

Emmaus, the name of two places in Palestine. 1. A village mentioned by St Luke (xxiv. 13), without any indication of direction, as being 60 stadia ($6\frac{9}{11}$ miles), or according to some MSS. 160 stadia, from Jerusalem. It has been identified (*a*) with Emmaus-Nicopolis, distant 176 stadia from Jerusalem; (*b*) with Kuryet el-ʿEnab, distant 66 stadia, on the carriage road to Jaffa; (*c*) with Kulónieh, distant 36 stadia, on the same road; (*d*) with el-Kubeibeh, distant 63 stadia, on the Roman road to Lydda; (*e*) with Urtas, distant 60 stadia; and (*f*) with Khurbet el-Khamasa, distant 86 stadia, on the Roman road to Eleutheropolis. Of these, el-Kubeibeh or Urtas seems the most probable. 2. Emmaus-Nicopolis, now

Amwás, a town on the maritime plain, and a place of importance during the Maccabæan and Jewish wars. Near it Judas Maccabæus defeated Lysias, 164 B.C., and Vespasian established a fortified camp A.D. 69. It was afterwards rebuilt and named Nicopolis.

Employers' Liability.—The law of England as to the liability of employers in respect of personal injuries to their servants can only be regarded as in a stage of transition. It depends upon no universal principles. It confers rights and imposes liabilities differing widely according to the employment, and even according to the accidental circumstances of the same employment. Some servants are practically insured against accident, others serve almost at their own risk, and no logical reason can be discovered for the difference. The common law, indeed, is definite enough, and in its strict limitation of a master's obligations admits of little ambiguity; but by the Employers' Liability Act, 1880, such exceptions have been grafted upon the common law, and by the Workmen's Compensation Act, 1897, principles so alien to the common law have been applied to some but not to all employments, that it is impossible now to present any view of this branch of the law as a logical whole. All that can be done is to state the nature of the liability at common law, the extension of it effected by the Employers' Liability Act, 1880, and the new liabilities introduced by the Acts of 1897 and 1900. It is necessary to bear in mind that while all servants have such rights as the common law gives them, and most may have the further rights conferred by the Act of 1880, some in certain specially favoured employments are also entitled to the peculiar benefits of the Workmen's Compensation Act.

Common law.

At common law the liability of a master is of a very limited character. There is, of course, nothing to prevent a master and servant from providing by special contract in any way they please for their mutual rights in cases of personal injury to the servant. In such cases the liability will depend upon the terms of the special contract. But apart from any special agreement, it may be broadly stated that a master is liable to his servants only for injuries caused by his own negligence. Injuries to a servant may arise from accident, from the nature of the service, or from negligence; and this negligence may be of the master, of another servant of the master, or of a stranger. If the injury is purely accidental, the loss lies where it falls. If it arises from the nature of the service, the servant must bear it himself; he has undertaken a service to which certain risks are necessarily incident; if he is injured thereby, it is the fortune of war, and no one can be made responsible. If the injury is caused by the negligence of a stranger, the servant has his ordinary remedy against the wrong-doer or any one who is responsible as a principal for the conduct of the wrong-doer. If it is caused by the negligence of a fellow-servant, he likewise has his ordinary remedy against the actual wrong-doer; but, by virtue of what is known as the doctrine of common employment, he cannot at common law make the master liable as a principal. The only case (independently of recent legislation: *see below*) in which he can recover damages from the master is where the injury has been caused by the negligence of the master himself. A master is negligent if he fails to exercise that skill and care which, in the circumstances of the particular employment, are used by employers of ordinary skill and carefulness. If he himself takes part in the work, he must act with such skill and care as may reasonably be demanded of one who takes upon himself to do work of that kind. If he entrusts the work to other servants, he must be careful in their selection, and must not negligently employ persons who are incompetent. He must take proper care so to arrange the system of work that his servants are not exposed to unnecessary danger. If tools or machinery are used, he must take proper care to provide such as are fit and proper for the work, and must either himself see that they are maintained in a fit condition or employ competent servants to do so for him. If he is bound by statute to take precautions for the safety of his servants, he must himself see that that obligation is discharged. For breach of any of these duties a master is liable to his servant who is injured thereby, but his liability extends no further.

Common employment.

That his obligations to a servant are so much less than to a stranger is chiefly due to the doctrine of common employment. As a rule a master is responsible for the negligence of his servant acting in the course of his employment; but, from about the middle of the 19th century, it became firmly rooted in the law that this principle did not apply where the person injured was himself a servant of the master and engaged in a common employment with the servant guilty of the negligence. In effect this rule protects a master as against his servant from the consequences of negligence on the part of any other of his servants; to this there is no qualification except that, for the rule to apply, both the injured and the negligent servant must be acting in pursuance of a common employment. They must both be working for a common object, though not necessarily upon the same work.

It is not easy to define precisely what constitutes a common employment in this sense, and there is peculiarly little judicial authority as to the limit at which work for the same employer ceases to be work in a common employment. It does not depend on difference in grade; all engaged in one business, from the manager to the apprentice, are within the rule. It does not depend on difference in work, if the work each is doing is part of one larger operation; all the servants of a railway company, whether employed on the trains, or at the stations, or on the line, are in a common employment. It does not necessarily depend on difference of locality; a servant who packs goods at the factory and a servant who unpacks them in the shop may well be in a common employment. On the other hand, it is not enough that the two servants are working for the same employer, if there is nothing in common between them except that they are making money for the same man; apart from special circumstances, the crews of two ships owned by the same company are probably not in common employment while navigating their respective ships. The test in each casc must be derived from the view, invented by the courts, upon which the doctrine was based, namely, that the servant by entering upon the service consented to run all the risks incidental to it, including the risk of negligence on the part of fellow-servants; if the relation between the two servants is such that the safety of the one may, in the ordinary course of things, be affected by the negligence of the other, that negligence must be taken to be one of the risks of the employment assented to by the servant, and both are engaged in a common employment. In ninety-nine cases out of a hundred it will be found that the doctrine is applicable, and the master protected from liability. It is thus seen that, in general, no action will lie against a master at the suit of his servant, unless the servant can prove personal negligence on the part of the master causing injury to the servant. And in such action the master may avail himself of those defences which he has against a stranger. He may rely upon contributory negligence, and show that the servant was himself negligent, and that, notwithstanding the negligence of the master, the injury was proximately caused by the negligence of the servant. Or (except in cases where the injury results from a breach of a statutory duty) he may prove such facts as establish the defence expressed in the maxim, *volenti non fit injuria;* that is, he may prove that the injured servant knew and appreciated the particular risk he was running, and incurred it voluntarily with full understanding of its nature. Mere knowledge on the part of the servant, or even his continuing to work with knowledge, does not necessarily establish this defence; it must be knowledge of such a kind and in such circumstances that it can be inferred that the servant contracted to take the risk upon himself. The action at common law is subject to the general rule that personal actions die with the person; except so far as the remedy for money loss caused by death by negligence has been preserved in favour of a husband or wife and certain near relatives, under Lord Campbell's Act.

Such was the law up to 1880. So long as industry was conducted on a small scale, and the master worked with his men, or was himself the manager, its hardship was perhaps little felt; his personal negligence could in many cases be established. But with the development of the factory system, and the ever-growing expansion of the scale on which all industries were conducted, it became increasingly difficult to bring home individual responsibility to the employer. As industry passed largely into the control of corporations, difficulty became almost impossibility. The employer was not liable to a servant for the negligence of a fellow-servant, and therefore, in most cases of injury, was not liable at all. It is not surprising that the condition of things thus brought about, partly by the growth of modern industry and partly by the decisions of the courts, caused grave dissatisfaction. The justice of the doctrine of common employment was vigorously called in question. In the result the Employers' Liability Act, 1880, was passed. The effect of this Act is to destroy the defence of common employment in certain specified cases. It does not abolish the doctrine altogether, nor, on the other hand, does it impose upon the master any new standard of duty which does not exist as regards strangers. All that it does is to place the servant, in certain cases, in the position of a stranger, making the master liable for the negligence of his servants notwithstanding the fact that they are in common employment with the servant injured. It is still necessary under the Act, as at common law, to prove negligence, and the master may still rely upon the defences of contributory negligence and *volenti non fit injuria.* But under the Act he cannot, as against the workmen who come within it and in the cases to which it applies, set up the defence that the negligence complained of was the negligence of a servant in a common employment. The Act does not apply to all servants. It does not apply to domestic or menial servants, or to seamen, or to any except railway servants and "any person who, being a labourer, servant in husbandry, journeyman, artificer, handicraftsman, miner, or otherwise engaged in *manual* labour . . . has entered into or works under a contract with an employer, whether the contract be oral or in writing, and be a contract of service or a contract personally to execute any work or labour." Whether a servant, not being one of those specially named, is within the Act depends on whether manual labour is the real and substantial employment, or whether it is merely incidental thereto; thus a carman who handles the goods he carries may be within the Act, but a tramcar driver or an omnibus conductor is not. The Act does not make the master liable for the negligence of all his servants, but, speaking generally, only for the negligent discharge of their duties by such as are entrusted with the supervision of machinery and plant, or with superintendence, or the power of giving orders, with the addition, in the case of a railway, of the negligence of those who are given the charge or control of signals, points, locomotive engines, or trains. The cases dealt with by the Act are five in number; in the first and fourth the words are wide enough to include negligence of the employer himself, for which, as has been seen, he is liable at common law. In such instances the workman has an alternative remedy either at common law or under the Act, but in all other respects the rights given by the Act are new, being limitations upon the defence of common employment, and can be enforced only under the Act.

The Act of 1880.

The first case is where the injury is caused by reason of any defect in the condition of the ways, works, machinery, or plant connected with or used in the business of the employer, provided that such defect arises from, or has not been discovered or remedied owing to, the negligence of the employer, or of some person in the service of the employer and entrusted by him with the duty of seeing that the ways, works, machinery, or plant are in proper condition. The second case is where the injury is caused by reason of the negligence of any person in the service of the employer who has any superintendence entrusted to him (that is, a person whose sole or principal duty is that of superintendence, and who is not ordinarily engaged in manual labour) whilst in the exercise of such superintendence. The third case is where the injury is caused by reason of the negligence of any person in the service of the employer to whose orders or directions the workman at the time of the injury is bound to conform and does conform, where such injury results from his so conforming. The fourth case is where the injury is caused by reason of the act or omission of any person in the service of the employer done or made in obedience to the rules or bye-laws of the employer, or in obedience to particular instructions given by any person delegated with the authority of the employer in that behalf, provided that the injury results from some impropriety or defect in such rules, bye-laws, or instructions. The fifth case is where the injury is caused by reason of the negligence of any person in the service of the employer who has the charge or control of any signal, points, locomotive engine, or train upon a railway.

In all these cases it is provided that the employer shall not be liable if it can be shown that the workman knew of the defect or negligence which caused his injury, and failed within a reasonable time to give, or cause to be given, information thereof to the employer or some person superior to himself in the service of the employer, unless he was aware that the employer or such superior already knew of the said defect or negligence. It was inevitable that these provisions should call for judicial interpretation, and a considerable body of authority has grown up about the Act. Where general words are used, it must always occur that, between the cases which are obviously within and those which are obviously without the words, there are many on the border line. Thus, under the Act, the courts have been called upon to determine the precise meaning of "way," "works," "machinery," "plant," and to say what is precisely meant by a "defect" in the condition of each of them. They have had to say what is included in "railway" and in "train," what is meant by having "charge" or "control," and to what extent one whose principal duty is superintendence may participate in manual labour without losing his character of superintendent, and what is the precise meaning of negligence in superintendence. These are only illustrations of many points of detail which, having called for judicial interpretation, will be found fully dealt with in the text-books on the subject. A workman who, being within the Act, is injured by such negligence of a fellow-servant as is included in one or other of the five cases mentioned above, has against his employer the remedies which the Act gives him. These are not necessarily the same as those which a stranger would have in the like circumstances; the amount of compensation is not left at large for a jury to determine, but is limited to an amount not exceeding such sum as may be found to be equivalent to the estimated earnings, during the three years preceding the injury, of a person in the same grade employed during those years in the like employment and in the district in which the workman is employed at the time of the injury. Moreover, the right to recover is hedged about with technicalities which are unknown at the common law; proceedings must be taken in the County Court, within a strictly limited time, and are maintainable only if certain elaborate provisions as to notice of injury have been complied with. Where the injury causes death the action is maintainable for the benefit of the like persons as are entitled under Lord Campbell's Act in an action at common law.

The law continued in this condition up to 1897. In the majority of cases of injury to a servant, the doctrine of common employment still protected the master; and where, under the Employers' Liability Act, it failed to do so, the liability was of a limited character and often, owing to technicalities of procedure, difficult to enforce. Moreover, there is nothing in the Act to prevent master and servant from entering into any special contract they please; and in many trades it became a common practice for contracts to be made wholly excluding the operation of the Act. In 1893 an attempt was made to alter the law by a total abolition of the defence of common employment, so as to make a master liable to a servant as to a stranger for the negligence of any of his servants acting in the course of their employment, and at the same time to prohibit any agreements to forego the rights so given to the servant. The Bill did not become law, and no further change was made until, in 1897, Parliament took the first step in what must ultimately be a complete revolution in the law of employers' liability. Up to that year, as has been seen, the foundation of a master's liability was negligence, either of the master himself, or, in certain cases, of his servants. But by the Workmen's Compensation Act, 1897,

The Act of 1897.

a new principle was introduced, whereby certain servants in certain employments were given a right to compensation for injuries, wholly irrespective of any consideration of negligence or contributory negligence. As regards such servants in such employments the master is in effect made an insurer against accidental injuries. The Act was confessedly tentative and partial; it dealt only with selected industries, and even within these industries was not of universal application. But where it does apply, it gives a right to a limited compensation in every case of injury by accident arising out of and in the course of the employment, whether that accident has been brought about by negligence or not, and whether the injured servant has or has not contributed to it by his own negligence. Owing in part to the novelty of the principles sought to be established, in part to the way in which the sections are drawn, the Act presents considerable difficulties of interpretation. In many respects, as has been said by the Court of Appeal, definition is difficult or impossible, and all that can be done is in each case, as it comes before the court, to say whether it falls within or without the Act. Many ambiguities have already been made clear by authoritative decision, but no statement of the effect of the Act can be made with any approach to finality.

The Act applies only to employment on, or in, or about certain localities where, at the same time, the employer is what the Act calls an "undertaker," that is, the person whose business is there being carried on. If we want to know whether a workman is within the Act, we must ask, first, was he employed on, or in, or about a railway, or a factory, or a mine, or a quarry, or an engineering shop, or a building of the kind mentioned in the Act; secondly, was he employed by one who was, in relation to that railway, &c., the undertaker as defined by the Act; and, thirdly, was he at the time of the accident at work on, or in, or about that railway, &c. Unless these three conditions are fulfilled the employment is not within the Act. What is included in the named localities and who are the undertakers in respect thereof will be dealt with below. But it must here be pointed out that an undertaker is in some cases liable as an employer, though he is in fact not the actual master of the workman. Section 4 of the Act in effect provides that where the undertaker has let out part of the work of his undertaking to a contractor, the workmen of such contractor shall be treated as employed by the undertaker, provided that the work so let out is part of or a process in the trade or business carried on by the undertaker; to such workmen the undertaker is made liable, whether for claims under the Act, or for claims founded on personal negligence or wilful act. The employment must be on, or in, or about the locality, and "about" means "in close propinquity to"; to this the Act makes one exception, where it provides that a workman employed in a factory which is a shipbuilding yard shall not be excluded by reason only that the accident arose outside the yard in the course of his work upon a vessel in any dock, river, or tidal water near the yard; with this exception no outworker has the benefit of the Act.

The effect of what has been said will best be seen by an illustration. A carries on business in an engineering shop, which is a factory. He employs B in the shop, and C to erect an engine in another person's mill; he also makes a contract with X whereby X undertakes part of the engineering work in the shop, X employing his own men, among whom is D; he also contracts with Y for the installation of electric light in the shop, and Y employs E to do the work. Among these workmen B and D are within the Act, C and E are without it. B is employed in a factory by the undertaker, and D is employed indirectly by the undertaker in a factory upon work which is part of the business carried on by the undertaker. C is not employed on, or in, or about a factory in relation to which his employer is an undertaker, and E, though employed about a factory and indirectly by the undertaker, is not doing work which is part of the business carried on by the undertaker.

The particular employments included in the Act are as follows:—

(1) Employment by a railway company on, in, or about a railway. A railway means the railway of any railway company to which the Regulation of Railways Act, 1873, applies, and includes a light railway made under the Light Railways Act, 1896. The "undertakers" are the railway company as defined by those Acts.

(2) Employment on, in, or about a factory by the occupier thereof. A factory means a factory within the Factory and Workshop Acts, 1878 to 1891. The "undertaker" is the occupier within the meaning of those Acts (see LABOUR LEGISLATION).

(3) Employment on, in, or about a laundry worked by steam, water, or other mechanical power, by the occupier thereof. The "undertaker" is the occupier within the meaning of the Factory and Workshop Acts, 1878 to 1895.

(4) Employment on, in, or about any dock, wharf, quay, warehouse, machinery, or plant, to which any provision of the Factory Acts is applied by the Factory and Workshop Act, 1895, by the occupier thereof within the meaning of that Act. The "undertaker" is the occupier as defined by the Act of 1895.

Docks.

Section 23 of the Factory and Workshop Act, 1895, extends certain provisions of the Factory Acts (relating to dangerous machines, notice of accidents and the like) to (*a*) every dock, wharf, quay, and warehouse, and, so far as relates to the process of loading or unloading therefrom or thereto, all machinery and plant used in that process; and (*b*) any premises on which machinery worked by steam, water, or other mechanical power, is temporarily used for the purpose of the construction of a building or any structural work in connexion with a building. The section further provides that the person having the actual use or occupation of a dock, wharf, quay, or warehouse, or of any premises within the same, or forming part thereof, and the person so using any such machinery, shall be deemed to be the occupier. This class has been the subject of much litigation, but after considerable conflict of judicial decision, most of the doubts have been set at rest. A workman engaged in an employment on, in, or about a dock, whether on the quays or on board a ship in the dock, is engaged in an employment on, in, or about a "factory" within the meaning of the Act. This does not settle the question whether the workman is within the Act, for the Act will not apply unless the employer is the "undertaker," that is to say, the occupier; and to be the occupier the employer must have the actual use or occupation of the dock, wharf, quay, or warehouse, or of premises within the same, and forming part thereof. If the workman is employed by the dock company or the warehouseman, he is clearly employed by the occupier, but if he is employed by others, say, the shipowner, or the receiver of goods, or the master stevedore who merely uses the dock or quay, or the merchant who merely stores his goods in the warehouse of another, it has to be determined whether such employer has the actual use or occupation of the dock, &c., or of premises within the same. Actual use means much more than legal occupation. On the other hand, it does not include a merely casual use. So far as the decisions go, the test seems to be whether the employer has a more or less exclusive use of something which can be defined as an area of the docks or quay. Thus a shipowner has the use of the berth in which his ship lies and of the quay on which he discharges cargo. A ship repairer has the use of the dry dock in which he is painting the ship. A merchant who merely sends a clerk across the quay has not the use of the quay. It is a question of fact to be determined according to the circumstances of each case. As to machinery or plant used in loading or discharge the question is less complicated; for, by the Factory Act, the person who, by himself, his agents or workmen, temporarily uses such machinery, is made the occupier, and is therefore an "undertaker." In general, therefore, a workman employed on or about machinery or plant used in loading or discharge will be within the Act, provided that his employer is the person who is in fact using that machinery or plant. Speaking broadly, it may be said that the majority of dock labourers are within the Act.

(5) Employment on, in, or about any mine to which the Coal Mines Regulation Act, 1887, or the Metalliferous Mines Regulation Act, 1872, applies, by the owner thereof within the meaning of those Acts. This includes all mines. The "undertaker" is the owner as defined by those Acts; that is to say, any person or body corporate who is the immediate proprietor, or lessee, or occupier of any mine, or of any part thereof; this does not include a person or body corporate who merely receives a royalty, rent, or fine from a mine, or is merely the proprietor of a mine subject to any lease, grant, or license for the working thereof, or is merely the owner of the soil, and not interested in the minerals of the mine.

(6) Employment on, in, or about any quarry under the Quarries Act, 1894, by the occupier thereof. A quarry includes every place (not being a mine) in which persons work in getting slate, stone, coprolites, or other minerals, and any part of which is more than twenty feet deep. The "undertaker" is the occupier.

(7) Employment on, in, or about an engineering work; that is to say, any work of construction, or alteration, or repair of a railroad, harbour, dock, canal, or sewer, including any other work for the construction, alteration, or repair of which machinery driven by steam, water, or other mechanical power is used. The employment must be by the person undertaking the construction, alteration, or repair, such person being the "undertaker" in respect of an engineering work.

(8) Employment on, in, or about certain buildings in course of construction, repair, or demolition, by the persons undertaking that work. The buildings included are (*a*) any building which exceeds thirty feet in height, and is being constructed or repaired by means of a scaffolding, (*b*) any building which exceeds thirty feet in height and is being demolished, and (*c*) any building on which machinery driven by steam, water, or other mechanical power is being used for the purpose of the construction, repair, or demolition thereof. The "undertaker" is the person undertaking the construction, repair, or demolition.

This class has been the subject of much litigation. What is meant by "construction," by "repair," by "scaffolding," are among the questions which have come before the courts. Questions such as these can only be determined in reference to the particular facts of each case. In practice further difficulties must arise in determining who is the undertaker. In work such as is included in classes (7) and (8), the operations are often divided among several employers who do different branches of the work. If the several contractors are indeed separate, each doing a part of the work for the building owner, each is an undertaker and liable to his own workmen. But where, as is more often the case, one contractor undertakes with the building owner to do the whole work, and then sublets portions of it to sub-contractors, such sub-contractors are not undertakers, and only the principal contractor is liable under the Act.

Given an employment to which the Act applies, all who are engaged therein are workmen within the Act, including workmen engaged in any employment (exclusive of naval or military service) by or under the Crown.

Conditions of claim.

To entitle a workman engaged in an employment to which the Act applies to compensation all the following conditions must be fulfilled:—(1) There must be personal injury by accident. This, it is submitted, will exclude (*a*) injury wilfully inflicted; (*b*) injury arising from the nature of the occupation without the occurrence of any fortuitous event, *e.g.*, lead poisoning; and (*c*) injury proximately due to a diseased condition of the workman. In the last case, where there is a diseased condition of the workman and also a fortuitous event, it will be a question of fact whether the injury was or was not proximately caused by the accident. (2) The accident must arise out of and in the course of the employment. In each case it will have to be determined whether the workman was at the time of the accident in the course of his employment, and whether the accident arose out of the employment. It will have to be considered when and where the particular employment, which, it must be remembered, must be one "on, in, or about" a particular locality, began and ended. Other difficulties have arisen and will frequently arise when the workman at the time of the accident is doing something which is no part of the work he is employed to do. So far as the decisions have gone, they indicate that if what the workman is doing is no act of service, but merely for his own pleasure, or if he is improperly meddling with that which is no part of his work, the accident does not arise out of and in the course of his employment; but if, while on his master's work, he upon an emergency acts in his master's interest, though what he does is no part of the work he is employed to do, the accident does arise out of and in the course of his employment. (3) The injury must be such as disables the workman for a period of at least two weeks from earning full wages at the work at which he was employed. (4) Notice of the accident must be given as soon as practicable after the happening thereof, and before the workman has voluntarily left the employment in which he was injured; and the claim for compensation (by which is meant notice that he claims compensation under the Act addressed by the workman to the employer) must be made within six months from the occurrence of the accident or, in case of death, from the time of death. Want of notice of the accident or defects in it are not to be a bar to proceedings, if occasioned by mistake or other reasonable cause, and the employer is not prejudiced thereby. But want of notice of a claim for compensation is a bar to proceedings, unless the employer by his conduct has estopped himself from relying upon it. (5) A workman who has given notice of an accident must, if so required by the employer, submit himself to medical examination.

When these conditions are fulfilled, an employer who is within the Act has no answer unless he can prove that the injury arose from the serious and wilful misconduct of the workman. The precise effect of these terms is not clear; but mere negligence is not within them.

Where the injury causes death, the right to compensation belongs to the workman's "dependants"; that is, such members of the workman's family specified in Lord Campbell's Act as were at the time of the death wholly or in part dependent upon the earnings of the workman for their maintenance.

Under the Act compensation is for loss of wages only, and is, as has been said, based upon the actual previous earnings of the injured workman in the employment of the employers for whom he is working at the time of the injury. In case of death, if the workman leaves dependants who were wholly dependent on his earnings, the amount recovered is a sum equal to his earnings in the employment of the same employer during the three years next preceding the injury, or the sum of £150, whichever is the larger, but not exceeding £300; if the period of his employment by the same employer has been less than three years, then the amount of his earnings during the three years is to be deemed to be 156 times his average weekly earnings during the period of his actual employment under the said employer. If the workman leaves only dependants who were not wholly dependent, the amount recovered is such sum as may be reasonable and proportionate to the injury to them, but not exceeding the amount payable in the previous case. If the workman leaves no dependants, the amount recoverable is the reasonable expenses of his medical attendance and burial, not exceeding £10. In case of total or partial incapacity for work resulting from the injury, what is recovered is a weekly payment during the incapacity after the second week not exceeding 50 per cent. of the workman's average weekly earnings during the previous twelve months, if he has been so long employed, but if not, then for any less period during which he has been in the continuous employment of the same employer; such weekly payment is not to exceed £1—and in fixing it regard is to be had to the difference between the amount of his average weekly earnings before the accident and the average amount which he is able to earn after the accident. Any payments, not being wages, made by the employer in respect of the injury must also be taken into account. If the workman is maimed, but for the time being suffers no loss, *e.g.*, if he loses a finger but continues to earn the same wages as before, no compensation can be awarded, but the Court will make a declaration of liability of the employer, leaving the amount and duration of the compensation to be fixed, upon an application to review, should the workman at any future time be unable, by reason of the injury, to earn the same wages as before the accident. The weekly payment may from time to time be reviewed at the request of either party, upon evidence of a change in the circumstances since the award was made, and after six months may be redeemed by the employer by payment of a lump sum. When the workman at the time of the injury has been in the employment for less than two weeks, so that there are no actual earnings from the same employer upon which a weekly average can be computed, the Act presents much difficulty. It has been finally decided by the House of Lords that such a workman is within the Act. But how are the average weekly earnings which he would have earned from the same employer to be estimated? The question must be determined as one of fact by reference to all the circumstances of the particular case. Suppose the workman to be engaged at six shillings a day and injured on the first day. If it can be inferred that he would have remained in such employment for a whole week, his average weekly earnings from the same employer may be taken at thirty shillings. If it can be inferred that he would have worked one day and no more, his average weekly earnings from the same employer may be taken at six shillings. The result is that the casual labourer is within the Act, but that the amount of compensation for which the casual employer is liable may be very small.

Amount.

All questions as to liability or otherwise under the Act, if not settled by agreement, are referred to arbitration in accordance with a scheme prescribed by the Act. Contracting out is not permitted, save in one event: where a scheme of compensation, benefit, or insurance for the workmen of an employer has been certified by the Registrar of Friendly Societies to be not less favourable to the general body of workmen and their dependants than the provisions of the Act, the employer and any of his workmen may contract that the provisions of the scheme shall be substituted for the Act; such certificate may not be for more than five years, and may in certain circumstances be revoked. The Act does not touch the workman's rights at common law or under the Employers' Liability Act, but the workman, if more than one remedy is open to him, can enforce only one. When the circumstances create a legal liability in some other person, *e.g.*, where the injury is caused by the negligence of a sub-contractor or of a stranger, in such cases the employer, if required to pay compensation under the Act, is entitled to be indemnified by such other person.

By the Workmen's Compensation Act, 1900, the benefits of the Act of 1897 were, after the 1st July 1901, extended to some workmen in agriculture. To come within the Act, the workman must be employed in agriculture by an employer who habitually employs one or more workmen in such employment. "Agriculture" includes horticulture, forestry, and the use of land for any purpose of husbandry, inclusive of the keeping or breeding of live stock, poultry, or bees, and the growing of fruit and vegetables. If a workman is employed by the same employer mainly in agricultural, but partly or occasionally in other work, the Act applies to the employment of the workman in such other work. The provisions of the Act of 1897, which entitle a workman employed by a contractor to recover against the undertaker whose work the contractor is doing, are limited by a provision that, where the contractor provides and uses machinery driven by mechanical power for the purpose of threshing, ploughing, or other agricultural work, he, and he alone, shall be liable to pay compensation to any workman employed by him on such work.

The Act of 1900.

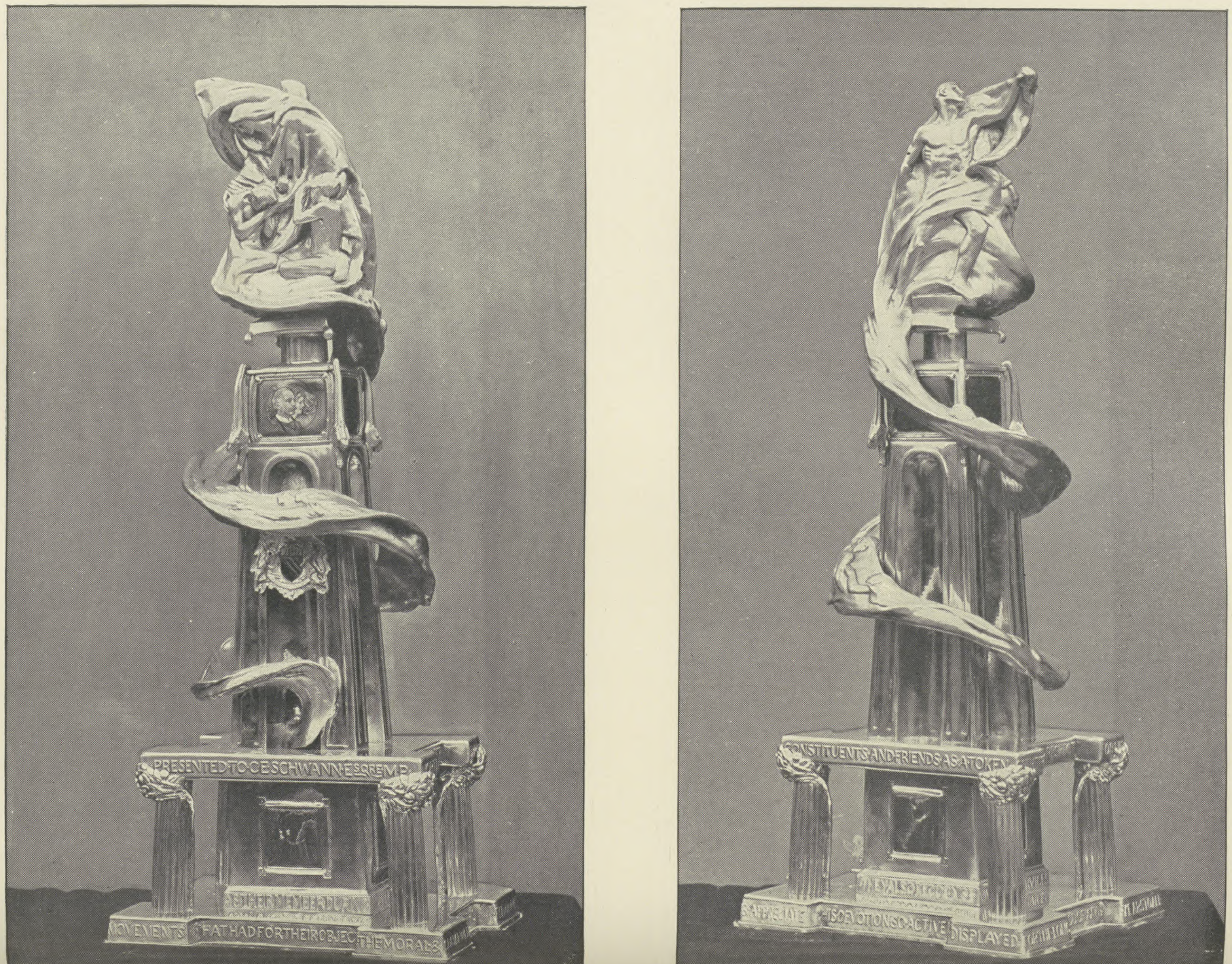
Under the Factory Acts, offences, when they result in death or bodily injury to health, may be punished by fine not exceeding £100, and the whole or any part of such fine may be applied for the benefit of the injured person or his family, or otherwise as the Secretary of State determines. Similar provisions occur in the Mines Acts. Any sum so applied must be taken into account in estimating compensation under the Employers' Liability and Workmen's Compensation Acts.

AUTHORITIES. —MACDONELL. *Law of Master and Servant.* London, 1883.—MANLEY SMITH. *Law of Master and Servant.* London, 1885.—ROBERTS and WALLACE. *Duty and Liability of Employers.* London, 1885.—BEVEN. *On Negligence.* London, 1895.—BEVEN. *Employers' Liability and Workmen's Compensation.* London, 1899.—E. HILL. *Workmen's Compensation and Employers' Liability.* London, 1898.—MINTON-SENHOUSE and EMERY. *Accidents to Workmen.* London, 1898.—MINTON-SENHOUSE. *Workmen's Compensation Cases*, 3 vols. London, 1899, 1900, 1901.—ROBINSON. *Employers' Liability.* London, 1898.—RUEGG. *Employers' Liability and Workmen's Compensation.* London, 1899.—WILLIS. *Workmen's Compensation Acts.* London, 1901. —SPENS and YOUNGER. *Employers and Employed.* Glasgow, 1887.

(M. H.*)

Emporia, capital of Lyon county, Kansas, U.S.A., in 38° 24′ N. lat. and 96° 10′ W. long., on the Neosho river, at an altitude of 1138 feet. It is regularly laid out on the level bottom-lands, and is divided into four wards. It has two railways, the Atchison, Topeka, and Santa Fé, and the Missouri, Kansas, and Texas. It is the seat of the College of Emporia, a Presbyterian institution, established in 1883. In 1900 the college had 12 instructors and 127 students, including those in the preparatory department. Emporia is also the seat of the State Normal School. Population (1880), 4631; (1890), 7551; (1900), 8223, of whom 686 were foreign-born and 663 were negroes.

Ems, a river of Germany, rising on the south slope of the Teutoburg Forest at an altitude of 358 ft., and flowing



A Silver and Enamel Centrepiece. Designed and made by Alexander Fisher.

generally north-west and north through Westphalia and Hanover to the east side of the Dollart, immediately south of Emden. After passing through the Dollart the navigable stream bifurcates, the eastern Ems going to the east, and the western Ems to the west, of the island of Borkum to the North Sea. Length, 205 miles.

Between 1892 and 1899 the river was canalized along its right bank for a distance of 43 miles. At the same time, and as part of the same general plan, a canal, the DORTMUND-EMS CANAL, was dug to connect the river (from Münster) with Herne in the Westphalian coal-field. At Heinrichenburg a branch from Herne (5 miles long) connects with another branch from Dortmund (10½ miles long). Another branch, from Olfen (north of Dortmund), connects with Duisburg, and so with the Rhine. There is, however, a difference in elevation of 46 ft. between the two branches first named, and vessels are transferred from the one to the other by means of a huge lift. The canal, which was constructed to carry small steamers and boats up to 220 ft. in length and 750 tons burden, measures 169 miles in length, of which 108½ miles were actually dug, and cost altogether £3,728,750. The surface width throughout is 98½ ft., the bottom width 59 ft., and the depth 8½ ft.

See VICTOR KURS, "Die künstlichen Wasserstrassen des Deutschen Reichs," in *Geog. Zeitschrift* (1898), pp. 601–617 and 665–694; and *Deutsche Rundschau f. Geog. and Stat.* (1898), pp. 130–131.

Ems, a town and watering-place of Prussia, province Hesse-Nassau, on the river Lahn, 11 miles by rail east from Coblenz. The hot alkaline springs (70°–135° F.), about a score in all, and on both sides of the stream, were apparently known in Roman times. A monument to the Emperor William I. was unveiled in 1893, and a stone has been set into the promenade to commemorate the spot where the emperor abruptly dismissed Benedetti, the French ambassador to Prussia. A funicular railway has been constructed to the Malberg, a favourite sanatorium. The population of 6492 (1900) is greatly increased during the summer months by visitors from all parts of the world, for whose accommodation many handsome villas have been erected.

Enamel.—The art of enamelling upon metals was practised in its simplest forms as far back in the history of man's achievements as the Assyrian and Egyptian civilizations. Since those remote ages there has been a succession of luxurious developments, followed by lapses into the decline and death of the art. In each revival there has been something added to that which was known and practised before, bearing witness to a slow progression. The last revival took place five hundred years ago, accompanying the rebirth of learning and the arts; but after flourishing for over a century, the art gradually fell into disuse, and remained so until the recent revival and further development, with which alone we are here concerned. The development consists, first, in the more complete knowledge of the technical processes, following upon the great advances which science has made; and, secondly, in a finer and more subtly artistic treatment of them. The advance in technical knowledge comprises greater facility and perfection in the production of the substance enamel, and its subsequent application to metal surfaces; more intimate knowledge of metals and their alloys to which it is applied, and greater ease in obtaining them from the metalliferous ores and reducing them to suitable dimensions and surfaces. For instance, it is now a simple matter to obtain perfectly pure copper by means of electricity. Again, formerly a flat sheet of metal was obtained by hammering, which involved an infinite amount of hard labour, whereas it is accomplished to-day with ease by means of flatting and rolling mills—*i.e.*, after the metal has been obtained from the ore in the form of an ingot, it is stretched equally to any degree of thinness by steel rollers. Further, the furnaces have been greatly improved by the introduction of gas as the heating power, instead of the wood or charcoal employed formerly.

In the manufacture of the substance enamel a much greater advance has been made, for whereas the colours, and consequently the schemes of colour, were extremely limited, we now possess an infinite gradation in the colours, as well as the transparency and opacity, the hardness and softness, of enamels. There are only two colours which cannot yet be obtained: these are opaque vermilion and lemon yellow. Many of the colours we now employ were not known by such enamellers as Leonard Limousin. Our enamels are also perfect in purity, brilliancy, and durability, qualities which are largely due to the perfect knowledge of the proportion of parts composing an enamel, and their complete combination. It is this complete combination, together with the absence of any destructible matter, which gives the enamel its lasting quality. The base of enamel is a clear, colourless, transparent, vitreous compound called flux, which is composed of silica, minium, and potash. This flux or base—termed *fondant* in France—is coloured by the addition of oxides of metals while in a state of fusion, which stain the flux throughout its mass. Enamels are either hard or soft, according to the proportion of the silica to the other parts in its composition. They are termed hard when the temperature required to fuse them is very high. The harder the enamel the less liable is it to be affected by atmospheric agencies, which in soft enamels produce a decomposition of the surface first, and ultimately of the whole enamel. It is therefore advisable to use hard enamel in all cases. This involves the employment of pure—or almost pure—metals for the plates, which are in most respects the best to receive and retain the enamel. For if there is an excess of alloy, either the metal will possibly melt before the enamel is fused, or afterwards they will part company. To the inferior quality of old silver may be attributed the fact that in all cases the enamel has flown off it; if it has not yet wholly disappeared, it will scale off in time. It is therefore essential that metals should be pure and the enamels hard. It is also noteworthy that enamels composed of a great amount of soda or potash, as compared with those wherein red lead is in greater proportion, are more liable to crack, and have less cohesion to the metal. It is better not to use silver as a basement, although it is capable of reflecting a higher and more brilliant white light than any other metal. Fine gold and pure copper, as thin as possible, are the best metals upon which to enamel. If silver is to be used, it should be fine silver, treated in the methods called *Champlevé* and *Cloisonné*.

The brilliancy of the substance enamel depends upon the perfect combination and proportion of its component parts. The intimacy of the combination depends upon an equal temperature being maintained throughout its fusion in the crucible. For this purpose it is better to obtain a flux which has been already fused and most carefully prepared, and afterwards to add the colouring oxides, which stain it dark or light according to the amount of oxide introduced. Many of the enamels are changed in colour by the difference of the proportion of the parts composing the flux, rather than by the change of oxides. For instance, turquoise blue is obtained from the black oxide of copper by using a comparatively large proportion of carbonate of soda; and a yellow green from the same oxide by increasing the proportionate amount of the red lead. All transparent enamels are made opaque by the addition of calx, which is a mixture of tin and lead calcined. White enamel is made by the addition of stannic and arsenious acids to the flux. The amount of acid regulates the density or opacity of the enamel.

To elucidate the development which has occurred, it will be necessary to describe some of the processes. After the enamel has been procured in the lump, the next stage in the process, common to all methods of enamelling, is to pulverize it. To do this properly the enamel must first be placed in an agate mortar and covered with water; next, with a wooden mallet a number of sharp blows must be given to a pestle held vertically over the enamel, to break it; then, holding the mortar firmly in the left hand, the pestle must be rotated with the right, with as much pressure as possible on the enamel, grinding it until the particles are reduced to a fine grain (Fig. 1). The powder is then subjected to a series of washings in distilled water until all the floury particles are removed. After this the metal is cleaned by immersion in acid and water. For copper, nitric acid is used; for silver, sulphuric; and for gold, hydrochloric acid. All trace of acid is then removed, first by scratching with a brush and water, and finally by drying in warm oak sawdust.

FIG. 1.—Laying enamel on a copper plate, and pulverizing enamel with a pestle and mortar.

After this the pulverized enamel is carefully and evenly spread over those parts of the metal designed to receive it, in sufficient thickness just to cover them and no more. The piece is then dried in front of the furnace, and when dry is placed gently on a fire-clay or iron *planche*, and introduced carefully into the muffle of the furnace, which is heated to a bright pale red (Fig. 2). It is now attentively watched until the enamel shines all over, when it is withdrawn from the furnace. The firing of enamel, unlike that of glass or pottery, takes only a few minutes, and in nearly all processes no annealing is required.

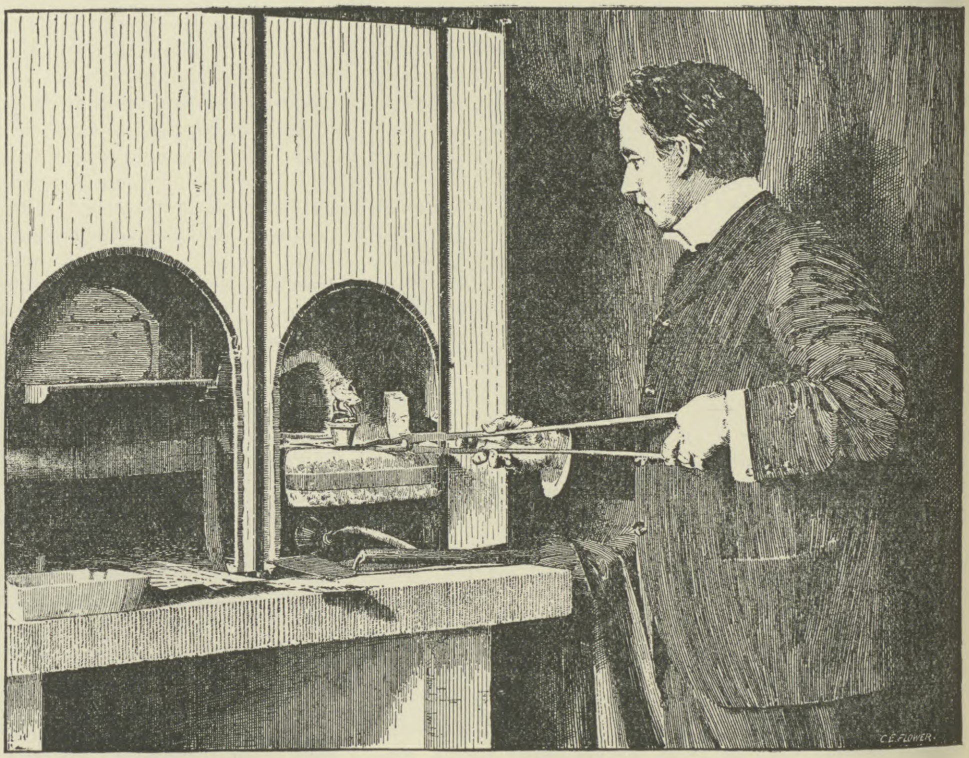


FIG. 2.—Placing an object covered with pulverized enamel into a muffle.

The following are the different modes of enamelling: Champlevé, Cloisonné, Basse-taille, Plique à jour, Painted Enamel, Encrusted, and Miniature-painted. These processes were known at successive periods of ancient art in the order in which they are named. To-day they are all known in their entirety. Each has been largely developed and improved. No new method has been discovered, although variations have been introduced into all. The most important are those connected with painted enamels, encrusted enamels, and *plique à jour*.

Champlevé enamelling is done by cutting away troughs or cells in the plate, leaving a metal line raised between them, which forms the outline of the design. In these cells the pulverized enamel is laid and then fused; afterwards it is filed with a corundum file, then smoothed with a pumice stone, and polished by means of crocus powder and rouge.

In *Cloisonné enamel* upon a metal plate or shape, thin metal strips are bent to the outline of a pattern, then fixed by silver solder or by the enamel itself. These strips form a raised outline, giving cells as in the case of *Champlevé*. The rest of the process is identical with that of *Champlevé* enamelling.

The *Basse-taille process* is also a combination of metalwork in the form of engraving, carving, and enamelling. The metal, either silver or gold, is engraved with a design and then carved into a bas-relief below the general surface of the metal, like an Egyptian bas-relief, so that when the enamel is fused it shall be level with the uncarved parts of the enamel and the design show through the transparent enamel.

Painted enamels are different from any of these processes, both in method and in result. The metal in this case is either copper, silver, or gold, but usually copper. It is cut with shears into a plate of the size required, and slightly domed with a burnisher or hammer, after which it is cleaned by acid and water. Then the enamel is laid equally over the whole surface, both back and front, and afterwards "fired." The first coat of enamel being fixed, the design is carried out, first by laying it in white enamel or any other which is opaque and most advantageous for subsequent coloration.

In the case of a *grisaille painted enamel*, the white is mixed with water or turpentine, or spike oil of lavender, or essential oil of petroleum (according to the taste of the artist), and the white is painted thickly in the light parts and thinly in the grey ones, whereby a slight sense of relief is obtained and a great degree of light and shade.

In *coloured painted enamels* the white is coloured by transparent enamels spread over the grisaille treatment, parts of which when fired are heightened by touches of gold, usually painted in lines. Other parts can be made more brilliant by the use of foil, over which the transparent enamels are placed and then fired.

Enamels by the *Plique à jour* method might be best described as *Translucent cloisonné* enamels; for they are similar to *cloisonné*, except that the ground upon which they are fired is removed, thus making them transparent, like stained glass.

Miniature enamel painting is not true enamelling, for after the white enamel is fired upon the gold plate, the colours used are not vitreous compounds—not enamels, in fact—as is the case in any other form of enamelling; but they are either raw oxides or other forms of metal, with a little flux added, not combined. These colours are painted on the white enamel, and afterwards made to adhere to the surface by partially fusing the enamel, which when in a state of partial fusion becomes viscous.

There are many of these so-called enamels to-day, which are much easier of accomplishment than the true enamel, but they possess none of the beautiful quality of the latter. It is most apparent when parts of a work are true enamels and parts are done in the manner described above. These enamel paintings—or rather paintings on enamel—are afterwards coated over with a transparent flux, which gives them a surface of enamel. Many are done in this way for the market.

All these methods were used formerly, before the present revival; but they were not so completely understood or carried so far as they are to-day, nor were the whole methods practised by any artist as they are now. The greatest advance has been in painted enamels. This process requires that both sides of the metal plate shall be covered with enamel; for this reason the plate is made convex on the top, so that the concave side does not touch the *planche* on which it is supported for firing, but rests upon its edges throughout. There are several reasons why these plates are *bombé*, the principal one being that in the firing they resist the tendency to warp and curl up at the edges, as a flat thin plate would do. Further, the enamel having been fused to both sides, is not so liable to crack or split in subsequent firings. This is most important, for otherwise the white which is placed on afterwards would be a network of cracks. The manner of firing has also to do with this, but not nearly so much as the preliminary care and mechanical perfection with which a plate is prepared. Nearly all the old enamels are seen to be cracked in the white if minutely examined. To obviate this the following points must be observed:—The plate must be of an excellent quality of metal, equal in thickness throughout and of perfectly regular shape. It must be arched equally from end to end. The first coat of enamel must be of a perfectly regular equal thickness on both sides, entirely covering the plate. Whatever the medium employed in painting the white on to the enamel, it must be completely evaporated before the plate is placed in the furnace. The furnace must be heated to a bright red heat, and the *planche* must be red-hot before being taken out for the enamel to be placed upon it, and then quickly returned to the furnace and the muffle door shut tight so as to allow no draught of cool air to enter. Then as soon as it has begun to fuse, which, if a small piece, it would do in a minute or so, the muffle door is slightly opened to afford a view of it. As soon as it shines all over its surface, it is withdrawn from the muffle.

The method of laying the white upon an enamel ground is a matter of individual taste, so far as the medium is concerned. By some, pure distilled water is preferred to any other liquid for mixing the enamel. Otherwise turpentine and the fat oil of turpentine, as well as spike oil of lavender. The oil mixture takes longer to dry, and thus gives a greater chance for modelling into fine shades, than the water. But it has several drawbacks. Firstly, there is the difficulty of drying the oil out—a process which takes some time and increases the risk of cracking in the drying process; and secondly, the enamel is not so fresh and clear after it is fired as when pure water has been employed. Besides, there is a great difference in the result: the water involves a quick, decided, direct touch and method, which carries with it its own charm. The oil medium, besides giving an effect of laborious rounded stippled surfaces, is apt partly to reduce the enamel, thus giving it a dull surface. The coloration of the white is comparatively simple, and is done by transparent enamels finely ground and evenly spread over the white after the latter has been fused. The only danger to be avoided is that of over-firing, which is produced by too great heat or a prolonged duration of firing, which causes the stannic and arsenious acids in the white to volatilize.

Plique à jour enamelling is done in the same way as *cloisonné* enamelling, except that the wires or strips of metal which enclose the enamel are not soldered to the metal basement, but are soldered to each other. Then these are simply placed upon a sheet of platinum, copper, silver, gold, or hard brass, which, after the enamel is fused and sufficiently annealed and cooled, is easily removed. For small pieces of *plique à jour* there is no necessity to apply any metallic basement, as the particles of enamel quickly fuse, become viscous, and when drawn set quite hard. Neither is there any need for annealing, as would be the case in larger work.

Commercially there has lately been an activity in enamels such as has never before occurred. This has been the case throughout Europe, Japan, and the United States of America. In London there has been a demand for a cheap form of gaudy coloured enamel, fused into sunk spaces of metal obtained by stamping with a steel dye; this has been applied to small objects of cheap jewellery, in the form of brooches, bracelets, and the like. There has also been a great demand for enamel watch-cases and small pendants, done mainly by hand, of a better class of work. Many of these have been produced in Birmingham, Berlin, Paris, and London. In Paris copies of pictures in black and white enamel, with a little gold paint in the draperies and background, have been manufactured in very large quantities and sometimes of great dimensions. Another curious demand, followed by as astonishing a production, is that of the imitations (a harder name for which is "forgeries") of old enamels, made with much skill, giving all the technical excellence of the originals, even to the cracks and scratches incidental to age. These are duly signed, and will deceive the most expert. They are copies of enamels by Nardon and Jean Pénicaud, Léonard Limousin, Pierre Reymond, Courtois, and others. The same artificers also produce copies of old Chinese *cloisonné* and *champlevé* enamels, as well as old Battersea enamel snuff-boxes, patch-boxes, and indeed every kind of enamelling formerly practised. It is advisable for the collector never to purchase any piece of enamelling as the work of an old master without having a pedigree extending at least over thirty years. From Japan there has been a continuous flow of *cloisonné* enamelled vases, boxes, and plates, either entirely covered with enamel or applied in parts. Compared with this enormous output, only a few small pieces of jewellery have come from Jaipur and other towns in India. There has also been a great quantity of *plique à jour* enamelling manufactured in Russia, Norway, and Sweden. And finally, it has been used in an unprecedented manner in large pieces upon iron and copper for purposes of advertisement.

Amongst the chief workers in the revival of this art are Claudius Popelin, Alfred Meyer, M. Grandhomme, Fernand Thesmar, Professor von Herkomer, and Mr Alexander Fisher. The work of Claudius Popelin is characterized by good technical skill, correctness, and a careful copying of the work of the old masters. Consequently it suffers from a lack of invention and individuality. His work was devoted to the rendering of mythological subjects and fanciful portraits of historical people. M. Alfred Meyer and M. Grandhomme are both accomplished and careful enamellers; the former is a painter-enameller and the author of a book dealing technically with enamelling. M. Grandhomme paints mythological subjects and portraits in a very tender manner, with considerably more artistic feeling than either Meyer or Popelin. There is a specimen of his work in the Luxembourg Museum. M. Fernand Thesmar is the great reviver of *plique à jour* enamelling in France. Specimens of his work are possessed by the Art Museums throughout Europe, and one is to be seen in the Victoria and Albert Museum, London. They are principally valued on account of their perfect technical achievement. Lucien Falize was an employer of artists and craftsmen, and to him we are indebted for the production of specimens of *Basse-taille* enamel upon silver and gold, as well as for a book reviewing the revival of the art in France, bearing particularly upon the work of Claudius Popelin. Until within the last few years there was a clear division between the art and the crafts in the system of producing art objects. The artist was one person and the workman another. It is now acknowledged that the artist must also be the craftsman, especially in the higher branches of enamelling. M. Falize initiated the production of a gold cup which was enamelled in the *Basse-taille* manner. The band of figures was designed by M. Luc Olivier Merson, the painter, and carved by a metal carver and enamelled by an enameller, both able craftsmen employed by M. Falize. Other pieces of enamelling in *Champlevé* and *Cloisonné* were also produced under his supervision and on this system; therefore lacking the one quality which would make them complete as an expression of artistic emotion by the artist's own hands. M. René Lalique is among the jewellers who have applied enamelling to their work in a peculiarly technically perfect manner. In England, Professor Hubert von Herkomer has produced painted enamels of considerable dimensions, aiming at the execution of pictures in enamel, such as have been generally regarded as peculiar to the province of oil or water-colour painting. Among numerous works is a large shield, into which plaques of enamel were inserted, as well as several portraits, one of which, made in several pieces, is 6 feet high—a portrait of the Emperor William II. of Germany. The present writer rediscovered the making of many enamels, the secrets of which had been jealously guarded. He has worked in all these processes, developing them from the Art side, and helping to make enamelling not only a decorative adjunct to metal-work, but raising it to a Fine Art. His work may be seen in the Victoria and Albert Museum, Brussels Museum, and the Chicago Art Galleries. Others who have been enamelling with success in various branches, and who have shown individuality in their work, are Messrs John Eyre, George Frampton, Nelson Dawson, and William Colton.

See also L. FALIZE. *Claudius Popelin et la Renaissance des Emaux Peints.*—L. DALPAYRAT. *Limoges Enamels.*—H. CUNYNGHAME. *The Art of Enamelling upon Metals.* (A. FI*.)

Energetics.—The most fundamental result attained by the progress of physical science in the 19th century was the definite enunciation and development of the doctrine of energy. Ever since physical speculation began in the atomic theories of the Greeks, its main problem has been that of unravelling the nature of the underlying correlation which binds together the various natural agencies. But it is only in recent times that scientific investigation has definitely established that there is a quantitative relation of simple equivalence between them, whereby each is expressible in terms of heat or mechanical power; that there is a certain measurable quantity associated with each type of physical action which is always numerically identical with a corresponding quantity belonging to the new type into which it is transformed, so that the energy, as it is called, is conserved in unaltered amount. The main obstacle in the way of an earlier recognition and development of this principle had been the doctrine of caloric, which was suggested by the principles and practice of calorimetry, and taught that heat is a substance that can be transferred from one body to another but cannot be created or destroyed, though it may become latent. So long as this idea maintained itself, there was no possible compensation for the destruction of mechanical power by friction; it appeared that mechanical effect had there definitely been lost. The idea that heat is itself convertible into power, and is in fact energy of motion of the minute invisible parts of bodies, had been held by Newton and in a vaguer sense by Bacon, and indeed long before their time; but it dropped out of the ordinary creed of science in the following century. It held a place, like many other anticipations of subsequent discovery, in the system of Natural Philosophy of Young (1804); and the discrepancies attending current explanations on the caloric theory were insisted on, about the same time, by Count Rumford and Sir H. Davy. But it was not till the actual experiments of Joule verified the same exact equivalence between heat produced and mechanical energy destroyed, by whatever process that was accomplished, that the idea of caloric had to be definitely abandoned. Some time previously R. Mayer, physician, of Heilbronn, had founded a weighty theoretical argument on the production of mechanical power in the animal system from the food consumed; he had, moreover, even calculated the value of a unit of heat, in terms of its equivalent in power, from the data afforded by Regnault's determinations of the specific heats of air at constant pressure and at constant volume, the former being the greater on Mayer's hypothesis (of which his calculation in fact constituted the verification) solely on account of the power required for the work of expansion of the gas against the surrounding constant pressure. About the same time Helmholtz, in his early memoir on the Conservation of Energy, constructed a cumulative argument by tracing in a highly original manner the ramifications of the principle throughout the whole range of physical science.

Mechanical and Thermal Energy.—The amount of energy, defined in this sense by convertibility with mechanical work, which is contained in a material system, must be a function of its physical state and chemical constitution and of its temperature. The change in this amount, arising from a given transformation in the system, is usually measured by degrading the energy that leaves the system into heat; for it is always possible to do this, while the conversion of heat back again into other forms of energy is impossible without assistance, taking the form of compensating degradation elsewhere. If we adopt the provisional view which is the basis of abstract physics, that all these other forms of energy are in their essence mechanical, that is, arise from the motion or strain of material or æthereal media, their distinction from heat will lie in the fact that these motions or strains are simply co-ordinated, so that they can be traced and controlled or manipulated in detail, while the thermal energy consists in irregular motions of the molecules or smallest portions of matter, which we cannot analyse on account of the bluntness of our sensual perceptions, but can only measure as regards their total amount.

Historical: Abstract Dynamics.—Even in the case of a purely mechanical system, capable only of a finite number of definite types of disturbance, the principle of the conservation of energy is very far from giving a complete account of its motions; it is only one among the equations that are required to determine their course. In its application to the kinetics of invariable systems, the principle was first emphasized as fundamental by Leibnitz, was then improved and generalized by the Bernoullis and by Euler, and was ultimately expressed in its widest form by Lagrange. It is recorded by Helmholtz that it was largely his acquaintance in early years with the works of those mathematical physicists of the previous century, who had formulated and generalized the principle as a help towards the theoretical dynamics of complex systems of masses, that started him on the track of extending the principle throughout the whole range of natural phenomena. On the other hand, the ascertained validity of this extension to new types of phenomena, such as those of electrodynamics, now forms a main foundation of our belief in a mechanical basis for these sciences.

In the hands of Lagrange the mathematical expression for the manner in which the energy is connected with the geometrical constitution of the material system became a sufficient basis for a complete knowledge of its dynamical phenomena. So far as statics was concerned, this doctrine took its rise as far back as Galileo, who recognized in the simpler cases that the work expended in the steady driving of a frictionless mechanical system is equal to its output. The expression of this fact was generalized in a brief statement by Newton in the *Principia*, and more in detail by the Bernoullis, until, in the analytical guise of the so-called principle of "virtual velocities" or virtual work, it finally became the basis of Lagrange's general formulation of dynamics. In its application to kinetics a purely physical principle, also indicated by Newton but developed long after with masterly applications by d'Alembert, that the reactions of the infinitesimal parts of the system against the accelerations of their motions statically equilibrate the forces applied to the system as a whole, was required in order to form a sufficient basis, and one which Lagrange soon afterwards condensed into the single relation of Least Action. As a matter of history, however, the complete formulation of the subject of abstract dynamics actually arose (in 1758) from Lagrange's precise demonstration of the principle of Least Action for a particle, and its immediate extension, on the basis of his new Calculus of Variations, to a system of connected particles such as might be taken as a representation of any material system; but here too the same physical as distinct from mechanical considerations come into play as in d'Alembert's principle. (See DYNAMICS, ANALYTICAL.)

It is in the cases of systems whose state is changing so slowly that kinetic reactions can be neglected, that the conditions are by far the simplest. In such systems, whether stationary or in a state of steady motion, the energy depends on the configuration alone, and its mathematical expression can be determined from measurement of the work required for a sufficient number of simple transformations; once it is thus found, all the statical relations of the system are implicitly determined along with it, and the results of all other transformations can be predicted. Thus the complete specification of a mechanical system as regards statical change is involved in its geometrical configuration and the function expressing its mechanical energy in terms thereof. Systems which have statical energy-functions of the same analytical form behave in corresponding ways, and can serve as models or representations of one another.

Extension to Thermal and Chemical Systems.—This dominant position of the principle of energy, in ordinary statical problems, has in modern times been extended to transformations involving change of physical state or chemical constitution as well as change of geometrical configuration. In this wider field we cannot assert that mechanical (or available) energy is never lost, for it may be degraded into thermal energy; but we can use the principle that on the other hand it can never spontaneously increase. If this were not so, cyclic processes might theoretically be arranged which would continue to supply mechanical power so long as energy of any kind remained in the system; whereas the irregular and uncontrollable character of the molecular motions and strains which constitute thermal energy, in combination with the vast number of the molecules, places an effectual bar on their unlimited co-ordination. In order, therefore, to establish a doctrine of *energetics* that shall form a sufficient foundation for a theory of the trend of chemical and physical change, we have to impart precision to this notion of available energy.

Carnot's Principle: Entropy.—The whole subject is involved in the new principle contributed to theoretical physics by Sadi Carnot in 1824, in which the far-reaching modern conception of cyclic processes was first scientifically developed. It was shown by Carnot, on the basis of certain axioms, whose theoretical foundations were subsequently corrected and strengthened by Clausius and Lord Kelvin, that a reversible mechanical process, working in a cycle and involving thermal changes, which takes heat, say H_1, into the material system at a given temperature T_1, and delivers the part of it not utilized, say H_2, at a lower given temperature T_2, is more efficient, considered as a working engine, than any other such process, operating between the same two temperatures but not reversible, could be. This relation of inequality involves a definite law of equality, that the efficiencies of all reversible cyclic processes are the same, whatever be the nature of their action or the material substances involved in them; that in fact the efficiency is a function solely of the temperatures at which the cyclically working system takes in and gives out heat. These considerations constitute a fundamental general principle to which all possible slow reversible processes, so far as they concern matter in bulk, must conform in all their stages; its application is almost coextensive with the scope of general physics, special kinetic theories excepted. (See THERMODYNAMICS.) If the system is an ideal gas-engine, in which a perfect gas (known from experience to be a possible state of matter) is passed through the cycle, and if temperature is measured from the absolute zero by the expansion of this gas, then simple direct calculation on the basis of the laws of ideal gases shows that $H_1/T_1 = H_2/T_2$; and as by the conservation of energy the work done is $H_1 - H_2$, it follows that the efficiency is $1 - T_2/T_1$. If we change the sign of H_2, and thus consider heat as positive when it is taken in by the system, the equation becomes $H_1/T_1 + H_2/T_2 = 0$; and as any complex reversible working system may be considered as compounded in various ways of elementary systems of this type, *whose effects are additive*, the general proposition follows, that in any reversible complete cyclic change which involves the taking in of heat by the system of amount δH_r when its temperature is between T_r and $T_r + \delta T$, the equation $\Sigma \delta H_r/T_r = 0$ holds good. Moreover, if the changes are not reversible, the proportion of the heat supply that is utilized for mechanical work will be smaller, so that $\Sigma \delta H_r/T_r$ or, as it may be expressed, $\int dH/T$, must have a smaller value, and must thus be negative. The first statement involves further, that for all reversible paths of change of the system from one state C to another state D, the value of $\int dH/T$ must be the same, because any one of these paths and any other one reversed would form a cycle; whereas for any irreversible path of change between the same states this integral must be less. The quantity represented by this integral was introduced by Clausius, and was named by him the increase of the *entropy* of the system in passing from the state C to the state D. This increase, being thus the same for the unlimited number of possible reversible paths involving independent variation of all its finite co-ordinates, along which the system can pass, can depend only on the terminal states. The entropy belonging to a given state is therefore a function of that state alone, irrespective of the manner in which it has been reached; and this is the justification of the assignment to it of a special name, connoting a property of the system depending on its actual condition and not on its previous history. Every reversible change in an isolated system thus maintains the entropy of that system unaltered; no possible spontaneous change can involve decrease of the entropy; while any defect of reversibility, arising from diffusion of matter or motion in the system, necessarily produces an increase of entropy. For a physical or chemical system with given total energy, only those changes are spontaneously possible which would increase the entropy; if the entropy is already a maximum, and so incapable of further continuous increase, there must be stable equilibrium.

This definite quantity belonging to a material system, its entropy ϕ, is thus concomitant with its energy E, which is also a definite function of its actual state by the law of conservation of energy, its temperature T, and the various co-ordinates expressing its geometrical configuration and its physical and chemical constitution; these are the quantities with which the thermodynamics of the system deals. That science develops the consequences involved in just two principles, (i) that the energy of every isolated system is constant, and (ii) that its entropy can never diminish; any complication that may be involved arises from complexity in the systems to which these two laws have to be applied.

The General Thermodynamic Equation.—When the physical or chemical system undergoes an infinitesimal change of state, we have $\delta E = \delta H + \delta U$, where δH is the heat that has been acquired from sources extraneous to the system during the change, and δU may be called the change in the internal energy of the system. It is, however, not possible to distinguish between heat acquired and internal energy, for neither δH nor δU is the exact differential of a function of the constitution of the system and independent of its previous history, although their sum is such; but δH is equal to $T\delta\phi$ where $\delta\phi$ is such, as has just been seen. Thus E and ϕ are properties of the system which, along with temperature, pressure, and other independent data specifying its constitution, must form the variables of an analytical argument. We have therefore to substitute $T\delta\phi$ for δH; also we have

$$\delta U = -p\delta v + \delta W + \mu_1\delta m_1 + \mu_2\delta m_2 + \cdots + \mu_n\delta m_n,$$

when the system consists of an intimate mixture (solution) of masses $m_1, m_2, \cdots m_n$ of given constituents, which differ physically or chemically but may be partially transformable into each other by chemical or physical action during the changes under consideration, the whole being of volume v and under extraneous pressure p, while W is potential energy arising from physical forces such as those of gravity, capillarity, &c. The variables $m_1, m_2, \cdots\cdots m_n$ may not be all independent; for example, if the system were chloride of ammonium gas existing along with its gaseous products of dissociation, hydrochloric acid and ammonia, only one of the three masses would be independently variable. The sufficient number of these variables together with two other variables, which may be v and T, or v and ϕ, specifies and determines the state of the system, considered as matter in bulk, at each instant. It is usual to include δW in $\mu_1\delta m_1 + \cdots$; in all cases where this is possible the single equation

$$\delta E = T\delta\phi - p\delta v + \mu_1\delta m_1 + \mu_2\delta m_2 + \cdots + \mu_n\delta m_n \cdots\cdots (1)$$

thus expresses the complete variation of the energy-function E arising from change of state; and when the part involving the n constitutive differentials has been expressed in terms of the number of them that are really independent, this equation by itself is the unique expression of *all* the thermodynamic relations of the system. These are in fact the various relations ensuring that the right-hand side is an exact differential, and are of type $d\mu_r/d\phi = dT/dm_r$.

The condition that the state of the system be one of stable equilibrium is that $\delta\phi$, the variation of entropy, be negative for all formally possible infinitesimal transformations which make δE vanish; for as $\delta\phi$ cannot actually be negative for any spontaneous variation, none of these transformations can then occur. From the form of the equation, this condition is the same as that $\delta E - T\delta\phi$ must be positive for *all possible* variations of state of the system without restriction.

We can change one of the independent variables expressing the state of the system from ϕ to T by subtracting $\delta(\phi T)$ from both sides of the equation of variation: then

$$\delta(E - T\phi) = -\phi\delta T - p\delta v + \mu_1\delta m_1 + \cdots + \mu_n\delta m_n.$$

It follows that for isothermal changes, *i.e.*, those for which δT is null, the condition of stable equilibrium is that the function $E - T\phi$ shall be a minimum. If the system is subject to an external pressure p, which as well as the temperature is imposed constant from without and thus incapable of variation through internal changes, the condition of stable equilibrium is similarly that $E - T\phi + pv$ shall be a minimum.

A chemical system maintained at constant temperature may thus have several states of stable equilibrium corresponding to different minima of the function here considered, just as there may be several minima of elevation on a landscape, one at the bottom of each depression; in fact, this analogy, when extended to space of n dimensions, exactly fits the case. If the system is sufficiently disturbed, for example, by electric shock, it may pass over from a higher to a lower minimum, but never (without compensation from outside) in the opposite direction. The former passage is often effected by introducing a new substance into the system; sometimes that substance is recovered unaltered at the end of the process, and then its action is said to be purely *catalytic*; its presence modifies the form of the function $E - T\phi$ so as to obliterate the ridge between the two equilibrium states in the geometrical representation. There are systems in which the equilibrium states are but very slightly dependent on temperature and pressure within wide limits, outside which reaction takes place. Thus while there are cases in which a state of mobile dissociation exists in the system which changes continuously as a function of these variables, there are others in which change does not sensibly occur at all until a certain temperature of reaction is attained, after which it proceeds very rapidly owing to the heat developed, and the system again becomes sensibly permanent in a transformed phase by completion of the reaction. In some cases of this latter type the cause of the delay in starting lies probably in passive resistance to change, of the nature of viscosity or hysteresis; but in many such reactions there seems to be no exact equilibrium at any temperature, short of the ultimate state of dissipated energy in which the reaction is completed, although the velocity of reaction is found to diminish exponentially with change of temperature, and thus becomes insignificant at a small interval from the temperature of pronounced activity.

Free Energy.—The quantity $E - T\phi$ thus plays the same fundamental part in the thermal statics of general chemical systems at uniform temperature that the potential energy plays in the statics of mechanical systems of unchanging constitution. It is a function of the geometrical co-ordinates, the physical and chemical constitution, and the temperature of the system, which determines the conditions of stable equilibrium at each temperature; it is, in fact, the potential energy generalized so as to include temperature, and thus be a single function available at each temperature and connecting the properties of the system at different temperatures. It has been called the *free energy* of the system by Helmholtz, for it is the part of the energy whose variation is connected with changes in the bodily structure of the system represented by the variables $m_1, m_2, \cdots m_n$, and not with the irregular molecular energy represented by heat, so that it can take part freely in physical transformations. Yet this holds good only subject to the condition that the temperature is not varied; it has been seen above that for the more general variation neither δH nor δU is an exact differential, and no line of separation can be drawn between thermal and mechanical energies.

Available Energy.—The same quantity ϕ arose in the early development of the subject, in the train of ideas of Rankine and Kelvin, in the expression of the *available energy* A of the material system. Suppose there were accessible an auxiliary system containing an unlimited quantity of heat at absolute temperature T_o, forming a condenser into which heat can be discharged from the working system, or from which it may be recovered at that temperature: we proceed to find how much of the heat of our system is available for transformation into mechanical work in a process which reduces the whole system to the temperature of this condenser. Provided the process of reduction is performed reversibly, it is immaterial, by Carnot's principle, in what manner it is effected: thus in following it out in detail we can consider each elementary quantity of heat δH removed from the system as set aside at its actual temperature between T and $T + \delta T$ for the production of mechanical work δW, and the residue of it δH_o as directly discharged into the condenser at T_o; the principle of Carnot gives $\delta H/T = \delta H_o/T_o$, so that the portion of the heat δH that is not available for work is δH_o, equal to $T_o \delta H/T$. In the whole process the part not available in connexion with the condenser at T_o is therefore $T_o \int dH/T$. This quantity must be the same whatever reversible process is employed: thus, for example, we may first transform the system reversibly from the state C to the state D, and then from the state D to the final state of uniform temperature T_o. It follows that the value of $T_o \int dH/T$, representing the heat degraded, is the same along all reversible paths of transformation from the state C to the state D; so that the function $\int dH/T$ is the excess of a definite quantitative property ϕ of the system in the former state as compared with the latter. It is usual to change the law of sign of δH so that gain of heat by the system is reckoned positive; then, relative to a condenser of unlimited capacity at T_o, the state C contains more mechanically *available energy* than the state D by the amount $E_C - E_D + T_o \int dH/T$, that is, by $E_C - E_D - T_o(\phi_C - \phi_D)$. In this way the existence of an entropy function with a definite value for each state of the system is again seen to be the direct analytical equivalent of Carnot's axiom that no process can be more efficient than a reversible process between the same initial and final states. The name *motivity* was proposed by Lord Kelvin in 1879 for this conception of available energy. It is here relative to a condenser of unlimited capacity at an assigned temperature T_o: the latter specification is necessary to the definition; in fact, if T_o were the absolute zero all the energy would be mechanically available.

But we can obtain an intrinsically different and more definite comparison of the available energies in a system in two different states at different temperatures, by ascertaining how much energy is dissipated in each in a reduction to the *same* standard state of the system at a standard temperature T_o. We have only to reverse the operation, and change back this standard state to each of the others in turn. This will involve abstractions of heat δH_o from the separate portions in the standard state, and returns of δH to the state at T; if this return were $\delta H_o \cdot T/T_o$ there would be no loss of availability in the direct process; hence there is actual dissipation $\delta H - \delta H_o \cdot T/T_o$, that is $T(\delta\phi - \delta\phi_o)$. On passing from state 1 to state 2 through state 0 the difference of these dissipations will represent the energy of the system that has become unavailable. Thus in this sense $E - T\phi + T\phi_o +$ const. represents for each state the amount of energy that is available; but instead of implying an unlimited source of heat at the standard temperature T_o, it implies that there is no such source. The available energy thus defined differs from $E - T\phi$, the *free energy* of Helmholtz, which involves no reference to any standard state, by a simple linear function of the temperature alone which is immaterial as regards its applications.

The determination of the available mechanical energy arising from differences of temperature between the parts of a system is a more complex problem, because it involves a determination of the common temperature to which reversible processes will ultimately reduce them; for the simple case in which no changes of state occur the solution was given by Lord Kelvin in 1853, in connexion with the above train of ideas (cf. Tait's *Thermodynamics*, § 179). In the present exposition the chemical system is in equilibrium, so that its temperature T is always uniform throughout; isolated portions at different temperatures would be treated as different systems.

Thermodynamic Potentials.—We have now to develop the relations involved in the general equation (1) of thermodynamics. Suppose the system includes two coexistent states or phases, with opportunity for free interchange of constituents—for example, a salt solution and the aqueous vapour in equilibrium above—it may be included in the material system. Then in equilibrium a slight transfer δm of the water-substance of mass m_r existing in the vapour, into the water-substance of mass m_s existing in the solution, should not produce any alteration of the first order in $\delta E - T\delta\phi$; therefore μ_r must be equal to μ_s. The quantity μ_r is called by Willard Gibbs the potential of the corresponding substance of mass m_r; it may be defined as its marginal available energy per unit mass at constant temperature. If then a system involves in this way coexistent phases which remain permanently separate, the potentials of any constituent must be the same in all of them in which that constituent exists, for otherwise it would tend to pass from the phases in which its potential is higher to those in which it is lower. If the constituent is non-existent in any phase, its potential when in that phase would have to be higher than in the others in which it is actually present; but as the potential increases logarithmically when the density of the constituent is indefinitely diminished, this condition is automatically satisfied. When the action of the force of gravity is taken into account, the potential of each constituent must include the gravitational potential gh; and in the equilibrium state the total potential of each constituent must be the same throughout all parts of the system into which it is freely mobile. A similar statement applies to other forms of mechanical potential energy arising from actions at a distance.

When a slight constitutive change occurs in a galvanic element at given temperature, producing available energy of electric current in a reversible manner and isothermally at the expense of chemical energy, it is the free energy of the system $E - T\phi$, not its total intrinsic energy, whose value must be conserved during the process. Thus the electromotive force is equal to the change of this free energy per electro-chemical equivalent of reaction in the cell. This proposition, developed by Gibbs and later by Helmholtz, modifies the earlier one of Kelvin — which tacitly assumed all the energy of reaction to be available —except in the cases in which the magnitude of the electromotive force does not depend sensibly on the temperature.

The effects produced on electromotive forces by difference of concentrations in dilute solutions can thus be accounted for and traced out, from the knowledge of the form of the free energy for such cases; as also the effects of pressure in the case of gas batteries. The free energy does not sensibly depend on whether the substance is solid or fused, though the total energy differs in these two cases by the heat of fusion; for this reason, as Gibbs has pointed out, voltaic potential differences are the same for the fused as for the solid state.

Relations involving Constitution only.—The potential of a component in a given solution can depend only on the temperature and pressure of the solution, and the densities of the various components, including itself; as no distance-actions are usually involved in chemical physics, it will not depend on the aggregate masses present. The example above mentioned, of two coexistent phases liquid and vapour, indicates that there may be relations between the constitutions of the phases present in a chemical system which do not involve their total masses. These are developed in a very direct manner in Willard Gibbs's original procedure. In so far as attractions at a distance (a uniform force such as gravity being excepted) and capillary actions at the interfaces between the phases are inoperative, the fundamental equation (1) can be integrated. Increasing the volume k times, and all the masses to the same extent —in fact, placing alongside each other k identical systems at the same temperature and pressure—will increase ϕ and E in the same ratio k; thus E must be a homogeneous function of the first degree of the independent variables ϕ, v, $m_1, \ldots, m_n$, and therefore by Euler's theorem relating to such functions

$$E = T\phi - pv + \mu_1 m_1 + \cdots + \mu_n m_n.$$

This integral equation merely expresses the additive character of the energies and entropies of adjacent portions of the system at uniform temperature, and thus depends only on the absence of sensible physical action directly across finite distances. If we form from it the expression for the complete differential δE, and subtract (1), there remains the relation

$$0 = \phi\delta T - v\delta p + m_1\delta\mu_1 + \cdots + m_n\delta\mu_n. \quad . \quad . \quad (2)$$

This implies that in each phase the change of pressure depends on and is determined by the changes in T, $\mu_1, \cdots \mu_n$; as we know beforehand that a physical property like pressure is an analytical function of the state of the system, it is therefore a function of these $n+1$ quantities. When they are all independently variable, the densities of the various constituents and of the entropy in the phase are expressed by the partial fluxions of p with respect to them: thus

$$\frac{\phi}{v} = \frac{dp}{dT}, \qquad \frac{m_r}{v} = \frac{dp}{d\mu_r}.$$

When, as in the case above referred to of chloride of ammonium gas existing partially dissociated along with its constituents, the masses are not independent, necessary linear relations, furnished by the laws of definite combining proportions, subsist between the partial fluxions, and the form of the function which expresses p is thus restricted in a manner which is easily expressible in each special case.

This proposition, that the pressure in any phase is a function of the temperature and of the potentials of the independent constituents, is a consequence of Carnot's axiom combined with the energy principle and the absence of effective actions at a distance. It shows that at a given temperature and pressure the potentials are not all independent, that there is a necessary relation connecting them, an equation of state or constitution of the phase, whose existence forms one mode of expression of Carnot's principle, and from which all the properties of the phase can be derived by simple differentiation.

The Phase Rule.—When the material system contains only a single phase, the number of independent variations that can spontaneously occur in its constitution is thus one less than the number of its independent components; in addition, the temperature and pressure can change. But where several phases coexist in the same system, the number of possible independent variations may be much smaller. The present independent variables $\mu_1, \cdots, \mu_n$ are specially appropriate in this problem, because each of them has the same value in all the phases. Now each phase has its own characteristic equation, giving a relation between δp, δT, and $\delta\mu_1, \cdots \delta\mu_n$, or such of the latter as are independent; if r phases coexist, there are r such relations; hence the number of possible independent variations, including those of v and T, is reduced to $m - r + 2$, where m is the number of independently variable chemical constituents the system contains. This number of degrees of constitutive freedom cannot be negative; therefore the number of possible phases that can coexist alongside each other cannot exceed $m + 2$. If $m + 2$ phases actually coexist, there is no variable quantity in the system, thus the temperature and pressure and constitutions of the phases are all determined; such is the triple point at which ice, water, and vapour exist in presence of each other. If there are $m+1$ coexistent phases, the system can vary in one respect only; for example, at any temperature of water-substance different from the triple point two phases only, say liquid and vapour, coexist, and the pressure is definite, as also are the densities and potentials of the components. Finally, when but one phase, say water, is present, both pressure and temperature can vary independently. The first example illustrates the case of systems, physical or chemical, in which there is only one possible state of equilibrium, forming a point of transition between different constitutions; in the second type each temperature has its own completely determined state of equilibrium; in other cases the constitution in the equilibrium state is indeterminate as regards the corresponding number of degrees of freedom. By aid of this phase rule of Gibbs the number of different chemical substances existing in a given complex system can be determined from observation of the degree of spontaneous variation which it exhibits; the rule thus lies at the foundation of the modern subject of chemical equilibrium and continuous chemical change in mixtures or alloys, and in this connexion it has been widely applied and developed in the experimental investigations of Roozeboom and van 't Hoff and other physical chemists, mainly of the Dutch school.

Cases in which the Theory can be practically developed.—It is only in systems in which the number of independent variables is small that the forms of the various potentials,—or the form of the fundamental characteristic equation expressing the energy of the system in terms of its entropy and constitution, or the pressure in terms of the temperature and the potentials,—which includes them all, can be readily approximated to by experimental determinations. Even in the case of the simple system water-vapour, which is fundamental for the theory of the steam engine, this has not yet been completely accomplished. The general theory is thus largely confined, as above, to defining the restrictions on the degree of variability of a complex chemical system which the principle of Carnot imposes. The tracing out of these general relations of continuity is much facilitated by geometrical diagrams, such as James Thomson first introduced in order to exhibit and explain Andrews's results as to the range of coexistent phases in carbonic acid. Gibbs's earliest thermodynamic surface had for its co-ordinates volume, entropy, and energy; it was constructed to scale by Maxwell for water-substance, and is fully explained in later editions of the *Theory of Heat* (1875); it forms a relief map which, by simple inspection, reveals the course of the transformations of water, with the corresponding mechanical and thermal changes, in its three coexistent states of solid, liquid, and gas. In the general case, when the substance has more than one independently variable constituent, there are more than three variables to be represented; but Gibbs has shown the utility of surfaces representing, for instance, the entropy in terms of the constitutive variables when temperature and pressure are maintained constant. Such graphical methods are now of fundamental utility in connexion with the phase rule, for the experimental exploration of the trend of the changes of constitution of complex mixtures with interacting components, as the physical conditions are altered. The study of the phenomena of condensation in a mixture of two gases or vapours, initiated by Andrews and developed in this manner by van der Waals and his pupils, forms a case in point. (See CONDENSATION OF GASES.)

There are, however, two simple limiting cases, in which the theory can be completed by a determination of the functions involved in it, which throw much light on the phenomena of actual systems not far removed from these ideal limits. They are the cases of mixtures of perfect gases, and of very dilute solutions.

If, following Gibbs, we apply his equation (2), expressing the pressure in terms of the temperature and the potentials, to a very dilute solution of substances $m_2, m_3, \cdots m_n$ in a substance m_1, and vary the co-ordinate m_r alone, p and T remaining unvaried, we have in the equilibrium state

$$m_r\frac{d\mu_r}{dm_r}+m_1\frac{d\mu_1}{dm_r}+\cdots+m_n\frac{d\mu_n}{dm_r}=0,$$

in which every m except m_1 is very small, while $d\mu_1/dm_r$ is presumably finite. This requires (when applied, for example, to the case where only two components are present) that the total potential of each component m_r, which is $m_r d\mu_r/dm_r$, shall be finite, say k_r, in the limit when m_r is null. Thus for very small concentrations the potential μ_r of a dilute component must be of the form $k_r \log m_r/v$, being proportional to the logarithm of the density of that component; it thus tends to an infinite value at evanescent concentrations, showing that removal of the last traces of any impurity would demand infinite expenditure of available energy.

The value of this logarithmic expression can be readily determined for the case of a perfect gas from its known properties, and can be thence extended to other dilute forms of matter. We have $pv=\mathrm{R}/m\cdot\mathrm{T}$ for unit mass of the gas, where m is the molecular weight being 2 for hydrogen, and R is a constant equal to $8{\cdot}2\times10^6$ in C.G.S. dynamical units, the same for all gases because they have all the same number of molecules per unit volume. The increment of heat received by the unit mass of the gas is $\delta\mathrm{H}=p\delta v+\kappa\delta\mathrm{T}$, where κ is the specific heat at constant volume, which can be a function only of the temperature. Thus

$$\phi=\int d\mathrm{H}/\mathrm{T}=\mathrm{R}/m.\ \log v\ +\int\kappa\mathrm{T}^{-1}d\mathrm{T};$$

and the available energy A per unit mass is $\mathrm{E}-\mathrm{T}\phi+\mathrm{T}\phi_o$ where $\mathrm{E}=\epsilon+\int\kappa d\mathrm{T}$, ϵ being intrinsic energy of chemical constitution, so that

$$\mathrm{A}=\epsilon+\phi_o\mathrm{T}+\int\kappa d\mathrm{T}-\mathrm{T}\int\kappa\mathrm{T}^{-1}d\mathrm{T}-\mathrm{R}/m.\ \mathrm{T}\log v.$$

If there are ν molecules in the unit mass, and N per unit volume, we have $m\nu=\mathrm{N}mv$, each being $2\nu'$ where ν' is the number of molecules per unit mass in hydrogen; thus the free energy per molecule is $a'+\mathrm{R}'\mathrm{T}\log b\mathrm{N}$, where $b=m/2\nu'$, $\mathrm{R}'=\mathrm{R}/2\nu'$, and a' is a function of T alone. In thermal energy units (calories) the gas-constant R is very approximately equal to 2. It is customary to avoid introducing the unknown molecular constant ν' by expressing the available energy per "gramme-molecule," that is, for a number of grammes equal to the molecular weight of the substance; this is a constant multiple of the available energy per molecule, and is $a+\mathrm{R}\mathrm{T}\log\rho$, ρ being the density, equal to $b\mathrm{N}$ where $b=m/2\nu'$. This formula may now be extended by simple summation to a mixture of gases, on the ground of Dalton's experimental principle that each of the components behaves in presence of the others as it would do in a vacuum. The components are actually separable wholly or partially in reversible ways which may be combined into cycles; for example, either (i) by diffusion through a porous partition, taking account of the work of the pressures, or (ii) by utilizing the modified constitution towards the top of a long column of the mixture arising from the action of gravity, or (iii) by reversible absorption of a single component. If we employ in place of available energy the form of characteristic equation which gives the pressure in terms of the temperature and potentials, the pressure of the mixture is expressed as the sum of those belonging to its components; this equation was made by Gibbs the basis of his analytical theory of gas mixtures, which he tested by its application to the only data then available, those of the mobile dissociation of nitric oxide vapour.

Van 't Hoff's Osmotic Principle: Theoretical Explanation.—We proceed to examine how far the same formulæ as hold for gases apply to the available energy of matter in solution which is so dilute that each molecule of the dissolved substance, though possibly the centre of a complex of molecules of the solvent, is nearly all the time beyond the sphere of direct influence of the other molecules of the dissolved substance. The available energy is a function only of the co-ordinates of the matter in bulk and the temperature; its change on further dilution, with which alone we are concerned in the transformations of dilute solutions, can depend only on the further separation of these molecular complexes that is thereby produced, as no one of them is in itself altered. The change is therefore a function only of the number N of the dissolved molecules per unit volume, and of the temperature, and is, per molecule, entirely independent of their constitution and of that of the medium in which they are dissolved. This suggests that the expression for the change is the same as the known one for a gas in which the same molecules would exist free and in the main outside each others' spheres of influence; which confirms and is verified by the experimental principle of van 't Hoff, that osmotic pressure obeys the laws of gaseous pressure with the same physical constants as those of gases. It can be held, in fact, that this suggestion does not fall short of a demonstration, on the basis of Carnot's principle, and independent of special molecular theory, that in all cases where the molecules of a component, whether it be of a gas or of a solution, are outside each others' spheres of influence, the available energy, so far as regards dilution, must have a common form, and the physical constants must therefore be the known gas-constants.

The single new element that thermodynamics introduces into the ordinary dynamical specification of a material system is temperature. This conception is akin to that of potential, except that it is given to us directly by our sense of heat. But if that were not so, we could still demonstrate, on the basis of Carnot's principle, that there is a definite function of the state of a body which must be the same for all of a series of connected bodies, when thermal equilibrium has become established so that there is no tendency for heat to flow from one to another. For we can by geometrical displacement change the order of the bodies so as to bring different ones into direct contact. If this disturbed the thermal equilibrium, we could construct cyclic processes to take advantage of the resulting flow of heat to do mechanical work, and such processes might be carried on without limit. This argument can be applied, by aid of adiabatic partitions, even when the bodies are in a field of force so that mechanical work is required to change their order; it has, in fact, been employed by Maxwell to extend from the case of a gas to that of any other system the proposition that the temperature is the same all along a vertical column in equilibrium under gravity. It had been shown from the kinetic theory by Maxwell that in a gas-column the mean kinetic energy of the molecules is the same at all heights. If the only test of equality of temperature consisted in bringing the bodies into contact, this would be rather a proof that thermal temperature is of the same physical nature in all parts of the field of force; but temperature can also be equalized across a distance by radiation, so that this law for gases is itself already necessitated by Carnot's general principle, and is merely confirmed by the special gas-theory.

Chemical Equilibrium based on Available Energy.—The complete theory of chemical and physical equilibrium in gaseous mixtures and in very dilute solutions may readily be developed in terms of available energy (cf. *Phil. Trans.*, 1897, A, pp. 266–280), which forms perhaps the most vivid and most direct procedure. The available energy per molecule of any kind, in a mixture of perfect gases in which there are N molecules of that kind per unit volume, has been found to be $a' + R'T \log bN$. This expression represents the marginal increase of available energy due to the introduction of one more molecule of that kind into the system as actually constituted. The same formula also applies, by what has already been stated, to substances in dilute solution in any given solvent. In any isolated system in a mobile state of reaction or of internal dissociation, the condition of chemical equilibrium is that the available energy at constant temperature is a minimum, so that it is stationary and slight change arising from fresh reaction would not sensibly alter it. Suppose that this reaction, per molecule, is equivalent to introducing n_1 molecules of type N_1, n_2 of type N_2, &c., into the system, $n_1, n_2, \cdots$ being the numbers of molecules of the different types that take part in the reaction, as shown by its chemical equation, reckoned positive when they appear negative when they disappear. Then in the state of equilibrium

$$n_1(a'_1 + R'T \log b_1N_1) + n_2(a'_2 + R'T \log b_2N_2) + \cdots$$

must vanish. Therefore $N_1^{n_1} N_2^{n_2} \cdots$ must be equal to K, a function of the temperature alone. This law, originally based by Guldberg and Waage on direct molecular statistics, expresses for each temperature the relation connecting the densities of the interacting substances, in dilution comparable as regards density with the perfect gaseous state, when the reaction has come to the state of mobile equilibrium.

All properties of any system, including the heat of reaction, are expressible in terms of its available energy A, equal to $E - T\phi + \phi_o T$. Thus as the constitution of the system changes with the temperature, we have

$$\frac{dA}{dT} = \frac{dE}{dT} - T\frac{d\phi}{dT} - (\phi - \phi_o)$$

where $dE = dH + dW$, $dH = Td\phi$, dH being heat and dW mechanical and chemical energy imparted to the system; hence $\phi - \phi_o = -\frac{d(A-W)}{dT}$, so that $A = E + T\frac{d(A-W)}{dT}$, leading to $E - W = -T^2\frac{d}{dT}\left(\frac{A-W}{T}\right)$. This general formula, applied differentially, expresses the heat $\delta E - \delta W$ absorbed by a reaction in terms of δA, the change produced by it in the available energy of the system, and of δW, the mechanical and electrical work done on the system during its progress.

In the problem of reaction in gaseous systems or in very dilute solution, the change of available energy per molecule of reaction has already been found to be

$$\delta A = \delta A_o + R'T \log K', \text{ where } K' = b_1^{n_1} b_2^{n_2} \cdots K;$$

thus, when the reaction is spontaneous without external work, the heat absorbed per molecule of reaction is $-T^2\frac{d}{dT}\frac{\delta A_o}{T}$, or $R'T^2\frac{d}{dT}\log K$. This formula has been utilized by van 't Hoff to determine, in terms of the heat of reaction, the displacement of equilibrium in various systems arising from change of temperature, K being the reaction-parameter through which alone the temperature enters into the law of chemical equilibrium.

Interfacial Phenomena: Liquid Films.—The characteristic equation hitherto developed refers to the state of an element of mass in the interior of a homogeneous substance: it does not apply to matter in the neighbourhood of an interface between two adjacent phases. A remarkable analysis has been developed by Gibbs in which the present methods concerning matter in bulk are extended to the phenomena at an interface, without the introduction of any molecular theory; it forms the thermodynamic completion of Gauss's purely mechanical theory of capillarity, based on the principle of energy. The validity of the fundamental doctrine of available energy, so far as regards all mechanical actions in bulk such as surface tensions, is postulated, even when applied to interfacial layers so thin as to be beyond our means of measurement; the argument from perpetual motions being available here also as soon as we have experimentally ascertained that the said tensions are definite physical properties of the state of the interface and not merely accidental. The procedure will then consist in assuming a definite excess of energy, of entropy, and of the masses of the various components, each per unit surface, at the interface, the potential of each component being, in equilibrium, the same as it is in the adjacent masses. The interfacial transition layer thus provides in a sense a new phase coexistent with those on each side of it and having its own characteristic equation. It is only the extent of the interface and not its curvatures that practically enters into this relation, because any slight influence of the latter can be eliminated from the equation by slightly displacing the position of the surface which is taken to represent the interface geometrically. By an argument similar to one given above it is shown that one of the forms of the characteristic equation is a relation expressing the surface tension as a function of the temperature and the potentials of the various components present on the two sides of the interface, from the differentiation of which the surface densities of the superficial distributions of these components (as above defined) can be obtained. The conditions that a given new phase may become developed when two other given ones are brought into contact, *i.e.*, that a chemical reaction may start at the interface, are thence formally expressed in terms of the surface tensions of the three transition layers and the pressures in the three phases. In the case of a thin soap-film, sudden extension of any part reduces the interfacial density of each component at each surface of the film, and so alters the surface tension, which requires time to recover by the very slow diffusion of dissolved material from other parts of the film; the system being stable, this change must be an increase of tension, and constitutes a species of elasticity in the film. Thus in a vertical film the surface tension must be greater in the higher parts, as they have to sustain the weight of the lower parts; the upper parts, in fact, stretch until the superficial densities of the components there situated are reduced to the amounts that correspond to the tension required for this purpose. Such a film could not therefore consist of pure water. But there is a limit to these processes: if the film becomes so thin that there is no water in bulk between its surfaces, the tensions cannot adjust themselves in this slow way by migration of components from one part of the film to another; if the film can survive at all after it has become of molecular thickness, it must be as a definite molecular structure all across its thickness. Of such type are the black spots that break out in soap-films, as has been suggested by Gibbs and proved by the measures of Reinold and Rücker: the spots increase in size because their tension is less than that of the surrounding film, but their indefinite increase is presumably stopped in practice by some clogging or viscous agency at their boundary.

Transition to Molecular Theory.—The subject of energetics, based on the doctrine of available energy, deals with matter in bulk and is not concerned with its molecular constitution. This analysis of the phenomena of surface tension shows how far the principle of negation of perpetual motions can carry us into regions which at first sight might be classed as molecular. But, as in other cases, it is limited to pointing out the general scheme of relations within which the phenomena can have their play. There is now a considerable body of knowledge correlating surface tension with chemical constitution, especially to a certain extent with the numerical density of the distribution of molecules; this takes us into the sphere of molecular science, and at present we have only somewhat vague indications largely derived from experiment, if we except the mere notion of interatomic forces of unknown character on which the older theories of capillarity, those of Laplace and Poisson, were constructed.

In other topics the same restrictions on the scope of the simple statical theory of energy appear. From the ascertained behaviour in certain respects of gaseous media we are able to construct their characteristic equation, and correlate their remaining relations by means of its consequences. Part of the experimental knowledge required for this purpose are the values of the gas-constants, which prove to be the same for all nearly perfect gases. The doctrine of energetics can give no clue as to why this should be so; it can only construct a scheme for each simple or complex medium on the basis of its own experimentally determined characteristic equation. The explanation of uniformities in the intrinsic constitutions of various media belongs to molecular theory, which is a distinct and in the main more complex and more speculative department of knowledge. When we proceed further and find, with van 't Hoff, that these same universal gas-constants reappear in the relations of very dilute solutions, our demand for an explanation such as can only be provided by molecular theory (as *supra*) is intensely stimulated. But except in these respects the doctrine of energetics gives a complete synthesis of the course and relations of the chemical reactions of matter in bulk, from which we can eliminate atomism altogether by restating the merely numerical atomic theory of Dalton as a principle of equivalent combining proportions. Of recent years there has been a considerable school of chemists who insist on this procedure as a purification of their science from the hypothetical ideas as to atoms and molecules in terms of which its experimental facts have come to be expressed. A complete system of doctrine can be developed in this manner, but its scope will be limited. It makes use of one principle of correlation, the doctrine of available energy, and discards another such principle, the atomic theory. Nor can it be said that the one principle is really more certain and definite than the other. This may be illustrated by what has sometimes in Germany been called Gibbs's paradox: the energy that is available for mechanical effect in the inter-diffusion of given volumes of two gases depends only on these volumes and their pressures, and is independent of what the gases are; if the gases differed only infinitesimally in constitution it would still be the same, and the question arises where we are to stop, for we cannot suppose the inter-diffusion of two identical gases to be a source of power. This then looks like a real failure, or rather limitation, of the principle; and there are other such, that can only be satisfactorily explained by aid of the complementary doctrine of molecular theory. That theory, in fact, shows that the more nearly identical the gases are, the slower will be the process of inter-diffusion, so that the mechanical energy will indeed be available, but only after a time that becomes indefinitely prolonged. It is a case in which the simple doctrine of energetics becomes inadequate before the limit is reached. The phenomena of highly rarefied gases provide other cases. And in fact the only reason hitherto thought of for the invariable tendency of available energy to diminish, is that it represents the general principle that in the kinetic play of a vast assemblage of independent molecules individually beyond our control the tendency is for the regularities to diminish and the motions to become less correlated: short of some such reason, it is an unexplained empirical principle. In the special departments of theoretical physics on the other hand, the molecular theory, there dynamical and therefore much more difficult and less definite, is an indispensable part of the framework of science; and even experimental chemistry now leans more and more on new physical methods and instruments. Without molecular theory the clue which has developed into spectrum analysis, bringing with it stellar chemistry and a new physical astronomy, would not have been available; nor would the laws of diffusion and conduction in gases have attained more than an empirical form; nor would it have been possible to weave the phenomena of electrodynamics and radiation into an entirely rational theory, as is now being done.

The doctrine of available energy, as the expression of thermodynamic theory, is directly implied in Carnot's *Essai* of 1824, and constitutes, in fact, its main theme; it took a fresh start, in the light of fuller experimental knowledge regarding the nature of heat, in the early memoirs of Rankine and Lord Kelvin, which may be found in their collected scientific papers; a subsequent exposition occurs in Maxwell's *Theory of Heat;* its most familiar form of statement is Lord Kelvin's principle of the dissipation of available energy. Its principles were very early applied by James Thomson to a physico-chemical problem, that of the influence of stress on the growth of crystals in their mother liquor. The "thermodynamic function" introduced by Rankine into its development is the same as the "entropy" of the material system, independently defined by Clausius about the same time. Clausius's form of the principle, that in an adiabatic system the entropy tends continually to increase, has been placed by Professor Willard Gibbs, of Yale University, at the foundation of his magnificent but complex and difficult development of the theory, "On the Equilibrium of Heterogeneous Substances," *Trans. Connecticut Academy*, 1876–78, pp. 320, abstracted by its author in the *American Journal of Science*, vol. xvi., which has been translated into German by Ostwald, and into French (as regards the more purely chemical part) by Le Chatelier. This monumental memoir made a clean sweep of the subject; and workers in the modern experimental science of physical chemistry have returned to it again and again to find their empirical principles forecasted in the light of pure theory, and to derive fresh inspiration for new departures. As specially preparatory to Gibbs may be mentioned Lord Rayleigh's memoir on the thermodynamics of gaseous diffusion (*Phil. Mag.*, 1876), which has been expounded by Maxwell in the 9th edition of the *Ency. Brit.* (vol. vii. p. 214, art. DIFFUSION). The fundamental importance of the doctrine of dissipation of energy for the theory of chemical reaction had already been insisted on in general terms by Rayleigh; subsequent to, but independently of, Gibbs's work it had been elaborated by von Helmholtz (*Gesamm. Abhandl.* ii. and iii.) in connexion with the thermodynamics of voltaic cells, and more particularly in the calculation of the free or available energy of solutions from data of vapour-pressure, with a view to the application to the theory of concentration cells, therein also coming close to the doctrine of osmotic pressure. Expositions and developments on various lines will be found in papers by Riecke and by Planck in *Annalen der Physik* between 1890 and 1900, in the course of a memoir by Larmor, *Phil. Trans.*, 1897, A, in Voigt's *Compendium der Physik*, in Planck's *Vorlesungen über Thermodynamik*, and in Duhem's elaborate *Traité de Mécanique Chimique* and *Le Potentiel Thermodynamique.* Numerous actual applications are expounded in van 't Hoff's *Lectures on Chemical Physics*, translated by Lehfeldt.

See also THERMODYNAMICS. (J. L*.)

Enfield, a township in the Enfield parliamentary division of Middlesex, England, 10 miles north of London by rail. There are nine Established churches (one containing ancient memorials); also Roman Catholic and various Nonconformist chapels. Recent erections are a church institute, parish hall, and public library. Associated with Enfield by residence have been Charles Lamb, Isaac D'Israeli (born here in 1766), Babbage the mathematician, Captain Marryat the novelist, and Keats the poet, who were educated within the parish. Area of township (an urban district), 12,600 acres. Population (1881), 18,944; (1901), 42,738.

Enfield, a town of Hartford county, Connecticut, U.S.A., on the east bank of the Connecticut river, and traversed by the New York, New Haven, and Hartford Railways. It includes an area of 35 square miles, containing a considerable rural population, together with the villages of Enfield, Thompsonville, and Hazardville. It is mainly known from its manufacture of gunpowder. Population of the town (1880), 6755; (1890), 7199; (1900), 6699.

Engadine, the upper or Swiss portion of the Valley of the Inn. Its length from the Maloja to Martinsbruck, by an excellent high road, is 59½ miles, of which 26¾ miles are in the Upper Engadine and the rest in the Lower Engadine. The *Upper Engadine* is now best known as one of the great "air cures" of Europe, especially in winter, though the mineral waters of St Moritz are also much employed in the summer time. Many good carriage roads lead to the Upper Engadine over the Maloja, Julier, Albula, and Bernina Passes, all built between 1820 and 1865. A railway is now being constructed by the Albula (tunnel beneath the pass). The *Lower Engadine* begins at the Punt 'Ota, close to the hamlet of Brail. It is far more picturesque and more romantic than the flat, level valley of the Upper Engadine, but is not so well known to tourists, though the waters of Tarasp have long been celebrated. The Lower Engadine is poor in carriage roads over the side passes, there being but two —over the Flüela Pass to Davos, and over the Ofen Pass to Mals, the former built in 1867, and the latter in 1871–72. Since 1282 the Lower Engadine has been separated from Tirol by the wild and savage gorge of Finstermünz, passable only on foot, the carriage road from Martinsbruck to Pfunds making a great ascent to Nauders, and then a great descent. In 1900 the population of the Upper Engadine (capital, Samaden, 1028 souls) was 5498, and that of the Lower Engadine (capital, Schuls, 1116 souls) 6275. Practically the whole population speaks the quaint Romance dialect known as Ladin.

E. IMHOF. *Itinerarium des S. A. C. für die Silvretta- und Ofenpassgruppe* (Mountains of the Lower Engadine). Bern, 1898. —E. LECHNER. *Das Oberengadin in der Vergangenheit und Gegenwart.* Leipzig, 1900.—A. LORRIA and E. A. MARTEL. *Le Massif de la Bernina* (complete monograph on the Upper Engadine, with full bibliography). Zürich, 1894.—P. C. VON PLANTA. *Die Currätischen Herrschaften in der Feudalzeit.* Bern, 1881.—Z. and E. PALLIOPPI. *Dizionari dels Idioms Romauntschs d'Engiadina ota e bassa, &c.* Samaden, 1895.—F. DE B. STRICKLAND. *The Engadine.* 2nd edition. London and Samaden, 1891.

(W. A. B. C.)

Engels, Friederich (1820–1896), German Socialist. See MARX.

Engineers, Military.—Military engineers first came to England with William of Normandy in 1066, and until the 18th century all engineers were military. They were the builders of castles and defensible strongholds, as well as the inventors, manufacturers, and directors in action of engines of war with which to attack or defend them. By the middle of the 13th century there existed an organized body of skilled workmen employed under a "chief engineer." At the siege of Calais in 1347 this corps consisted of masons, carpenters, smiths, tentmakers, miners, armourers, gunners, and artillerymen. At the siege of Harfleur in 1415, the chief engineer was designated Master of the King's Works, Guns, and Ordnance, and the corps under him numbered 500 men, including 21 foot-archers. Headquarters of engineers existed at the Tower of London before 1350, and a century later developed into the Office of Ordnance (afterwards the Board of Ordnance), whose duty was to administer all matters connected with fortifications, artillery, and ordnance stores.

Henry VIII. employed many engineers (of whom Sir Richard Lee is the best known) in constructing coast defences from Penzance to the Thames and thence to Berwick-on-Tweed, and in strengthening the fortresses of Calais and Guisne in France. He also added to the organization a body of pioneers under trenchmasters and a master trenchmaster. Charles II. increased the peace establishment of engineers and formed a separate one for Ireland, with a chief engineer who was also Surveyor-General of the King's Works. In both countries only a small permanent establishment was maintained, a special ordnance train being enrolled in war-time for each expedition and disbanded on its termination. The commander of an ordnance train was frequently, but not necessarily, an engineer, but there was always a chief engineer of each train. At the battle of Blenheim in 1704 Marlborough's ordnance train was commanded by Holcroft Blood, a distinguished engineer, who brought up the guns and placed them in position. But after the rebellion of 1715 it was decided to separate the artillery from the engineers, and the royal warrant of 26th May 1716 established two companies of artillery as a separate regiment, and an engineer corps composed of 1 chief engineer, 3 directors, 6 engineers-in-ordinary, 6 engineers extraordinary, 6 sub-engineers, and 6 practitioner engineers. From this warrant the Royal Artillery date their birth and the Royal Engineers their release from artillery duties.

Until 14th May 1757 officers of engineers frequently held, in addition to their military rank in the corps of engineers, commissions in foot regiments; but on and after that date all engineer officers were gazetted to army as well as engineer rank—the chief engineer as colonel of foot, directors as lieutenant-colonel, and so forth down to practitioners as ensigns. On 18th November 1782 engineer grades, except that of chief engineer, were abolished, and the establishment was fixed at: 1 chief engineer and colonel, 6 colonels commandant, 6 lieutenant-colonels, 9 captains, 9 captain lieutenants (afterwards second captains), 22 first lieutenants, and 22 second lieutenants. Ten years later a small invalid corps was formed. On 25th April 1787 the designation "Royal" was conferred upon the engineers, and its precedence settled to be on the right of the army, with the royal artillery.

In 1802 the title of Chief Engineer was changed to Inspector-General of Fortifications. From this time to the conclusion of the Crimean War various augmentations took place, consequent on the increasing and widely extending duties thrown upon the officers. These, in addition to ordinary military duties, comprised the construction and maintenance of fortifications, barrack and ordnance store buildings, and all engineering services connected with them. The cadastral survey of the United Kingdom (called the "Ordnance Survey") had been entrusted to the engineers as far back as 1784, and absorbed many officers in its execution. Officers were also selected for various important civil positions, such as permanent under-secretaries of State, colonial governors, railway inspectors, mint-masters, consuls-general, international boundary and other commissioners, colonial engineers and surveyors-general, directors of Admiralty works, and so on.

On 6th March 1772 the formation at Gibraltar of "The Company of Soldier Artificers," officered by Royal Engineers, was authorized, and a second company was added soon afterwards. By royal warrant of 10th October 1787 "The Corps of Royal Military Artificers" was established at home, consisting of six companies, with which the Gibraltar companies were amalgamated. In 1806 this corps was doubled, and in 1811 increased to 32 companies. In 1813 its title was changed to "The Royal Sappers and Miners." On 12th October 1856, at the close of the Crimean War, it was incorporated with "The Corps of Royal Engineers," by whom it had always been officered. At that date the corps numbered about 340 officers and 4000 non-commissioned officers and men, comprised in 1 troop and 32 companies.

In 1770 the East India Company reorganized the engineer corps of the three Presidencies, composed of officers only. Native corps of sappers or pioneers were formed later, and officered principally by engineers. The officers of engineers were employed in peace-time on the public works of the country, their services when required being placed at the disposal of the military authorities. The Indian Engineers have not only distinguished themselves in the operations of war, but have left monuments of engineering skill in the irrigation works, railways, surveys, roads, bridges, public buildings, and defences of the country. When Indian administration was transferred to the Crown (1862) the Indian Engineers became "Royal," and have since almost died out, so that there now exists but one corps, the Royal Engineers.

The corps is composed of about 1000 officers of all ranks, and 7700 warrant and non-commissioned officers and men. Of the officers some 220 are attached to units, about 400 are employed either at home or in the colonies on engineering duties in military commands, on the staff, or on special duty, and about 370 are on the Indian establishment.

The head of the corps at the War Office is the Inspector-General of Fortifications, who is assisted by two deputy inspectors-general of fortifications, one in charge of the fortification subdivision and the other of the barrack subdivision. Each of these deputies has two assistant inspectors-general with a staff of officers, warrant officers, civil surveyors, clerks, and draughtsmen. There is at the present time a third deputy inspector-general with his staff, forming a special barrack subdivision for the administration of the loans for the construction of new barracks. In the fortifications subdivision the deputy inspector-general has under him inspectors of submarine mining defences and of iron structure with their staffs. A post-captain of the Royal Navy and a field officer of artillery are attached to the office of the Inspector-General of Fortifications as expert advisers. A deputy adjutant-general and an assistant adjutant-general of Royal Engineers, under the adjutant-general to the forces and in consultation with the Inspector-General of Fortifications, deal with all questions of *personnel* of the corps and the armament and equipment in its possession.

The officer commanding the Royal Engineers in a military district or command is called the District Commanding Royal Engineer, and is the staff officer of the general or other officer commanding for engineer services. A district is generally divided into subdistricts, to each of which is appointed a Subdistrict Commanding Royal Engineer, who carries out the engineer services in the subdistrict by means of a staff of officers of Royal Engineers, military foremen of works, and other subordinates, and is responsible to the District Commanding Royal Engineer. The senior officer of Royal Engineers in Ireland is called the Chief Engineer.

(R. H. V.)

ENGINES.

1. Steam Engines.

Recent developments in steam engineering have been directed, for the most part, towards improving the efficiency of the engine as a thermodynamic machine. Increase in speed, with consequent increase in the power developed by an engine of given weight, has also been aimed at, and the mechanical problems involved in high-speed running have received much attention. Reduction of weight is in some cases a matter of primary importance, but much more generally the chief consideration is that the engine may convert into work as large as possible a fraction of the heat which is supplied to it. The early progress of steam engineering was largely empirical; in the most recent developments the influence of theory is apparent. Recognizing that thermodynamic principles establish a limit of efficiency which in given conditions cannot be surpassed, engineers have directed their attention to tracing, and as far as possible removing, the causes which make the real performance fall short of this ideal. Any scientific criticism of the actual steam engine requires that we should in the first place consider what is the ideal which may fairly be set up as a standard with which the real performance is to be compared.

Theoretical limits of efficiency.

In the sketch of thermodynamics as applied to heat engines which was given in the article STEAM ENGINES in the ninth edition of this *Encyclopædia*, it was shown that the action of a heat engine depends on its receiving heat at a temperature higher than that at which it is capable of rejecting heat to surrounding objects. The working substance in the engine must necessarily pass from an upper temperature, at which it takes in heat, to a lower temperature, at which it rejects heat, the difference between the heat taken in and the heat rejected being the thermal equivalent of the work done. It was further shown that when the conditions are such as to make this difference as great as possible,—in other words, to make the efficiency reach its ideal limit,—the ratio of the heat taken in to the heat rejected depends only on the temperature at which reception and rejection of heat occur. Calling τ_1 and τ_2 the absolute temperatures at which heat is taken in and rejected respectively, and Q_1 and Q_2 the quantities of heat taken in and rejected, the limit of efficiency is reached when

$$\frac{Q_1}{Q_2}=\frac{\tau_1}{\tau_2},$$

and the efficiency then has the value

$$\frac{Q_1-Q_2}{Q_1}=\frac{\tau_1-\tau_2}{\tau_1}.$$

In the ideal engine imagined by Carnot the action is of this simple character. The working substance is brought by adiabatic compression from the lower to the upper extreme of temperature. It then takes in heat, without changing in temperature. It then expands adiabatically until its temperature falls to the lower extreme, and at that temperature it rejects enough heat to restore it to its initial state, thereby completing a cycle of operations. The ideal cycle of Carnot is not, however, an appropriate standard with which to compare the action of a steam engine, for the steam engine makes no attempt to restore the working substance to its upper limit of temperature by adiabatic compression. Taking the case of a condensing engine, the working substance passes through a cycle of operations which, except for practical imperfections, has three stages corresponding to three of the stages in the Carnot process. At the boiler temperature it takes in heat; it then expands, doing work and falling in temperature towards the lower limit, at which condensation is to occur. It then gives out heat at this lower temperature by being condensed, and if the expansion were adiabatic the correspondence would so far be exact. But the stage of adiabatic compression is wanting, and its place is taken by the direct return of the condensed water to the boiler, a process which involves the heating of the water by its taking in heat at a varying temperature, which ranges from the lower to the upper limit. The chief part of the heat which the working substance receives is still taken in at the upper limit of temperature, during the process of evaporation, but a certain part has been taken in before this, namely, during the heating of the feed water, while the water had a lower temperature. Any heat so taken in loses something of its availability for conversion into work, because it is taken in at a temperature below the top of the range, and consequently the ideal efficiency of the cycle is reduced.

To determine the theoretical limit in the amount of work obtainable from a given quantity of heat in a cycle in which heat is taken in at various temperatures, let δQ represent that portion of the whole heat which is taken in at any temperature τ. The temperature of rejection of heat will be represented, as before, by τ_2. Then the amount of work which may be obtained under ideally favourable conditions from this portion of the heat is, by Carnot's principle,

$$\frac{\delta Q(\tau-\tau_2)}{\tau},$$

and the whole amount of work ideally obtainable in the complete process is to be found by calculating

$$\Sigma\frac{\delta Q(\tau-\tau_2)}{\tau},$$

where the summation includes all the heat that is taken in. In a steam engine using saturated steam the principal item in this sum is the latent heat L_1, which is taken in at constant temperature τ_1, during the change of state from water to steam. But there is, in addition, the heat taken in by the feed-water before it reaches the temperature at which steam is formed, and this may be represented as the sum of a series of elements $\sigma\delta\tau$ taken in at varying temperatures τ, where σ is the specific heat of water. Thus if W represents the thermal equivalent of the work theoretically obtainable per ℔ of steam, under ideally favourable conditions,

$$W=\Sigma\frac{\sigma\delta\tau(\tau-\tau_2)}{\tau}+\frac{L_1(\tau_1-\tau_2)}{\tau_1}.$$

The experiments of Regnault show that σ, within the limits of temperature that obtain in boilers, is a nearly constant quantity, and no serious error will be introduced in this integration by treating it as a constant, with a value equal to the mean value, as determined by Regnault, between the limits of τ_1 and τ_2. On this basis

$$W=\sigma(\tau_1-\tau_2)-\sigma\tau_2\log_\epsilon\frac{\tau_1}{\tau_2}+\frac{L_1(\tau_1-\tau_2)}{\tau_1}.$$

This expresses the greatest amount of work which a ℔ of steam can yield when the temperature τ_1 at which it reaches the engine and the temperature τ_2 at which it leaves the engine are assigned. It consequently serves as a standard with which the actual performance may usefully be compared. The actual yield per ℔ of steam is always considerably less, chiefly because the ideal condition of adiabatic expansion from the higher to the lower extreme of temperature is never satisfied.

In practice the lower limit of temperature, in a condensing engine, is in favourable cases about 100° Fahr., which corresponds to a pressure in the exhaust pipe of nearly 1 ℔ per square inch. Taking this as a fairly representative figure, the following table of values of W has been calculated for various pressures of admission. The table also gives the number of ℔ of steam which would be required per horse-power-hour under the same ideally favourable conditions. Taking the thermal unit to be equivalent to 778 foot-pounds, one horse-power-hour is equivalent to 2545 thermal units, and the ideal number of ℔ of steam per horse-power-hour is therefore got by dividing 2545 by W:—

Ideal Performance of Saturated Steam, assuming the Lower Limit of Temperature to be 100° *Fahr.*

Absolute Pressure of Supply in ℔ per Square Inch.	W Thermal Units.	Number of ℔ of Steam per Horse-Power-hour.
50	248	10·26
60	259½	9·81
70	269	9·46
80	277½	9·17
90	285	8·93
100	292	8·72
110	298	8·54
120	303½	8·39
130	308½	8·25
140	313	8·12
150	318	8·00
160	322	7·90
170	326	7·81
180	329½	7·73
190	333	7·66
200	335½	7·59
210	338½	7·53

The performance of the ideal engine may be exhibited graphically by drawing the pressure-volume curve or "indicator diagram" of the process, but a more interesting construction is to draw the diagram of entropy and temperature. The study of this diagram has contributed materially to the elucidation of steam-engine problems. Entropy is a condition of the working substance defined by the statement that when a substance takes in or rejects any quantity of heat δQ at the (absolute) temperature τ, its entropy is increased or reduced by the amount $\frac{\delta Q}{\tau}$. Thus $\Sigma\frac{\delta Q}{\tau}$ measures the whole change of entropy in a process which involves the taking in or rejection of heat at more than one temperature. We shall denote entropy by ϕ, and consider it as reckoned per unit of mass of the substance.

Entropy-temperature diagrams.

Since by definition of entropy $\delta\phi = \delta Q/\tau$, $\tau\delta\phi = \delta Q$, and hence if a curve be drawn with τ and ϕ for ordinates to exhibit the action of a working substance, the area under the curve, or $\int \tau d\phi$, being equal to $\Sigma\delta Q$, measures the heat which the substance has received or rejected during the operation which the curve represents.

In a reversible cycle of operations Carnot's principle shows that $\Sigma\frac{\delta Q}{\tau}=0$, and it is obvious in such a case that the entropy returns at the end of the cycle to its primitive value. The same result may be extended to a cycle which includes any non-reversible step, by taking account of the heat generated within the substance by such a step, as if it were heat communicated from outside, in the reckoning of entropy. Thus, for example, if at one stage in the cycle the substance passes through a throttle-valve, which lowers its pressure without letting it do work, the action is equivalent in effect to an adiabatic expansion, together with the communication to the substance, as heat, of the work which is lost in consequence of the irreversible expansion through the throttle-valve taking the place of adiabatic expansion against a piston. If this heat be included in the reckoning, $\Sigma\frac{\delta Q}{\tau}=0$ for the complete cycle.

The entropy-temperature diagram for any complete cyclic process is a closed curve, and the area it encloses, being the excess of the heat received over the heat rejected, measures the work done. The entropy-temperature diagram shares this useful characteristic with the pressure-volume diagram, but in addition it shows directly the heat received and the heat rejected by the areas under the forward and backward limbs of the curve. To draw the entropy-temperature diagram for the ideal steam engine, we have to reckon first the entropy which water acquires in being heated, and next the entropy $\frac{L_1}{\tau_1}$ which is acquired when the conversion into steam has taken place. Reckoning from any standard temperature τ_o, in the heating of the feed-water up to any temperature τ, the entropy acquired is

$$\phi_w = \int_{\tau_o}^{\tau} \frac{\sigma d\tau}{\tau},$$

and taking σ as sensibly constant,

$$\phi_w = \sigma(\log_\epsilon \tau - \log_\epsilon \tau_o).$$

During evaporation at τ_1 a quantity of heat L_1 is taken in at temperature τ_1, and hence the entropy of the steam

$$\phi_s = \phi_w + \frac{L_1}{\tau_1} = \sigma(\log_\epsilon \tau_1 - \log_\epsilon \tau_o) + \frac{L_1}{\tau_1}.$$

There results the diagram illustrated in Fig. 1, where ab, a

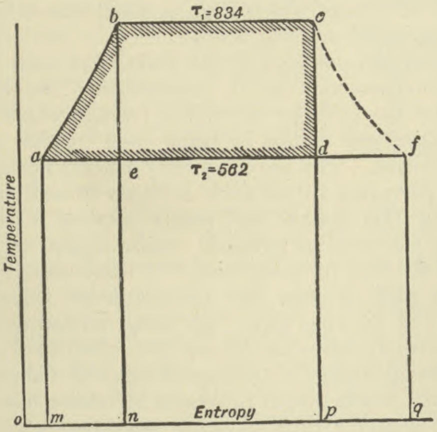


Fig. 1.

logarithmic curve, represents the process of heating the feed-water, and bc the passage from the state of water into that of steam. The diagram is drawn to scale for a case in which steam is formed at a pressure of 180 ℔ per square inch, and condensed at a pressure of 1 ℔ per square inch. After the formation of the steam, the next step in the ideal process is adiabatic expansion from the higher to the lower limit of temperature, which is represented by the vertical straight line cd, an adiabatic process being also isentropic. Finally, the cycle is completed by da, which represents the condensation of the steam after its temperature has been reduced by adiabatic expansion to the lower limit of temperature. The area $abcd$ represents the work done, and its value per ℔ of steam is identical with W as reckoned above. The area $mabcp$ is the whole heat taken in, and the area $madp$ is the heat rejected.

Further, let a curve cf be drawn to show the values of the entropy of steam for various temperatures of saturation: then if ad be produced to meet the curve in f, the ratio $\frac{fd}{fa}$ represents the fraction of the steam which was condensed during adiabatic expansion. For the point f represents the state of 1 ℔ of saturated steam, and in the condensation of 1 ℔ of saturated steam the heat given out would be the area under fa, whereas the heat actually given out in the condensation from d was the area under da. Thus the state at d is that of a wet mixture in which $\frac{da}{fa}$ represents the fraction present as steam, and $\frac{fd}{fa}$ the fraction present as water. It obviously follows that by drawing horizontal lines at intermediate temperatures the development of wetness in the expanding steam can be readily traced. Again, if the steam is not dry when expansion begins, its state may be represented by making the expansion line begin at a point in the line bc, such that the segments into which the line is divided are proportional to the constituents of the wet mixture. In this way the ideal process may be exhibited for steam with any assumed degree of initial wetness. Further, the entropy-temperature diagram admits of ready application to the case of incomplete expansion. Suppose, for example, that after adiabatic expansion from c to c' (Fig. 2) the steam is

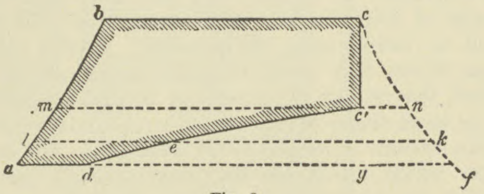


Fig. 2

directly cooled to the lower-limit temperature by the application of cooling water instead of by continued expansion. This process is represented by the line $c'ed$, which is a curve of constant volume. Its form is determined by the consideration that at any point e the proportion of steam still uncondensed, or $\frac{le}{lk}$, is such that the mixture fills the same volume as was filled at c'.

In the above calculation of ideal performance, and in the diagrams which have been sketched, it has been assumed that the steam is supplied to the engine in a saturated state. To extend the same treatment to the case of superheated steam, we have to take account of the supplementary supply of heat which the steam receives after the point c is reached, and before expansion begins. When superheating is resorted to, as is now often the case in practice, the superheat is given at constant pressure. If κ represent the specific heat of steam at constant pressure, the addition of entropy during the process of superheating from τ_1 to τ' is $\kappa(\tau' - \tau_1)$. In the absence of precise knowledge regarding the value of κ it is usually treated as a constant, and the addition to the entropy may then be written as $\kappa(\log \tau' - \log \tau_1)$. This gives a line such as cr on the entropy diagram (Fig. 3), and increases the value of W by the amount $\int_{\tau_1}^{\tau'} \frac{\kappa d\tau(\tau-\tau_2)}{\tau}$, which is represented on the diagram by the area $dcrs$. During adiabatic expansion from r the steam remains superheated until it reaches the state t,

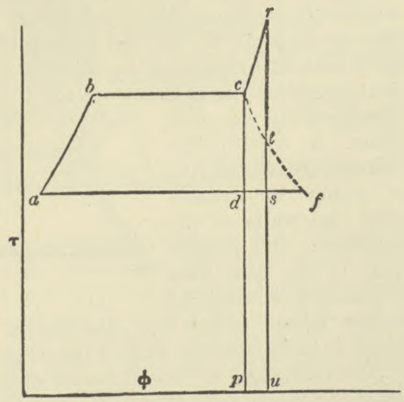


Fig. 3.

when it is just saturated, and further expansion results in the condition of wetness indicated by *s*. The extra work *d c r s* is done at the expense of the extra supply of heat *p c r u*, and an inspection of the diagram suffices to show that the efficiency of the ideal cycle is only very slightly increased by even a large amount of superheating. In practice, however, superheating does much to promote efficiency, because it materially reduces the amount by which the actual performance of an engine falls short of the ideal performance, by keeping the steam comparatively dry in its passage through the engine, and thereby reducing exchanges of heat between the steam and the metal.

Actual performance.

Trials of engines using saturated steam show that in the most favourable cases from 60 to 65 per cent. of the ideally possible amount of work is realized as "indicated" work. One of the causes of loss is that the expansion is incomplete. In practice the steam is allowed to escape to the condenser, while its pressure is still considerably higher than the pressure at which condensation is to take place. When the pressure of steam in the cylinder has been so far reduced by expansion that it can only overcome the friction of the piston, there is no advantage in going on further; the indicated work due to any additional expansion would add nothing to the output of the engine, when allowance is made for the work spent on friction within the mechanism itself. Considerations of bulk often lead to an even earlier release of the expanding steam; and another consideration which points the same way is that when expansion is carried very far, the losses due to exchange of heat between the cylinder and the steam, referred to below, tend to increase. Again, since experience shows that the most efficient engines are those in which the process of expansion is divided into two, three, or more stages by the use of compounded cylinders, a certain amount of loss is to be ascribed to the drops in pressure which are liable to occur through unresisted expansion in the transfer of steam from one vessel to another. But the chief cause of loss is to be found in the exchanges of heat which take place between the steam and the metal. In each cylinder there is a process of alternate condensation and re-evaporation—condensation during the period of admission, when the steam finds itself brought into contact with metal which has been chilled by evaporation during the preceding exhaust stroke, and then evaporation, when the pressure has fallen sufficiently, during the later stage of expansion as well as during exhaust. The consequence is that the steam, though supplied in a dry state, may contain some 20 or 30 per cent. of moisture when admission to the cylinder is complete, and the entropy diagram for the real process of expansion takes a form such as is indicated by the line c' c'' in Fig. 4. The heat supplied is still measured by the area under *a b c*. The condensation from *c* to c' occurs by contact with the walls of the cylinder; and though part of the heat thus abstracted is restored before release occurs at c'', the general result is to make a large reduction in the area of the diagram.

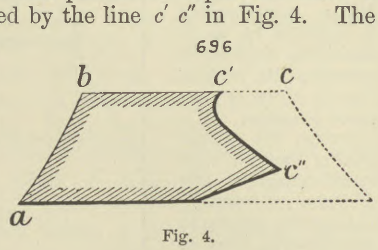


Fig. 4.

The exchanges of heat between steam and metal in the engine cylinder have been made the subject of an elaborate experimental examination by Professors Callendar and Nicolson (see *Min. Proc. Inst. C.E.* vol. cxxxi. p. 147), who studied the cyclic variations of temperature throughout the metal by means of thermo-electric junctions set at various depths. They found that the range of temperature through which the surface of the metal fluctuates is much less than the range of temperature passed through by the steam; the processes of condensation and re-evaporation are slow, and the time is too short to bring the surface of the metal into anything like equilibrium with the steam. The amount of condensation up to the point of cut-off, as inferred from the heat which the metal takes up, is also much less than the "missing quantity" or difference between the steam supplied per stroke and the dry steam then present. According to their experiments, the discrepancy is accounted for by leakage of steam past the valve, direct from the steam chest to the exhaust, and they suggest that this source of error may have been present in many estimates of initial condensation based on determinations of the missing quantity. This may explain cases in which the initial condensation has apparently been excessive, but large amounts of initial condensation certainly do occur, and constitute the most potent factor in making the real performance of the engine fall short of the ideal standard.

In the alternate condensation and re-evaporation of steam in the cylinder more heat is given to the metal by each pound of steam that is condensed than is taken from the metal by each pound of steam that is re-evaporated, the temperature of condensation being higher than that of re-evaporation. The quantity $H_1 - H_2$, namely, the difference of total heat at the two temperatures, represents this excess of heat. Unless this is in some way abstracted from the metal, the process cannot occur. Hence the action of the cylinder walls in causing alternate condensation and re-evaporation to occur may be limited by imposing conditions which prevent or reduce the abstraction of heat. By the use of a steam jacket the metal may be prevented from losing heat externally, and may even be made to take up heat. Under these conditions the action depends on the fact that more water is re-evaporated than is condensed. To some extent this is a necessary result of the work done during expansion, which (in an adiabatic process) would make the steam become wetter as expansion proceeds, and would therefore leave more water to be evaporated than is initially condensed by the action of the cylinder walls. But it is important to notice that any water which is introduced into the cylinder along with the steam will be an important factor in supplying the means by which this thermal balance is maintained. With steam that is perfectly dry before admission the action of the walls takes its limit from the condensation which expansion brings about; with steam that is wet before admission no such limit applies. Hence the importance of having steam that is initially dry. To secure this, no method is so certain as to give some initial superheat to the steam, and hence the practical advantage which even a small amount of superheating is found to bring about.

To a considerable extent the slide-valve itself promotes initial condensation, for it requires that the hot steam shall enter the cylinder through a passage which, immediately before, was chilled by being used for the escape of exhaust steam. The use of entirely distinct admission and exhaust ports and valves tends towards economy of steam, partly for this reason and partly because it allows the clearance spaces to be reduced. Accordingly, we find that many of the best recorded results of tests relate to engines in which each cylinder has four separate valves of the Corliss or of the drop type. By using horizontal cylinders with admission valves on the top and exhaust valves below, the further advantage of drainage through the exhaust valves is secured. Water which is present at release has then the chance of escaping without being re-evaporated, a circumstance which contributes largely to reduce the exchange of heat between the working substance and the metal. Thus a horizontal triple-expansion engine with drop valves, by Messrs Sulzer, using saturated steam at an absolute pressure of 160 ℔ per square inch, and indicating not much more than 200 horse-power, is reported, in a test by Professor Stodola, to have used only 11·52 ℔ of steam per indicated horse-power-hour (see *Engineer*, 1st July 1898; also summary of trials by B. Donkin, *Ibid.*, 13th October 1899). By the table given above it will be seen that the ideal consumption for the same pressure of supply will be 7·9 ℔. The performance in the test is therefore equivalent to nearly 69 per cent. of the ideal, an exceptionally high figure. In other particularly favourable records of trials the consumption of steam with triple-expansion engines has been found to lie between 12 and 13 ℔ per indicated horse-power-hour. Some of the best results relate to slow-running pumping engines fitted with steam jackets on the barrels and on the covers of the cylinders, and may be taken as showing how influential, in a long-period engine, the jacket may prove in reducing the evils of initial condensation. In the mean of several apparently authoritative trials by different observers on different engines, the consumption of steam was 12·2 ℔ per horse-power-hour, at an absolute pressure of about 140 ℔ per square inch, which corresponds to 66 per cent. of the ideal performance. It should be added that these figures are exceptional. A consumption of 13 or 14 ℔ of steam per horse-power-hour is much more usual even in large and well-designed triple-expansion engines; and with two-cylinder compound engines, using steam with an absolute pressure of 100 or 120 ℔ per square inch, anything from 14 to 15 ℔ may be reckoned a good performance.

Experimental results as to efficiency.

Willans engine.

Amongst comparatively recent developments in steam-engine practice a conspicuous place must be given to the work of the late Mr P. W. Willans, who, both by his design and manufacture of engines and by his published trials, did much to introduce a highly successful type of engine, the characteristic of which is great frequency of stroke. The quicker the period of the engine, the less time is there given for exchanges of heat to take place between the working substance and the metal, and consequently the more near is the approach towards adiabatic action. Thus high frequency tends to reduce the deleterious action of the cylinder walls, and in this respect to cause a close approximation to the condition of the ideal engine. As a partial set off, however, it augments to some extent the losses by throttling in admission and exhaust and in transfer from one cylinder to another, and it presents to the designer what is in several respects a more difficult mechanical problem than he has to face in dealing with low speeds. The comparatively high speed of rotation required in the driving of dynamo-electric machinery has been an important factor in stimulating the use of high-frequency engines, which admit of being directly coupled to high-speed dynamos without the intervention of gearing. Most, though by no means all, of such high-speed engines are of the single-acting class, of which the Willans engine is a conspicuous example. In this the piston-rods are vertical, and steam is admitted to the upper side only of each piston, with the result that the rods are kept in a state of thrust throughout the action, and no reversal of stress is allowed to occur at the joints. Notwithstanding the admission of steam to one side only, reversal of thrust would occur, as a consequence of the inertia of the reciprocating parts, if special means were not taken to prevent it. This is done by introducing a cushion cylinder in which air is compressed during the up-stroke of the piston, so that the energy which the reciprocating masses have to part with during the second half of their up-stroke is absorbed in compressing air, and is restored during the down-stroke. In the compound and triple expansion forms of this engine the two or three compounded cylinders are set in tandem, and the space below the upper piston serves as an intermediate receiver. In some of the smaller engines a single crank is used, but generally two or three sets of cylinders are grouped in parallel vertical lines, each set acting on one crank. The piston-rod of each set is hollow, and within it there is a valve-rod furnished with piston-valves for the admission and release of the steam. The valve-rod is worked by an eccentric on the crank-pin, so that it may have the proper relative movement with respect to the hollow piston-rod in which it works. The cross-head takes the form of a piston, which acts as the air-buffer to produce the cushioning referred to above. These features will be better understood by reference to Fig. 5, which

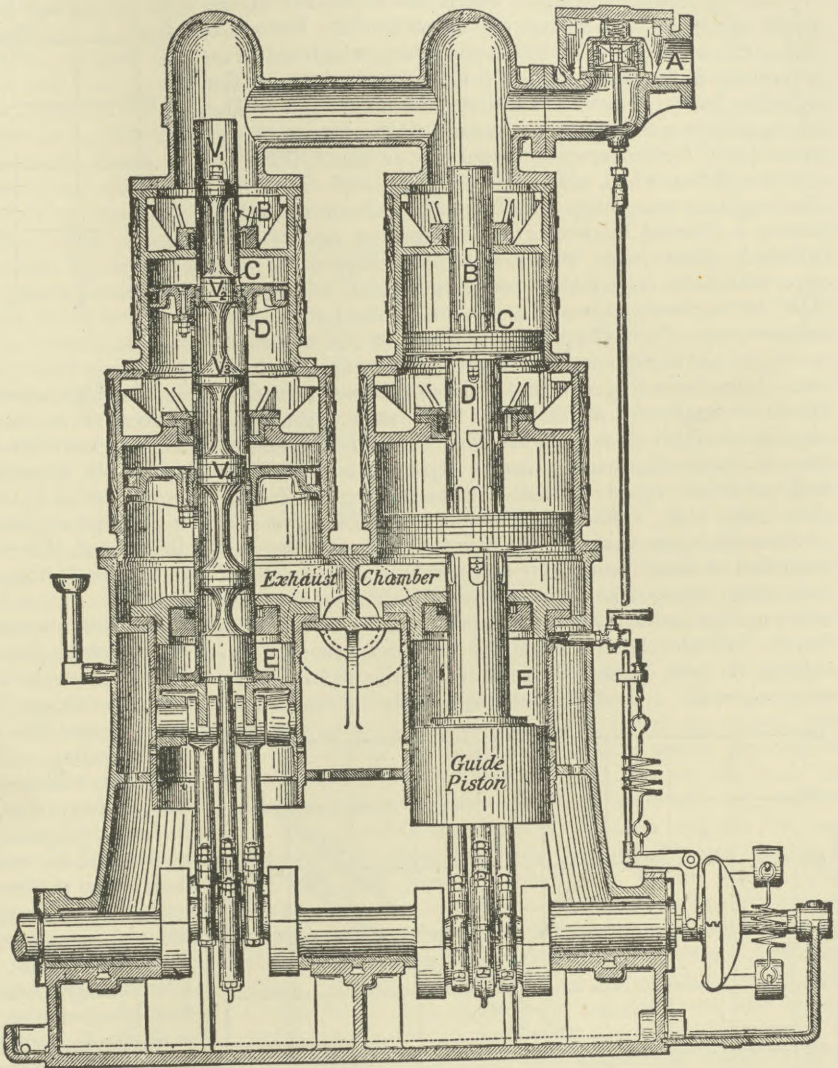


Fig. 5.

gives a section through the two lines of cylinders in a two-crank compound engine. The two lines are alike, but in the drawing the pistons and piston-rod of one line are shown in section, so that the piston-valves may be seen. Steam enters at A through a throttle valve which is controlled by a shaft governor, and is admitted to the topmost cylinder through the ports B and C in the hollow piston-rod. Cut-off occurs when the ports B are covered by disappearing into the gland of the top cylinder cover as the rod descends. Subsequently the relative motion of the valve-rod within makes the valve V_2 cover the port C, and near the end of the down-stroke the ports C and D are put in communication with each other between the valves V_2 and V_3, so that the steam which has expanded in the upper cylinder passes during the up-stroke into the space below the upper piston. From this space, which serves as a receiver, it is admitted in the next down-stroke to the cylinder below, where it continues its expansion. The air-cushion which prevents reversal of the thrust at the crank-pin is formed by compressing air in the cylinder E above a piston, which also serves as guide and cross-head. The engine is completely encased, and much of the lubrication is effected by letting the cranks dip into oil and splash it about freely within the case. Engines of this type with three cranks have been built which work up to 2400 horse-power, and engines of 1200 horse-power are in common use. In the larger sizes a speed of 200 or 250 revolutions per minute is usual; with small engines of the same type indicating one or two hundred horse-power the speed is commonly about 450. That such engines are capable of highly economical working was demonstrated by the remarkably thorough series of experiments carried out and published by Mr Willans ("Steam Engine Trials," *Proc. Inst. C.E.*, 1888 and 1893). An important feature of these trials was that they dealt not simply with the consumption of steam under the favourable conditions which hold when the engine is fully loaded, but also with the consumption under various amounts of light load, including the extreme case in which the engine is merely overcoming its own frictional resistance without doing any external work. To represent the results of such tests

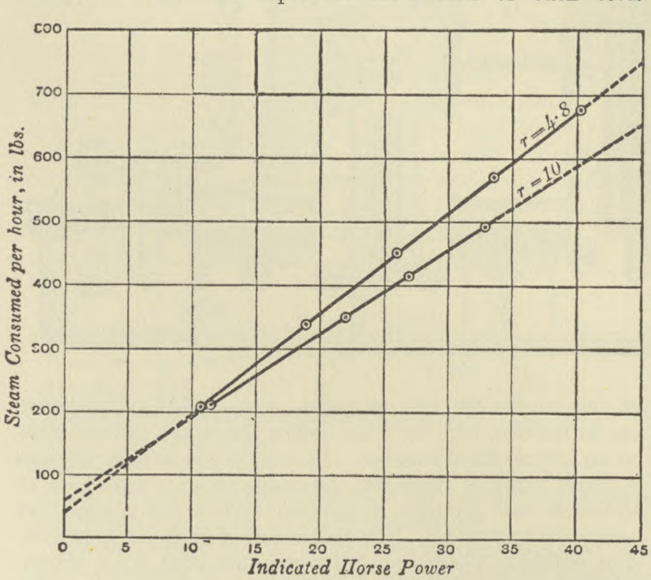


Fig. 6.

Willans introduced the practice of drawing curves which show the total consumption of steam per hour in relation to the horse-power. He found that the Willans line, as such a curve is now generally called, is sensibly straight when the reduction of power from full load to lighter load or to no load is effected by throttling the steam, while the point of cut-off remains unchanged. Examples of two such lines are given in Fig. 6, which shows the results of two tests by Willans of the same engine, using two different ratios of total expansion, namely, 4·8 and 10. Another useful curve is drawn by plotting the relation between the horse-power and the steam used per horse-power-hour; the same trials are exhibited in this way in Fig. 7.

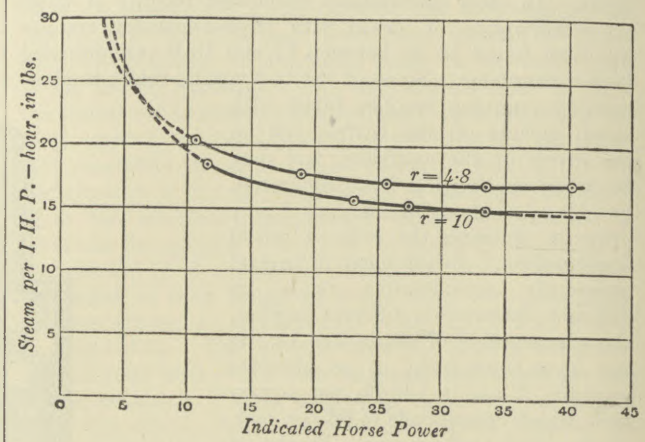


Fig. 7.

The high speed single-acting type of engine has been successful in the hands of more than one maker, and success has also attended efforts which have been made to secure the advantages of high speed without the sacrifice of power which is involved in single-action. Of double-acting high speed engines an interesting form is that of Messrs Belliss and Morcom, the chief distinctive feature of which is the use of forced lubrication at the pin-joints and shaft-bearings. In a double-acting engine, where the thrust acts alternately on one and the other side of the crank-pins and cross-head pins, high frequency of stroke tends to produce much knocking and wear unless the brasses are very closely adjusted, and in that case the pins are liable to get hot, and to "seize" by expanding sufficiently to fill the small clearance. This difficulty, which exists when lubrication is carried out in the ordinary way, is overcome in the Belliss engine by feeding the bearings with a continuous supply of oil, which is pumped in under a pressure of about 15 ℔ per square inch. The presence of a film of oil is thereby continuously secured, and knocking is prevented although the brasses are not set very close (see Dales, "High-Speed Engines," *Proc. Inst. C.E.*, 1899; and Morcom "High-Speed Self-Lubricating Steam Engines," *Proc. Inst. Mech. Eng.*, 1898). Notable examples in which double action is combined with a relatively high frequency of stroke are found in naval engineering practice, especially in the engines of high-speed cruisers and torpedo-boat destroyers. As a rule these engines employ triple expansion, with four cranks and four cylinders, the third stage of the expansion being performed in two cylinders, which divide the steam between them. The steam is supplied from water-tube boilers at a pressure of about 250 ℔ per square inch. The engines of the *Powerful*, which develop nearly 26,000 horse-power under forced draught, have cylinders 45 inches, 70 inches, and two of 76 inches in diameter, with a stroke of 4 feet. The cylinder ratio is therefore 1 : 2·4 : 5·7. At 114 revolutions per minute the piston speed is 915 feet per minute, and the total weight of machinery per indicated horse-power is made up of 93 ℔ in the engine and 101 ℔ in the boilers, which are of the Belleville water-tube type. In recent torpedo-boat destroyers the mean piston

Other high-speed engines.

speed approaches 1200 feet per minute, with nearly 400 revolutions per minute and an 18-inch stroke, and the horse-power developed is about 6000. In some instances this is accomplished with a total weight of 50 lb per indicated horse-power, which is nearly equally divided between the engines and the boilers (Durston and Oram, "The Machinery of Warships," *Proc. Inst. C.E.*, 1899).

Balancing. In such engines, and in other cases where quickly reciprocating masses have to be dealt with, the problem of balancing the forces due to inertia assumes great importance. This is especially true of marine engines, on account of the absence of massive foundations; but even in land engines a want of balance may, at high speeds, cause enough vibration to constitute a serious nuisance. In considering the question of balance, the system of excentrically revolving masses and the system of reciprocating masses have to be considered separately. A reciprocating mass such as a piston cannot be balanced by the use of revolving masses, for the forces which are due to the inertia of the piston necessarily act along the line of its stroke, while those due to revolving masses are continually changing their direction. The inertia of each connecting-rod may be approximately treated by resolving its mass into two constituents, one of which moves with the crank-pin, and is therefore an addition to the revolving system, while the other moves with the cross-head, and is therefore an addition to the reciprocating system. The mass of the rod may be divided for this purpose into parts which are inversely proportional to the distances of its centre of gravity from the crank-pin and the cross-head respectively. Let M_1, M_2, M_3, &c., represent the various revolving masses, r_1, r_2, r_3, &c., their effective radii of rotation, and a_1, a_2, a_3, &c., their distances from any assumed plane of reference taken perpendicular to the shaft. Then the conditions necessary for balance amongst them are that the vector sum of $M r$ shall vanish, and also that the vector sum of $M a r$ shall vanish, this latter quantity being the resultant of the moments of the centrifugal forces with respect to the plane of reference. In a four-crank engine there is no serious difficulty in arranging the revolving masses in such a manner that these conditions shall be satisfied, so far as those masses are concerned. The problem, as Professor Dalby has shown, lends itself readily to graphical treatment (see "Balancing of Engines," *Trans. Inst. Naval Architects*, 1899). With respect to the reciprocating masses, a first approximation towards balance is attained by satisfying the conditions which would secure balance if the motions were simply harmonic. These conditions are identical with those which have just been stated for the revolving masses, when r is interpreted as the semi-amplitude of the harmonic motion. When the conditions in question are satisfied, the only remaining source of disturbance is that which comes from the fact that the reciprocating masses are connected to the cranks by rods of finite length; in other words, that the motions are not simply harmonic. For this reason the force required to accelerate each piston is greater when the piston is at the end of the stroke farthest from the shaft than when it is at the other end, and consequently the balance, which would be perfect if the connecting-rods were indefinitely long, is disturbed by the presence of forces which vary periodically with a frequency twice that of the rotation. When three cranks, 120° apart, are employed, it will be found that the effect of the shortness of the connecting-rods in causing forces to act in the line of the stroke is almost completely eliminated; or rather the effect is reduced to a couple tending to tilt the engine in a fore and aft direction, which may in its turn be balanced by using a second set of three cranks on the same shaft, the second set being so arranged that the couple to which it gives rise neutralizes the couple due to the first set. A six-crank engine may be arranged in this way to secure an extremely close approximation to perfect balance, and the same state of balance can be secured when the number of cranks is reduced to five (see Robinson, "Single Acting High-Speed Engines," *Journ. Inst. Elec. Eng.*, 1895).

Superheated steam. The advantage of superheated steam, which arises mainly from its influence in reducing the exchange of heat between the steam and cylinder walls, was demonstrated by the experiments of Hirn, and as early as 1860 it was not unusual to supply superheaters with marine engines. But the practice of superheating was soon abandoned, chiefly on account of difficulties in regard to lubrication. By the introduction of heavy mineral oils this objection has been removed, and a revival in the use of superheating has recently taken place, with striking effect on the thermodynamic economy of engines. Experiments made in 1892 by the Alsatian Society of Steam Users on a large number of engines, showed that superheating effected an average saving in coal to the extent of about 20 per cent. when the superheater was simply placed in the boiler flue, so that it utilized what would otherwise be waste heat, and about 12 per cent. when the superheater was separately fired. In those cases the steam was superheated only about 60° or 80° Fahr. above the temperature of saturation, but in more recent practice much greater amounts of superheat have been successfully applied. Professor Schröter has tested a factory engine of 1000 horse-power, using steam superheated by some 93° Fahr., and has shown that this amount of superheat is not sufficient to prevent some of the steam from becoming condensed on the walls during admission to the cylinder (*Zeitschrift der Vereins deutscher Ingenieure*, vol. xl., 1896). It follows that still larger amounts of superheat will be thermodynamically advantageous. That this is the case has been demonstrated by the remarkable results which have been obtained with very highly superheated steam by Mr W. Schmidt. Using engines of somewhat special design, Mr Schmidt has shown that it is perfectly practicable to employ steam superheated by as much as 300° Fahr., and that an efficiency not attainable from steam in any other way is thereby reached. In several authentic trials of Schmidt engines the consumption of steam has been considerably less than 10 lb per indicated horse-power-hour,—a figure which, after allowance is made for the heat taken up during the process of superheating, represents a better performance than that of the best engines using saturated or slightly superheated steam. It has been found that the consumption of coal, in the boiler and superheater together, need not exceed $1\frac{1}{3}$ lb per indicated horse-power even with engines of small power. To attain this remarkable result it is of course necessary that, after the hot gases have passed the superheater, a further extraction of heat from them should take place. This is done by an economizer or feed-water heater of peculiar form, consisting of a long coil of small pipes which maintain a circulation of hot distilled water through a closed system containing an external coil, which forms the heater of a tank through which the feed-water passes on its way to the boiler. Some of the Schmidt engines adopt the principle of single action, to escape the necessity of having a piston-rod and gland on the side which is exposed to contact with high-temperature steam; but it is found that this precaution is not essential, and that with glands of suitable design a double-acting piston may be used without inconvenience, and without risk of undue wear. In some instances Mr

Schmidt transfers to the partially expanded steam in the intermediate receiver a portion of the heat which is conveyed to the engine by the highly superheated steam; and when this is done, the steam may properly receive a still higher degree of initial superheat. In tests by the present writer of a Schmidt plant indicating 180 horse-power, in which this device was employed, the initial superheat was as much as 385° Fahr., namely, from 360° Fahr., the temperature of saturation, to 745° Fahr. In this trial the temperature of the chimney gases was reduced, by the use of Mr Schmidt's feed-water, to 347° Fahr., and the consumption of coal was 1·31 ℔ per indicated horse-power-hour.

Steam turbines. The most interesting, and without doubt also the most important, feature of modern steam practice is the development of the steam turbine. In the hands of Mr C. A. Parsons the steam turbine has reached a degree of efficiency which equals, even if it does not surpass, that of the best engines of the piston and cylinder type. The mechanical problems to be solved before this result could be attained were of a high order of difficulty, but the success with which they have been overcome is not more conspicuous than the simplicity of the means by which it has been achieved. The central idea in the Parsons steam turbine has been to make the action compound; the steam is allowed to fall in pressure by a long series of steps, each step so small that the steam acquires comparatively little velocity through its drop in pressure. This enables the kinetic energy which is acquired in each step to be given up with a good degree of efficiency to turbine blades running at a moderate speed, before the steam passes on to acquire more velocity before it encounters the next series of moving blades. The whole turbine is made up of a long series of rings of moving blades, sandwiched between which there are rings of fixed blades, forming guides to deliver the steam with proper direction and velocity against the moving blades. The latter are mounted on a drum, from which they project radially outwards; the fixed blades project radially inwards from a casing, within which the drum revolves. The arrangement of guide

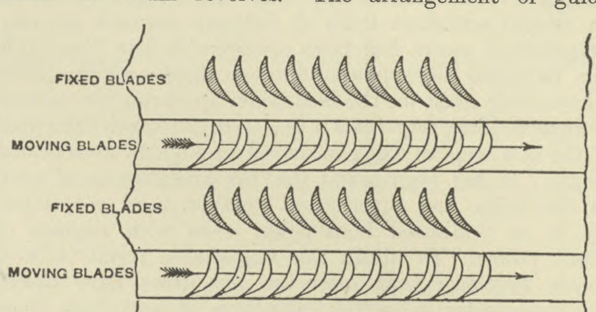


Fig. 8.

blades and moving blades is illustrated in Fig. 8, where the guide blades are shown in section. Fig. 9 shows a portion of the drum, with the moving blades projecting from it as they appear when part of the cover is removed. The general direction taken by the steam is parallel to the axis as it passes from ring to ring of blades. In its passage the energy of the steam is gradually extracted as it expands from a pressure which is in some cases as much as 200 or 250 ℔ per square inch, down to 1 ℔ per square inch. With a condenser it is practicable in the steam turbine to utilize pressures as low as can be reached; there is no such lower limit, as friction and other considerations impose in engines of the ordinary

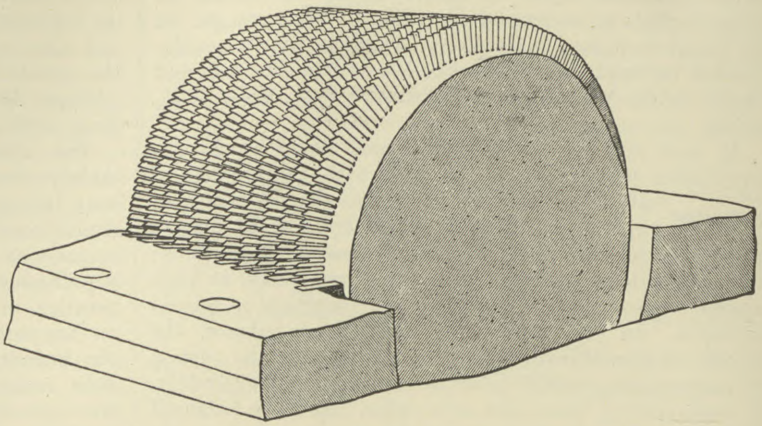


Fig. 9.

type. Even with this division of the whole expansion into many steps the speed of the turbine blades has to be fairly high; and to permit the shaft to revolve smoothly at a high speed the bearings are of a special design, which is shown in section in Fig. 10. In each bearing a number of coaxial cylindrical sleeves are slipped over the shaft to form the bush in which the shaft revolves, and oil is continuously pumped in under pressure. The result is that a film of oil is maintained round the shaft and between each sleeve and the one outside it. This gives the shaft some freedom to adjust itself by lateral displacement, but at the same time the viscosity of the oil films effectively damps out any oscillations which may tend to become set up. The general arrangement of a Parsons steam turbine is shown in Fig. 11, which is a section through a turbine with some eighty successive rings of moving blades. Steam is admitted to the turbine rings at A, and passes through them to the right, passing first through short and closely spaced blades, and then through blades which are longer and of coarser pitch, to give a greater area of passage as the pressure falls and the volume increases. It finally escapes to the condenser at B. The moving blades are grouped in three sets, on three drums of different diameters. Owing to the one-sided action of the steam, each of these drums is forced to the right; and to balance this pressure there are sets of "dummies" or balance-discs of corresponding diameter, which are forced with equal pressure to the left. These are shown at C, D, and E. Each dummy consists of a group of discs revolving in close juxtaposition to rings which project inwardly between the discs from the casing; and between each dummy and the corresponding portion of the turbine drum there is a channel, which secures that both shall be subjected to the same pressure of steam. Finally, a thrust block at F serves to take up any longitudinal force that may remain unbalanced. A worm on the turbine shaft at G gives a comparatively slow motion of rotation to the worm-wheel H, from the axis of which the air-pump and oil-pump are driven. Admission of steam takes place through the valve J, which is periodically lifted to let the steam enter in a series of gusts; and the speed of the turbine is regulated by adjusting the duration of each gust. The

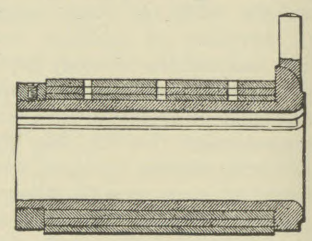


Fig. 10.

valve J is opened by the action of steam admitted through a small relay-valve K to the spring piston L. The duration of each gust depends on the amplitude of motion of the relay-valve K; and this is controlled by the governor, which acts by varying the position of the fulcrum of a rocking-lever M, by which the relay-valve is actuated. This lever is caused to rock periodically by a connexion between it and the worm-wheel H. When the turbine has only a light load, the rocking of the lever barely suffices to open the relay-valve, and each gust of steam is accordingly of very brief duration. When the load is heavy, the gusts are so long as to become blended into a nearly continuous blast. In turbines used for electric lighting, the control of the rocking-lever is usually effected by an electro-magnetic solenoid with the result that the speed is so regulated as to keep the volts constant; in

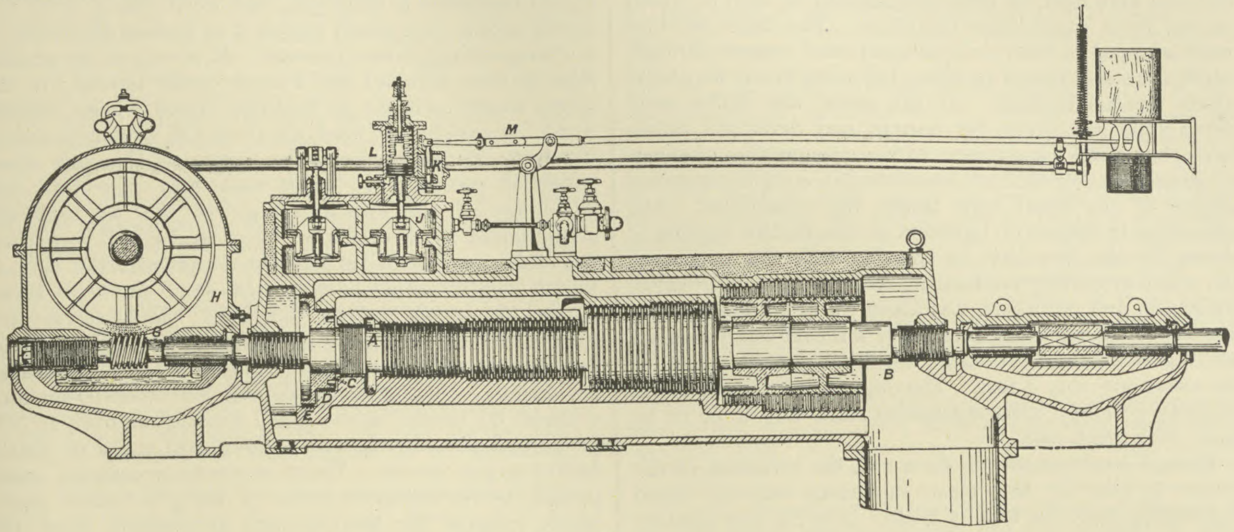


Fig. 11.

other cases the control is supplied by a centrifugal governor, which acts so as to preserve a uniform speed. This governor is remarkably effective; and a conspicuous merit of the steam turbine is that nearly the whole of the load may be suddenly thrown on or off without causing more than a trifling variation in the speed, and without in any way straining the machine. Another important mechanical advantage is the perfect balance of the moving parts,—a balance much more perfect than is attainable in any reciprocating engine,—which allows the steam turbine to be used with practically no foundations. Other points to be noted are the small internal friction of the turbine as a mechanism, its small weight and small size in relation to the power it develops, the extreme simplicity of its working parts, and the fact that as there are no rubbing surfaces exposed to the action of the steam, the steam can be kept free from oil, a matter of considerable moment in engines which condense the steam and return it to the boiler.

Efficiency.

The compound steam turbine dates from 1885, but it was not till 1891 that the introduction of the condensing type demonstrated that the turbine is capable of yielding results which are on a par, as regards efficiency, with those given by piston and cylinder engines. In the turbine one great source of loss is avoided which is present in the piston engine, namely, the periodic give and take of heat between the steam and the cylinder walls. On the other hand, the turbine suffers losses through leakage of steam in the clearance spaces round the blades and round the "dummies," as well as from the imperfect utilization of the kinetic energy acquired by the steam in each step of the expansion. The ideal return which the steam is capable of giving is the same in both types of engine; and though the sources of loss are very different in the two, it appears that their total effect in making the actual performance fall short of the ideal performance is, in the best cases, much alike. Large steam turbines succeed in utilizing between 60 and 70 per cent. of the energy which the steam is ideally capable of giving out, which is fully as high a fraction as is reached in the most favourable tests of large piston engines. With small turbines the results are less favourable, the losses due to clearance leakage being relatively greater. Trials made in April 1900 by the present writer of a Parsons turbine of about 2000 horse-power, running at 1500 revolutions per minute, directly coupled to a dynamo, gave striking evidence of the high degree of efficiency to which this type of engine has been brought. Electrical measurements were used to determine the effective output. In one of the trials, with steam at 155 ℔ per square inch, superheated 84° Fahr., the useful electrical output was 1435 kilowatts and the consumption of steam was 18¼ ℔ per kilowatt-hour. Since 1 kilowatt is 1·34 horse-power, this consumption is equal to 13·6 ℔ per electrical horse-power-hour. Trials of the best piston engines, driving dynamos, show that under the most favourable conditions about 84 per cent. of the indicated power may take the form of useful electrical output. Accordingly, the above result is equivalent to the performance of an engine using 11·4 ℔ of steam per indicated horse-power-hour. This represents about 68 per cent. of the work theoretically obtainable from the steam. An important characteristic of the steam turbine is that it maintains its efficiency while working under lighter loads. The table below illustrates this by giving the result of a series of trials of the same machine under various conditions as to load:—

Load in Kilowatts.	Consumption of Steam per Kilowatt-hour in ℔.
1450	18·1
1250	18·5
1000	19·2
750	20·3
500	22·6
250	34·0

The most considerable application of the steam turbine has hitherto been to the driving of dynamo-electric machinery, but Mr Parsons has demonstrated its suitability for the propulsion of steamships, and it may confidently be expected to come widely into use for this purpose. The *Turbinia*, a vessel of the dimensions of a torpedo-boat, fitted with Parsons steam turbines adapted to use steam with a pressure of fully 200 ℔ per square inch, achieved in 1897 the then unprecedented speed of $32\frac{3}{4}$ knots in trials on the measured mile; and more recently the *Viper*, a torpedo-boat destroyer with turbine engines of about 10,000 horse-power, built to the order of the British Admiralty, reached a speed of $35\frac{1}{2}$ knots. In the *Turbinia* three steam turbines were used, on three separate shafts, each of which carried three small screw propellers. The three turbines were arranged to form a single compound system through which the steam passed in series, becoming finally expanded about two-hundredfold. At full speed the shafts made about 2200 revolutions per minute, and developed rather more than 2000 horse-power, with a consumption of steam no greater than would have been found in a triple-expansion engine of the usual type under like conditions. The advantage in respect of lightness of the turbine engines is shown by the fact that in the *Turbinia* the weight of the whole propelling mechanism, including engines, boiler, condenser, and propellers, was about 22 ℔ per horse-power developed. The running machinery was completely encased and was well below the water-line, although the draught of the vessel was only 3 feet. The engines were found to be remarkably handy, allowing sudden starts and stops to be made with great ease.

Applications.

Enough has been said to show that the invention of the steam turbine is the most important step in steam engineering since the time of Watt. It is the first solution of the problem of using steam efficiently in an engine without reciprocating parts. The object in most steam engines is to deliver power to revolving machinery, and much ingenuity has been expended in attempts to devise engines which will produce rotation directly, instead of by conversion of reciprocating motion. No rotary engine, however, was permanently successful until the steam turbine took a practical form. The direct impact of a jet of steam on moving vanes was used by Hero of Alexandria in a philosophical toy, which may be described as the very earliest steam engine. Attempts were made in the 17th century by Giovanni Branca to turn this method to practical account, but no success was achieved until the compound system of working a turbine was developed by Parsons.

De Laval's turbine.

Subsequently to his invention, the simpler type of steam turbine, which utilizes the direct impact of a steam jet against a single ring of revolving blades, has been brought to a remarkable degree of efficiency by De Laval. In De Laval's turbine the steam expands at one step from the full pressure of the supply to the pressure of the exhaust by discharge in the form of a jet from a conical orifice, and the jet acquires a corresponding amount of kinetic energy. It then acts on a ring of blades in much the same way as the jet of water acts on the blades of a Pelton wheel or other form of pure impulse turbine. To utilize this impact of steam the blades have to run at an enormous velocity, and the speed of the shaft which carries them is so great that gearing down is resorted to before the motion is applied to useful purposes. The general arrangement of the steam nozzle and turbine blades is illustrated in Fig. 12. The blades project from the circumference of a disc-shaped wheel and form a complete ring round it, only a few of the blades being shown in the sketch. The nozzle has a divergent form, which causes the steam to expand before it leaves the mouth, and so causes the pressure energy to be used in giving kinetic energy to the jet before it is projected against the blades. The jet impinges at one side, and escapes at the other after having had its direction of motion nearly reversed. The expansion in the nozzle is carried to atmospheric pressure, or near it, if the turbine is to be used without a condenser; but in many cases an ejector condenser is employed, and when that is done the nozzle is of a form which adapts it to expand the steam to a correspondingly lower pressure. It is only in the smaller sizes of these turbines that a single nozzle is used; in the larger steam turbines, as in large Pelton wheels, several nozzles are applied at intervals along the circumference of the disc. To permit the blades to run at the high speed which is necessary in order that they may take full advantage of the kinetic energy of the jet, they are strengthened by shrinking a ring of steel round their tips; and this also serves as a cover to prevent the ring of blades from acting as a centrifugal fan. In a 50 horse-power De Laval turbine the shaft which carries the turbine disc makes 16,000 revolutions per minute; in the 5 horse-power size it makes as many as 30,000 revolutions per minute. A turbine developing 300 horse-power uses a wheel 30 inches in diameter, running at over 10,000 revolutions per minute, with a peripheral speed of nearly 1400 feet per second. These enormous speeds are made possible by the ingenious device of using a flexible shaft, which protects the bearings and foundations from the vibration which any want of balance would otherwise produce. The elasticity of the shaft is such that its period of vibration is much longer than the time taken to complete a revolution. The high-speed shaft which carries the turbine disc is geared, by means of double helical wheels with teeth of specially fine pitch, to a second-motion shaft, which runs at one-tenth of the speed of the first; and from this the motion is taken, by direct coupling or otherwise, to the machine which the turbine is to drive. Turbines of this class are now in extensive use for driving dynamos, fans, and centrifugal pumps. Compared with the Parsons turbine, De Laval's lends itself well to work where comparatively small amounts of power are wanted, and there it achieves a higher efficiency, though in large sizes the Parsons turbine is the more efficient of the two. Trials of a De Laval turbine used with a condenser, and developing about 63 horse-power, have shown an average steam consumption at the rate of about 20 ℔ per brake-horse-power hour, and even better results are reported in turbines of a larger size. (J. A. E.)

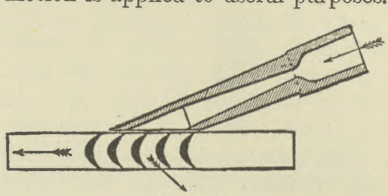


Fig. 12

2. Gas Engines.

A gas engine is a heat engine in which the working fluid is atmospheric air and the fuel an inflammable gas or vapour. It differs from a hot air or a steam engine in that the heat is given to the working fluid by combustion within the motive power cylinder. In most gas engines—in fact, in all those at present on the market—the working fluid and the fuel that supplies it with heat are mixed with each other before the combustion of the fuel. The fuel—which in the steam and in most hot air engines is burned in a separate furnace—is, in the gas engine, introduced directly to the motor cylinder and burned there; it is, indeed, part of the working fluid. A gas engine, therefore, is an internal combustion engine using gaseous or vapour fuel.

The commercial history of the gas engine dates from 1876, when the late Dr Otto patented the well-known engine now in extensive use, but long before that year inventors had been at work, attempting to utilize gas for producing motive power. The first proposal made in Great Britain is found in Street's Patent

No. 1983 of 1794, where an explosion engine is suggested, the explosion to be caused by vaporizing spirits of turpentine on a heated metal surface, mixing the vapour with air in a cylinder, firing the mixture, and driving a piston by the explosion produced. Most of the early engines were suggested by the fact that a mixture of an inflammable gas and atmospheric air gives an explosion when ignited—that is, produces pressure which can be applied in a cylinder to propel a piston. Lebon, in France, proposed a gas engine in which the gas and air were raised to a pressure above that of the atmosphere before use in the cylinder, but he did not appear to be clear in his ideas. Samuel Brown, in patents dated 1823 and 1826, proposed to fill a closed chamber with a gas flame, and so expel the air; then he condensed the flame by injecting water, and operated an air engine by exhausting into the partial vacuum so obtained. The idea was evidently suggested by Watt's condensing steam engine, flame being employed instead of steam to obtain a vacuum. Brown's engine is said to have been actually employed to pump water, drive a boat on the Thames, and propel a road carriage. L. W. Wright in 1833 described an explosion engine working at atmospheric pressure and exploding on both sides of the piston. The cylinder is shown as water-jacketed. In William Barnett's engine of 1838 two great advances were made. The engine was so constructed that the mixture of gas and air was compressed to a considerable extent in the motor cylinder before ignition. The method of igniting the compressed charge was also effective. The problem of transferring a flame to the interior of a cylinder when the pressure is much in excess of that of the external air was solved by means of a hollow plug cock having a gas jet burning within the hollow. In one position the hollow was opened to the atmosphere, and a gas jet issuing within it was lit by an external flame, so that it burned within the hollow. The plug was then quickly rotated, so that it closed to the external air and opened to the engine cylinder; the flame continued to burn with the air contained in the cock, until the compressed inflammable mixture rushed into the space from the cylinder and ignited at the flame. This mode of ignition is in essentials the one adopted by Otto about thirty years later. To Barnett belongs the credit of being the first to realize clearly the great idea of compression before explosion in gas engines, and to show one way of carrying out the idea in practice. Barnett appears to have constructed an engine, but he attained no commercial success. Several attempts to produce gas engines were made between 1838 and 1860, but they were all failures. Several valuable ideas were published in 1855. Drake, an American, described a mode of igniting a combustible gaseous mixture by raising a thimble-shaped piece of metal to incandescence. In 1857 Barsanti and Matteucci proposed a free-piston engine, in which the explosion propelled a free piston against the atmosphere, and the work was done on the return stroke by the atmospheric pressure, a partial vacuum being produced under the piston. The engine never came into commercial use, although the fundamental idea was good.

Previous to 1860 the gas engine was entirely in the experimental stage, and in spite of many attempts no practical success was attained. Lenoir, whose patent is dated 1860, was the inventor of the first gas engine that was brought into general use. The piston, moving forward for a portion of its stroke by the energy stored in the fly-wheel, drew into the cylinder a charge of gas and air at the ordinary atmospheric pressure. At about half stroke the valves closed, and an explosion, caused by the electric spark, propelled the piston to the end of its stroke. On the return stroke the burnt gases were discharged, just as a steam engine exhausts. These operations were repeated on both sides of the piston, and the engine was thus double-acting. Four hundred of these engines were said to be at work in Paris in 1865, and the Reading Iron Works Company Limited built and sold one hundred of them in Great Britain. They were quiet, and smooth in running; the gas consumption, however, was excessive, amounting to about 100 cubic feet per indicated horse-power per hour. The electrical ignition also gave trouble. Hugon improved on the engine in 1865 by the introduction of a flame ignition, but no real commercial success was attained till 1867, when Otto and Langen exhibited their free-piston engine in the Paris Exhibition of that year. This engine was identical in principle with the Barsanti and Matteucci, but Otto succeeded where those inventors failed. He worked out the engine in a very perfect manner, used flame ignition, and designed a practical clutch, which allowed the piston free movement in one direction but engaged with the fly-wheel shaft when moved in the other; it consisted of rollers and wedge-shaped pockets—the same clutch, in fact, as has since been so much used in free-wheel bicycles. This engine consumed about 40 cubic feet of gas per brake horse-power per hour—less than half as much as the Lenoir. Several thousands were made and sold, but its strange appearance and unmechanical operation raised many objections. Several inventors meanwhile advocated compression of the gaseous mixture before ignition, among them being Schmidt, a German, and Million, a Frenchman, both in 1861.

To a Frenchman, M. Alph. Beau de Rochas, belongs the credit of proposing, with perfect clearness, the cycle of operations now widely used in compression gas engines. In a pamphlet published in Paris in 1862, he stated that to obtain economy with an explosion engine four conditions are requisite: (1) The greatest possible cylinder volume with the least possible cooling surface; (2) the greatest possible rapidity of explosion; (3) the greatest possible expansion; and (4) the greatest possible pressure at the beginning of the expansion. The sole arrangement capable of satisfying these conditions he stated would be found in an engine operating as follows: (1) Suction during an entire outstroke of the piston; (2) compression during the following instroke; (3) ignition at the dead point, and expansion during the third stroke; (4) forcing out of the burnt gases from the cylinder on the fourth and last return stroke. Beau de Rochas thus exactly contemplated, in theory at least, the engine produced by Dr Otto fourteen years later. He did not, however, put his engine into practice, and probably had no idea of the practical difficulties to be overcome before realizing his conception in iron and steel. To the late Dr Otto belongs the honour of independently inventing the same cycle, now correctly known as the Otto cycle, and at the same time overcoming all practical difficulties and making the gas engine of world-wide application. This he did in 1876, and his type of engine very rapidly surpassed all others, so that now the Otto cycle engine is manufactured over the whole world by hundreds of makers. In 1876 Dr Otto used low compression only about 30 ℔ per square inch above atmosphere. Year by year compression was increased and greater power and economy were obtained, and at present compressions of 100 ℔ per square inch are commonly used with most satisfactory results.

The history of the subject since 1876 is one of gradual improvement in detail of construction, enabling higher compressions to be used with safety. Attempts have also been made to produce gas engines giving an impulse at every revolution instead of one at every two revolutions, but these attempts so far have not been commercially successful. Perhaps the best known of this type is the Clerk engine, produced in 1881, and since followed by many designers.

Gas engines may be divided, so far as concerns their working process, into three well-defined types:—

(1) Engines igniting at constant volume, but without previous compression;

(2) Engines igniting at constant pressure, with previous compression;

(3) Engines igniting at constant volume, with previous compression.

For practical purposes engines of the first and second types may be disregarded. Gas engines without compression are now considered to be much too wasteful of gas to be of commercial importance. Those of the second type have never really reached the stage of commercial application; they are scientifically interesting, however, and may take an important place in the future development of the gas engine. The expectations of the late Sir William Siemens with regard to them have not been realized, although he spent many years in experiments. Of other engineers who also devoted much thought and work to this second type may be mentioned Brayton, 1872; Foulis, 1878; Crowe, 1883; Hargreaves, 1888; Clerk, 1889; and Diesel, 1892. All the gas and oil engines now in commercial use are of the third type.

The working cycles of the three types are as follows:—

First Type.—Four operations.
- (a) Charging the cylinder with explosive mixture at atmospheric pressure.
- (b) Exploding the charge.
- (c) Expanding after explosion.
- (d) Expelling the burnt gases.

Second Type.—Five operations.
- (a) Charging the pump cylinder with gas and air mixture at atmospheric pressure.
- (b) Compressing the charge into an intermediate receiver.
- (c) Admitting the charge to the motor cylinder, in a state of flame, at the pressure of compression.
- (d) Expanding after admission.
- (e) Expelling the burnt gases.

Third Type.—Five operations.
- (a) Charging the cylinder with gas and air mixture at atmospheric pressure.
- (b) Compressing the charge into a combustion space.

(*c*) Exploding the charge.
(*d*) Expanding after explosion.
(*e*) Expelling the burnt gases.

In all these types the heating of the working fluid is accomplished by the rapid method of combustion within the cylinder, and for the cooling necessary in all heat engines is substituted the complete rejection of the working fluid with the heat it contains, and its replacement by a fresh portion taken from the atmosphere at atmospheric temperature. This is the reason why those cycles can be repeated with almost indefinite rapidity, while the old hot-air engines had to run slowly in order to give time for the working fluid to heat or cool through metal surfaces.

Otto cycle engines belong to the third type, being explosion engines in which the combustible mixture is compressed previous to explosion. Fig. 1 is a side elevation, Fig. 2 is a plan, and Fig. 3 is an end elevation of an engine

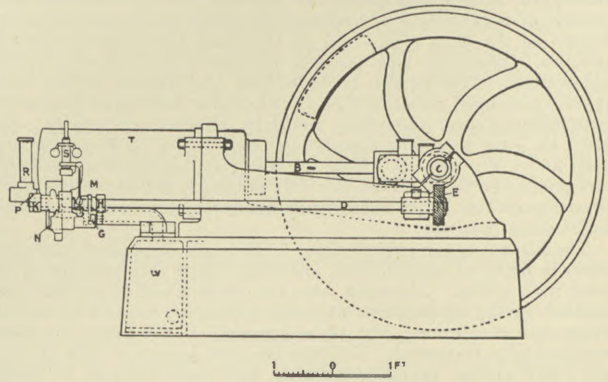


Fig. 1.—Side elevation of Otto Cycle Engine.

built by Messrs Crossley of Manchester, who were the original makers of Otto engines in Great Britain. In external appearance it somewhat resembles a modern high-pressure steam engine, of which the working parts are excessively strong. In its motor and only cylinder, which is horizontal and open-ended, works a long trunk piston, the front end of which carries the crosshead pin. The crank shaft is heavy, and the fly-wheel large, considerable stored energy being required to carry the piston through the negative part of the cycle. The cylinder is considerably longer than the stroke, so that the piston when full in leaves a space into which it does not enter. This is the combustion space, in which the charge is first compressed and then burned. On the forward stroke, the piston A (Fig. 2) takes into the cylinder a charge of mixed gas and air at atmospheric

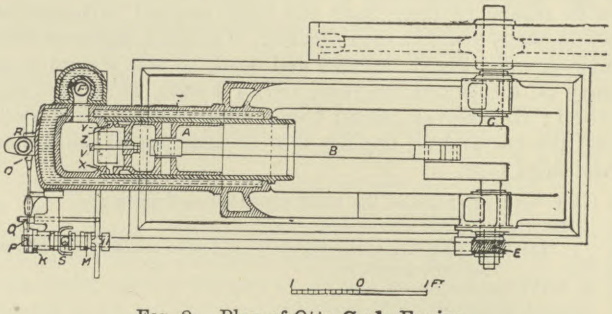


Fig. 2.—Plan of Otto Cycle Engine.

pressure, which is compressed by a backward stroke into the space Z at the end of the cylinder. The compressed charge is then ignited, and so the charge is exploded with production of a high pressure. The piston now makes a forward stroke under the pressure of the explosion, and on its return, after the exhaust valve is opened, discharges the products of combustion. The engine is then ready to go through the same cycle of operations. It thus takes four strokes or two revolutions of the shaft to complete the Otto cycle, the cylinder being used alternately as a pump and a motor, and the engine, when working at full load, thus gives one impulse for every two revolutions. The valves, which are all of the conical-seated lift type, are four in number—charge inlet valve, gas inlet valve, igniting valve, and exhaust valve. The igniting valve is usually termed the timing valve, because it determines the time of the explosion. Since the valves have each to act once in every two revolutions, they cannot be operated by cams or eccentrics placed directly on the crank shaft. The valve shaft D is driven at half the rate of revolution of the crank shaft C by means of the skew or worm gear E, one wheel of which is mounted on the crank shaft and the other on the valve shaft. Ignition is accomplished by means of a metal tube heated to incandescence by a Bunsen burner. At the proper moment the ignition or timing valve is opened, and the mixed gas and air under pressure being admitted to the interior of the tube, the inflammable gases come into contact with the incandescent metal surface and ignite; the flame at once spreads back to the cylinder and fires its contents, thus producing the motive explosion.

The working parts are as follows:—A the piston, B the connecting rod, C the crank shaft, D the side or valve shaft, E the skew gearing, F the exhaust valve, G the exhaust valve lever, H the exhaust valve cam, I the charge inlet valve, J the charge inlet valve lever, K the charging valve cam, L the gas inlet valve, M the gas valve cam, N lever and link operating gas valve, O igniting or timing valve, P timing valve cam, Q timing valve lever or tumbler, R igniting tube, S governor, T water jacket and cylinder, U Bunsen burner for heating ignition tube. On the first forward or charging stroke the charge of gas and air is admitted by the inlet valve I, which is operated by the lever J from the cam K, on the valve shaft D. The gas supply is admitted to the inlet valve I by the lift valve L, which is also operated by the lever and link N from the cam M, controlled, however, by the centrifugal governor S. The governor operates either to admit gas wholly, or to cut it off completely, so that the variation in power is obtained by varying the

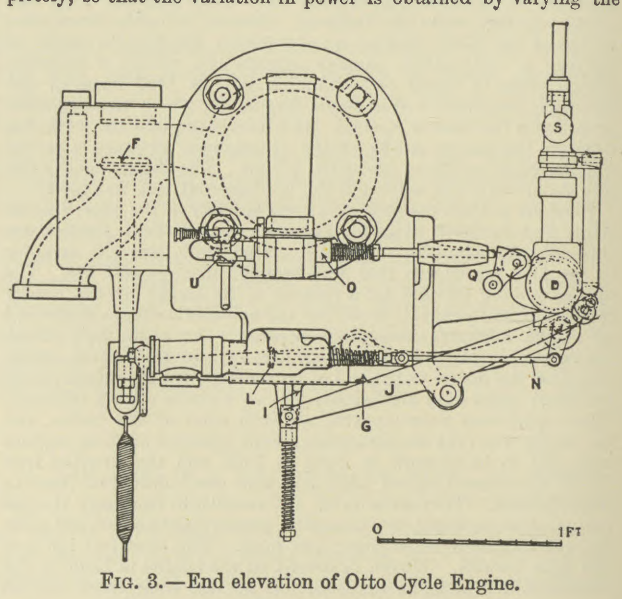


Fig. 3.—End elevation of Otto Cycle Engine.

number of the explosions. The exhaust valve F is actuated by the lever G and cam H. The ignition is produced by admitting a portion of the compressed inflammable charge from the compression space to the metal tube R, rendered incandescent by the Bunsen flame. The passage to the incandescent tube is controlled by the timing valve O, operated by the lever Q and cam P. The valve O is double-seated, and during the compression period of the engine the face nearest the compression space is kept up against the seat by a powerful spring. The incandescent tube is thus kept open to the atmosphere, and notwithstanding any leak which may occur from the cylinder, the tube remains empty until the moment when it is required for ignition. When the valve is lifted from one seat, a small portion of the compressed mixture is discharged through a small port to the air, and this clears out the burnt gases from the passages between the cylinder and the igniting tube; these burnt gases would otherwise render the ignition irregular. By this device a pure combustible mixture at once reaches the incandescent interior surface of the igniting tube, when the outer valve closes on its seat and the charge at once ignites.

The adoption of lift valves for the admission and discharge of gases to and from the engine cylinder is an important advance on the slide valve employed in the earlier engines, for it renders possible the use of much higher compressions. So long as slide valves were used it was difficult to provide a sufficiently large inlet area, as the area of the port determined the pressure necessary to hold the slide valve up against the cylinder face; hence a large port necessitated a heavy pressure, and a slide pressed up by a heavy pressure against a port carrying flame at a temperature of at least 1600° C. was easily overheated, and cut on the surface. Slide valves therefore made it practically impossible to use either large ports or high explosion pressures. The slide valve, too, with its flame igniter, proved more troublesome in practice than the tube igniter. With lift valves and tube ignition the difficulties are removed. In Great Britain slide valves and flame igniters have quite disappeared, and all designs of Otto cycle engines use lift valves and tube ignition in various forms. In the older Otto engines also the side shaft was driven by bevel or spur gear from the crank shaft. In recent engines the skew or worm gear is generally adopted. It is found to produce a more sightly engine, and also to operate much more smoothly than the old arrangement.

Since the engine shown in Figs. 1 to 3 was built further modifications have been made, principally in the direction of dispensing with or diminishing port space, that is, so arranging the ports that the compression space is not broken up into several separate chambers. In this way the cooling surface in contact with the intensely hot gases is reduced to a minimum. This is especially important when high compressions are used, as then the compression space being small, the port spaces form a large proportion of the total space. For maximum economy it is necessary to get rid of port space altogether; this is done by making the lift valves open directly into the compression space. This arrangement can be readily made in small and medium-sized engines, but in the larger engines it becomes necessary to provide ports, so as to allow the valves to be more easily removed for cleaning. Fig. 4 is an external view of a modern Crossley Otto engine, arranged with its valves opening directly into the combustion chamber, as made for engines of moderate powers. Fig. 5 is an external view of one of the largest gas engines built by Messrs Crossley. It is a double cylinder engine, with the cylinders facing each other; the opposing connecting rods engage the same crank pin. The valve arrangements involve the use of short ports, but the port space is relatively very small. The cylinders are each of 26 inches diameter, and the stroke is 3 feet. The speed is 150 revolutions per minute, and the maximum indicated horse-power 530. The engine was built for Messrs Brunner, Mond, and Co. of Northwich, to work with Mond producer gas.

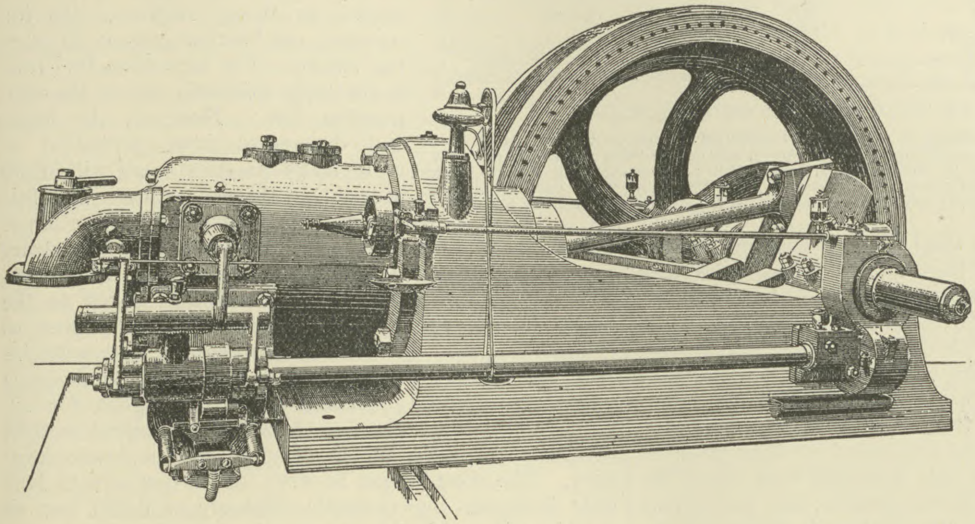


FIG. 4.—Crossley Otto Engine.

Otto cycle engines, with slight variations from the type described above, are made by a number of British firms. The minor points in which they differ often display considerable ingenuity.

Fig. 6 is an indicator diagram from a Crossley Otto gas engine. A B is the atmospheric line, B C the compression line, C D the explosion line, D E the expansion line, and E B A the exhaust line. The scale of this diagram is small because of the heavy pressures to be registered, and accordingly the suction line and the exhaust lines are not distinguishable from the atmospheric line. Fig. 7 is an indicator diagram taken from the same engine by means of a light spring in the indicator; it gives only part of the compression and part of the fall of pressure, because the movement of the indicator piston was limited. It shows clearly, however, the different course of the exhaust line and the suction line. As before, A B is the atmospheric line, F G H is the exhaust line, during which the piston is moving in the direction of the arrow 1. At G this line crosses below the atmospheric line, and remains below till the end of the stroke at I. The suction line is I H K. It remains slightly below atmospheric pressure during the whole time the piston is moving in the direction of the arrow 2. In both Figs. 6 and 7 the arrows indicate the direction of the movement of the piston of the engine while the particular curve is being traced. It will be seen from Fig. 6 that the gas consumption is 14·8 cubic feet per indicated horse-power per hour, and 17 cubic feet per brake horse-power hour, the engine being a small one, with cylinder 7 inches diameter and 15 inches stroke, giving practically 12 brake horse-power. Larger engines recently made by Messrs Crossley give one brake horse-power hour on so low a consumption as 13·5 feet of the same gas. Manchester coal gas used in these tests has a heating value of 530,000 foot pounds per cubic foot, so that the latter result gives a conversion of 27·6 per cent. of the whole heat of the gas into brake, that is, effective, horse-power. It may now be taken that a modern Otto cycle

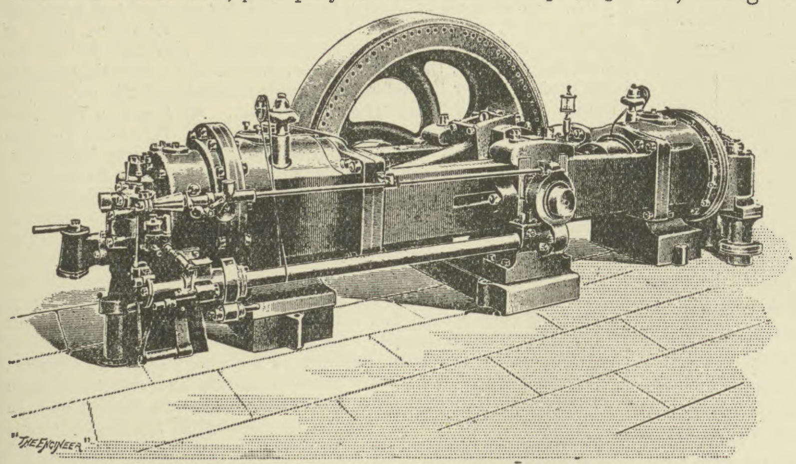


FIG. 5.—530 I.H.P. Crossley Otto Engine.

gas engine by a standard maker will consume in ordinary work, if of large size, about 17 cubic feet of gas per brake horse-power hour, and about 25 cubic feet per brake horse-power hour if of small size.

It was first pointed out by the present writer that the theoretic efficiency of an Otto cycle engine depends on the compression, and that it is constant for any given compression and independent of the maximum temperature of the explosion. Assume an ideal Otto cycle engine, operating with pure air; assume the compression line to be truly adiabatic, the explosion to take place at constant volume, and the expansion from the maximum temperature to be adiabatic—*i.e.*, assume an air engine in which the air does not lose heat to the enclosing walls of the cylinder, or gain it from these walls; further, suppose that the air is admitted to and discharged from the cylinder without loss. Then on such an engine the proportion of heat given to the engine, and converted into indicated work upon the piston, depends only on the compression, and is constant for any given compression. The indicated efficiency is the proportion of heat given to the engine which is converted into work, and it may be expressed in terms of the volume of the air before and after compression as

$$E = 1 - \left(\frac{V_c}{V_o}\right)^{\gamma - 1}$$

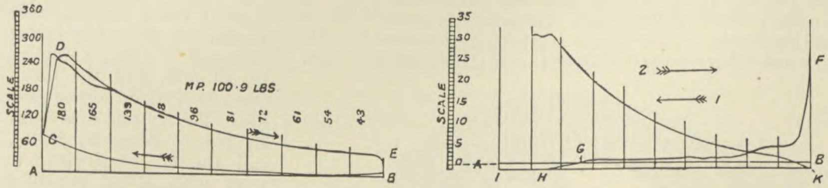
When V_o is the total volume of gases in the cylinder and compression space before compression, and V_c is the volume at maximum compression, $\gamma = 1{\cdot}408$, a constant for the ratio between the specific heat of air at constant pressure and constant volume, and E is the efficiency. Working out the theoretic efficiencies for different pressures of compression in an Otto cycle engine, the following values are found for certain selected compressions:—

	Pressure in lb per Square Inch above Atmosphere.	Theoretic Efficiency for Corresponding Pressure.
1	38	0·33
2	67	0·40
3	87	0·43
4	210	0·55

The first three pressures have been chosen as pressures which have been used at different times in the Otto cycle engine. The fourth is chosen as a probable limit for Otto cycle engines without added compounding. It is now universally accepted that the theoretic efficiency depends absolutely on the compression. Hence, since the introduction of the Otto cycle engine, the history is one of gradually increasing compression and gradually increasing economy. The following figures give the actual indicated efficiency found in practice from 1882 to 1894 in engines using different degrees of compression:—

	Years.	Efficiency.	Pressure of Compression above Atmosphere.
1	1882–88	0·16	38 lb per square inch.
2	1888–94	0·19	67 lb per square inch.
3	1894	0·25	87 lb per square inch.

The pressures correspond to the pressures in the preceding table, and the actual efficiency steadily rises with increased compression, and practically in proportion to the increased theoretic efficiency. In each case, in fact, the actual efficiency is equal, roughly, to half the theoretic efficiency. The actual engine, of course, has losses of heat to the cylinder; with the flame within the cylinder at the temperature of a blast-furnace these could not be avoided.



FIGS. 6, 7.—4 N.H.P. Crossley Otto Scavenging Engine.

Diameter of cylinder, 7 inches; stroke, 15 inches; revolutions per minute, 200; I.H.P., 14 at 100 lb per square inch mean pressure (average of three cards); gas consumption per I.H.P. per hour, 14·8 cubic feet (Openshaw gas, 20 candle-power); B.H.P. 11·97: gas consumption per B.H.P. per hour, 17 cubic feet; maximum pressure of explosion, 275 lb per square inch; pressure of compression, 87·5 lb per square inch; compression space, 34 per cent. of volume swept by piston.

There are other losses, too, from imperfection in carrying out the conditions of the cycle. The heat is not all added at the beginning of the stroke, as theory requires. On the contrary, combustion goes on through the stroke. The expansion line thus is not truly adiabatic, nor is the compression line. However, the losses and departures from perfection of cycle make practice come within 50 per cent. of theory, and even with this the gas engine converts a far larger proportion of heat given to it into work than any steam engine and boiler. In steam engines of moderate dimensions only 12 per cent. of the total heat given to the boiler in the form of coal appears in the engine as indicated work. It is found in practice that with increased compression the percentage of actual to theoretic efficiency increases. Taking the third figure, for example, 0·25, the highest of the actual efficiencies is 0·58 of the theory, while 0·16 is only 0·45 of the lower efficiency. The compression to over 200 lb per square inch only increases the theoretic efficiency to 0·55; but an actual engine with this compression would probably give an efficiency of 0·38. The engine, however, would have a maximum pressure of about 700 lb per square inch, with a usual explosion temperature of about 1700° C. This would make it too heavy in proportion to its power to be commercially successful.

Some 50,000 Otto cycle engines have been made and sold in the British Isles alone, and 35,000 on the Continent. About the year 1880 most of the engines were of small dimensions; the largest size was known as 16 horse-power nominal, and the most popular engine was the 3 horse-power size. Gradually the power of the engines increased, and engines have since been built with two cylinders indicating over 500 horse-power. The whole gas engine power now at work in Britain cannot fall far short of half a million horse-power, nor can the Continental power be much short of 300,000 horse-power. The work performed is multifarious—all the stationary work of the steam engine, in fact. An interesting inquiry has been made by Schaefer into the distribution of the gas engine among the various industries in Germany. He found in 1894 that of 2300 gas engines distributed throughout thirty-six German cities, 65·6 per cent. were distributed among the following industries: printing, pumping water, textile, electric lighting, machine shops, joiners and cabinetmakers, butchers, locksmiths, coffee-roasters, cutlery, elevators. Of these the number used in the printing industry was in excess of the others by 14·4 per cent.; next came pumping with 8·6 per cent., and so on. The remaining 34·4 per cent. was scattered through 140 more industries. One-half the engines were used in large factories. In England the average power per engine used has been stated by Mr Dowson to be about 12 horse-power per engine. So far the substantial application of the gas engine has been confined to stationary engines. Several attempts have been made to propel tramcars and cars running in Germany, and between Blackpool and St Anne's in England, in which the motive power is given by gas engines supplied with gas compressed and carried in reservoirs. Compressed gas, too, has been used in one barge in France to operate gas engines driving a screw propeller, but no important application has been made in this direction. The light oil engines, now largely used for motor-cars, are practically gas engines, and will be described later.

The unit of heat supplied to a gas engine in the form of coal gas is more costly than the unit of heat supplied to the steam engine in the form of coal, so that the gas engine using town's gas is at a disadvantage. So long as coal gas alone was used, only the smaller powers really competed with steam, their lower cost of attendance and the wastefulness of the small steam engine giving them the advantage. The disadvantage of the more expensive heat unit is not felt in such cases, because the governing of the engine (so far as fuel consumption is concerned) and the heat efficiency are so much superior to any small steam engine, that the gas engine is more economical even in actual expense of fuel. Accordingly it is quite unnecessary to trouble about gas other than town's gas for engines under 20 horse-power, but larger engines working at or near full load require cheaper gas to compete. They are therefore supplied with gas by a Dowson or some similar producer. Good results are thus obtained. With an engine indicating, for example, 100 horse-power, a consumption of 1 ℔ of anthracite per indicated horse-power is usual, and even lower consumptions have been recorded. (See GAS PLANTS FOR POWER PURPOSES.)

Blast-furnace gases are now used to a limited extent on the Continent for the purpose of producing motive power by gas engines. Although the experiments were first made in Great Britain, yet Continental engineers have been first in the field commercially. Mr B. H. Thwaite in 1895 started an experimental plant at the Glasgow Iron Works, Wishaw, arranging an apparatus which took gas from the blast-furnace main, purified it by scrubbing and passed it into a gas-holder. A 20 horse-power gas engine, supplied from the holder, drove a dynamo for electric lighting with good results. Mr Thwaite considered that one brake horse-power per hour could be obtained for every $1\frac{1}{4}$ ℔ of fuel fed into the blast-furnace, and he further calculated that each blast-furnace of ordinary dimensions would provide sufficient gas to give a spare power by gas engine of about 2500 horse-power. This opens up a great field for the saving of fuel and the cheap production of power. The blast-furnaces of the United States of America, Mr W. H. Booth calculated, could produce 2,000,000 horse-power continuously by gas engine. Mr Thwaite's plant has also been set up at Frodingham, near Doncaster. Simultaneously with Mr Thwaite's experiments, the Société Cockerill at Seraing, in Belgium, also attacked the problem. They have established at their Seraing works two engines each of 200 horse-power, and one engine of 600 horse-power, operated by blast-furnace gas. The three engines were working well when inspected by the present writer in 1901. Several engines of 1200 horse-power have been constructed at the same works. The Cockerill engines operate on the Otto cycle. Two engines, each of 600 horse-power, have been set up at the Hoerde Iron Works in Westphalia. These engines are of the impulse every revolution type, somewhat after the Clerk cycle, and are the invention of Mr Oechelhauser. The Gas Motoren Fabric Deutz have built large engines for this purpose, among them being one with two cylinders, each giving 300 horse-power; this has been erected at Oberhausen. English makers are also constructing large gas engines for blast-furnace gases, and an interesting advance in the power of the engines may be expected. The largest English gas engine constructed so far is one by Messrs Crossley Brothers of 700 horse-power for Sir Alfred Hickman's works, to be operated with blast-furnace gas. Other large gas engines have been constructed by the Premier Company, 500 horse-power; Stockport engine, 300 horse-power; Tangye engine, 100 horse-power; Fielding engine, 100 horse-power; Campbell engine, 100 horse-power; and Westinghouse engine, 650 horse-power. The last of these was built in America, but the new works of the British Westinghouse Electric Company at Manchester have been built to undertake their manufacture in Great Britain. The Westinghouse gas engine is of the enclosed crank, vertical cylinder type; electrical ignition is used, and there is an interesting system of mixing the gas and air before admission to the engine cylinder. The engine is governed by throttling the gas and air charge after mixing. The Otto cycle is followed, and in the large gas engines the piston is supplied with a forced water circulation. All the large gas engines of both English and Continental makers now water-jacket the pistons.

3. OIL ENGINES.

Oil engines resemble gas engines in that the power is generated by the explosion of a compressed inflammable gaseous mixture in an engine operating according to the Otto cycle. In the earlier forms, and in those used on motor cars, where very light inflammable oils of the gasoline or petrol kind are consumed, the problem of vaporizing the oil is comparatively simple. It is only necessary to draw air over a surface saturated with gasoline or some lighter oil to produce a mixture of vapour and air which, when taken into the cylinder, readily supplies the place of coal gas, and gives explosions under compression closely resembling those obtained with coal gas. The earliest proposal to use oil as a means of producing motive power by explosion was made by Street in 1791, but the first practical petroleum engine was that of Julius Hock of Vienna, produced in 1870. It was of the non-compression kind, like Lenoir's; it took in a charge of air and light petroleum spray during part of the forward stroke of the piston, ignited the charge by a flame jet, and so produced a low-pressure explosion. In 1873 Brayton, an American engineer, produced an oil engine using light oil on the constant-pressure system. The engine was a flame engine, operating without explosion, and it was the earliest compression engine to use oil fuel instead of gas. Shortly after the introduction of the Otto gas engine in 1876, air charged with inflammable vapour by being passed through gasoline was drawn into the engine cylinder with a further supply of air to form an explosive mixture, which was compressed and ignited in the usual way. The Spiel petroleum engine was the first Otto cycle engine introduced into practice which dispensed with an independent vaporizing apparatus. Light oil, of specific gravity not greater than ·725, was injected directly into the cylinder on the suction stroke. It mixed with the air and was vaporized, and on compression an explosion was obtained, just as with a gas engine. Many engines consuming light oil are used in America for stationary work, but in Great Britain they are confined almost entirely to motor-cars, motor-cycles, and motor vehicles generally.

The first aud the most successful of all the light oil road carriage motors is the Daimler. Many other ingenious motors are in use, but if the peculiarities of this form be understood, it is not difficult to follow the others. Fig. 8 is a diagrammatic section of the Daimler motor. A is the cylinder, B the piston, C the connecting rod, and D the crank, which is entirely enclosed in a casing. A small fly-wheel is carried by the crank shaft, and it serves the double purpose of a fly-wheel and a clutch. *a* is the combustion space, E the single port, which serves both for inlet and charge and for discharge of exhaust. W is the exhaust valve, F the charge inlet valve, which is automatic in its action, and is held closed by a spring *f*, G the vaporizer, H the igniter tube, I the igniter tube lamp, K the air charge inlet passage, L the air filter chamber, and M an adjustable air inlet cap for regulating the air inlet area. The light oil—or petrol, as it is commonly called—is supplied to the float chamber N of the vaporizer by means of the valve O. So long as the level of the petrol is high, the float *n*, acting by levers above it, holds the valve O closed against oil forced by air pressure along the pipe P. When the level falls, however, the valve opens and more oil is admitted. When the piston B makes its suction stroke, air passes from the atmosphere by the passage K through the valve F, which it opens automatically. The pressure falls within the passage K, and a spurt of petrol passes by the jet G^1, separate air at the same time passing by the passage K^1 round the jet. The petrol breaks up into spray by impact against the walls of the passage K, and then it vaporizes and passes into the cylinder A as an inflammable mixture. When the piston B returns it compresses the charge into *a*, and upon compression the incandescent igniter tube H fires the charge. H is a short platinum tube, which is always open to the compression space. It is rendered incandescent by the burner I, fed with petrol from the pipe supplying the vaporizer. The open incan-

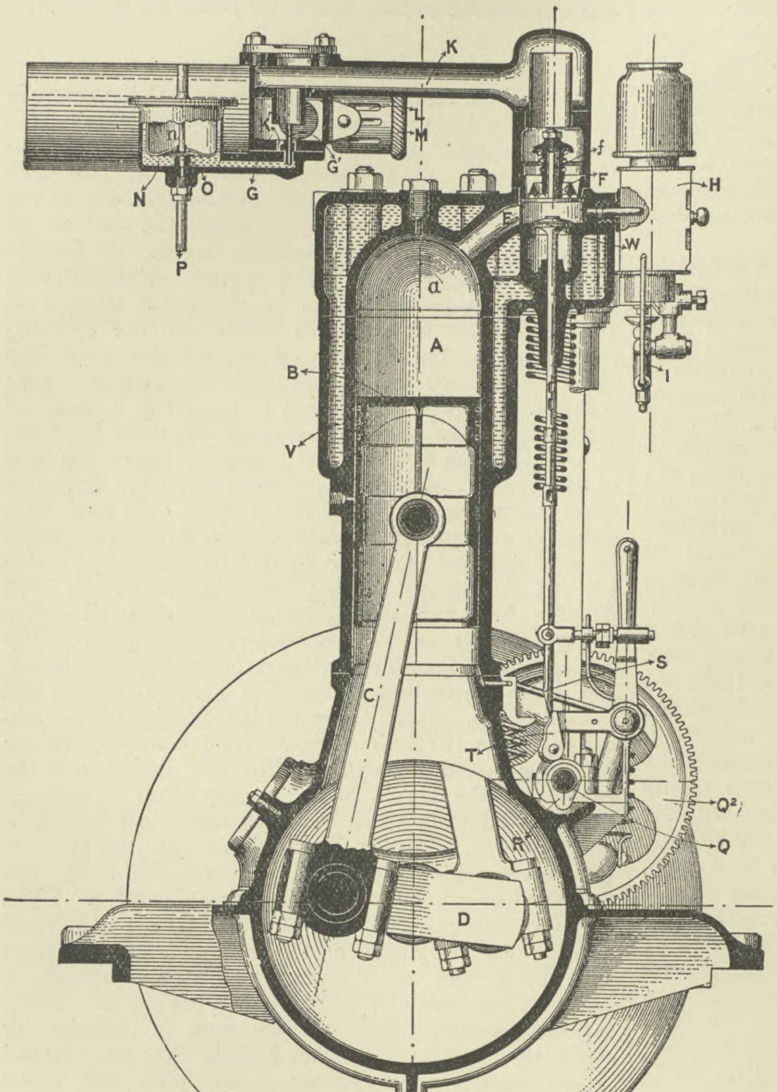


FIG. 8.—Diagrammatic section of Daimler Motor.

descent tube is found to act well for small engines, and it does not ignite the charge until compression takes place, because the inflammable mixture cannot come into contact with the hot part till it is forced up the tube by the compression. The engine is started by giving the crank shaft a smart turn round by means of a detachable handle. The exhaust valve is alone actuated from the valve shaft. The shaft Q is operated by pinion and a spur wheel Q^2 at half the rate of the crank shaft. The governing is accomplished by cutting out explosions as with the gas engine, but the governor operates by preventing the exhaust valve from opening, so that no charge is discharged from the cylinder, and therefore no charge is drawn in. The cam R operates the exhaust valve, the levers shown are so controlled by the governor (not shown) that the knife edge S is pressed out when speed is too high, and cannot engage the recess T until it falls. The engine has a water jacket V, through which water is circulated. Cooling devices are used to economize water.

Most of the motor-car engines resemble the Daimler. For the smaller vehicles, however, such as cycles, the cylinders are not water-jacketed, but are provided with ribs to radiate away the heat. Some engines also use electric spark ignition generated by battery and coil, or by magneto-electric devices. The application of oil engines to motor carriages has led to a multitude of most ingenious details, which cannot here be dealt with. The Daimler engine and similar engines have been extensively applied to small marine work, such as launches and dinghies.

Heavy oil engines are those which consume oil having a flashing point above 73° F.—the minimum at present allowed by Act of Parliament in Great Britain for oils to be consumed in ordinary illuminating lamps. Such oils are American and Russian petroleums and Scottish paraffins. They vary in specific gravity from ·78 to ·825, and in flashing point from 75° to 152° F. Engines burning such oils may be divided into three distinct classes :—

1st. Engines in which the oil is subjected to a spraying operation before vaporization.

2nd. Engines in which the oil is injected into the cylinder and vaporized within the cylinder.

3rd. Engines in which the oil is vaporized in a device external to the cylinder, and introduced into the cylinder in the state of vapour.

The method of ignition might also be used to divide the engines into those igniting by the electric spark, by an incandescent tube, or by the heat of the internal surfaces of the combustion space. Spiel's engine was ignited by a flame-igniting device similar to that used in Clerk's gas engine, and it was the only one introduced into Great Britain in which this method was adopted, though on the Continent flame igniters were not uncommon. Recently, however, electrically-operated igniters have come into extensive use on the Continent. In Great Britain all other methods of ignition both in gas and oil engines have for practical purposes been displaced by hot-tube and hot-surface igniters.

The engines at present in use in Great Britain which fall under the first head are the Priestman and the Samuelson, the oil being sprayed before being vaporized in both. The principle of the spray producer used is that so well and so widely known in connexion with the atomizers or spray producers used by perfumers. Fig. 9 shows such a spray producer in section. An air blast passing from the small jet A crosses the top of the tube B, and creates within it a partial vacuum. The liquid contained in C flows up the tube B, and issuing at the top of the tube through a small orifice is at once blown into very fine spray by the action of the air jet. If such a scent distributor be filled with petroleum oil, such as Royal Daylight or Russoline, the oil will be blown into fine spray, which can be ignited by a flame and will burn, if the jets be properly proportioned, with an intense blue non-luminous flame. The earlier inventors often expressed the idea that an explosive mixture could be prepared without any vaporization whatever, by simply producing an atmosphere containing inflammable liquid in extremely small particles distributed throughout the air in such proportion as to allow of complete combustion. The familiar explosive combustion of lycopodium, and the disastrous explosions caused in the exhausting rooms of flour mills by the presence of finely-divided flour in the air, have also suggested to inventors the idea of producing explosions for power purposes from combustible solids. Although, doubtless, explosions could be produced in that way, yet in oil engines the production of spray is only a preliminary to the vaporization of the oil. If a sample of oil be sprayed in the manner just described, and injected in a hot chamber also filled with hot air, it at once passes into a state of vapour within that chamber, even though the air be at a temperature far below the boiling point of the oil. The spray producer, in fact, furnishes a ready means of saturating any volume of air with heavy petroleum oil

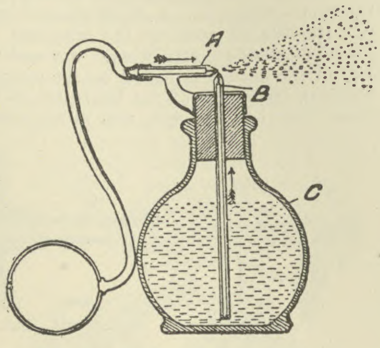


Fig. 9.—Perfume Spray Producer.

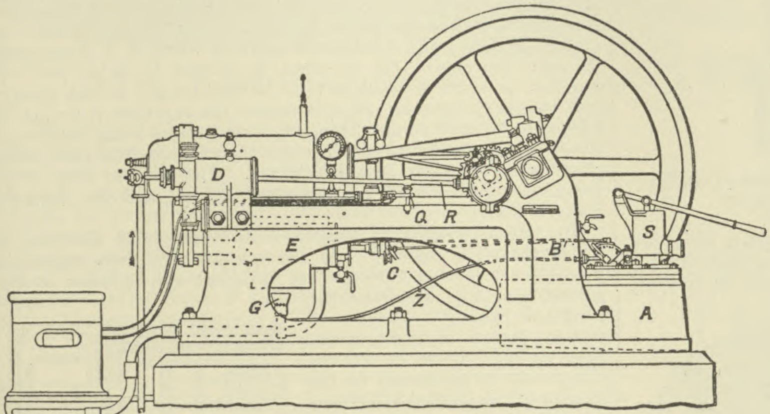


Fig. 10.—Priestman Oil Engine (general arrangement).

to the full extent possible from the vapour tension of the oil at that particular temperature. The oil engines described below are in reality explosion gas engines of the ordinary Otto type, with special arrangements to enable them to vaporize the oil to be used. Only such parts of them as are necessary for the treatment and ignition of the oil will, therefore, be described.

In Fig. 10 is shown the general arrangement of the Priestman engine, which was the first capable of using heavy safe oils. Fig. 11 is a vertical section through the cylinder and vaporizer, and Fig. 12 is a section on a larger scale, showing the vaporizing jet and the air admission and regulation valve leading to the vaporizer. Oil is forced by means of air pressure from the reservoir A through the pipe B to the spraying nozzle C, and air passes from the air-pump D by way of the annular channel *b* into the sprayer *c*, and there meets the oil jet issuing from *a*. The oil is thus broken up into spray, and the air charged with spray flows into the vaporizer E, which is heated up in the first place on starting the engine by means of a lamp G. In the vaporizer the oil spray becomes oil vapour, saturating the air within the hot walls. On the out-charging stroke of the piston the mixture passes by way of the inlet valve H into the cylinder, air flowing into the vaporizer to replace it through the valve I (Fig. 12). The cylinder K is thus charged with a mixture of air and hydrocarbon vapour, some of which may exist in the form of very fine spray. The piston L then returns and compresses the mixture, and when the compression is quite complete an electric spark is passed between the points M, and a compression explosion is obtained precisely similar to that obtained in the gas engine. The piston moves out, and on its return stroke the exhaust valve N is opened and the exhaust gases discharged by way of the pipe O, round the jacket P, enclosing the vaporizing chamber. The latter is thus kept hot by the exhaust gases when the engine is at work, and it remains sufficiently hot without the use of the lamp G. To obtain the electric spark a bichromate

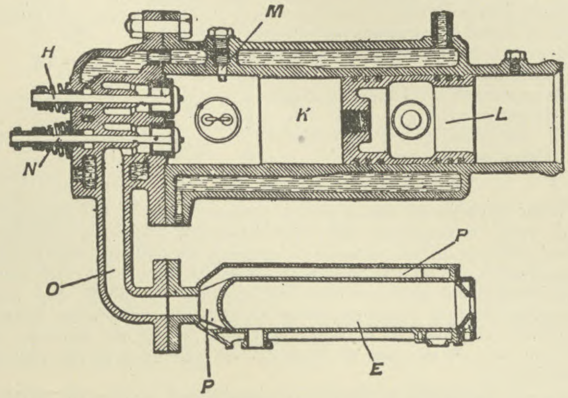


Fig. 11.—Priestman Oil Engine (vertical section through cylinder and vaporizer).

battery with an induction coil is used. The spark is timed by contact pieces Q, operated from the eccentric rod R, used to actuate the exhaust valve and the air-pump for supplying the oil chamber and the spraying jet. To start the engine the hand pump is worked until the pressure is sufficient to force the oil through the spraying nozzle, and oil spray is formed in the lamp G; the spray and air mixed produce a blue flame which heats the vaporizer. The fly-wheel is then rotated by hand, and the engine moves away. The eccentric shaft is driven from the crank shaft by means of toothed wheels, which reduce the speed to one-half the revolutions of the crank shaft. The charging inlet valve is automatic. Governing is effected by throttling the oil and air supply. The governor operates on the butterfly valve T (Fig. 12), and on the plug-cock *t* connected to it, by means of the spindle t^1. The air and oil are thus simultaneously reduced, and the attempt is made to maintain the charge entering the cylinder at a constant proportion by weight of oil and air, while reducing the total weight, and therefore volume, of the charge entering. The Priestman engine thus gives an explosion on every second revolution in all circumstances, whether the engine be running light or loaded. The compression pressure of the mixture before admission is, however, steadily reduced as the load is reduced, and at very light loads the engine is running practically as a non-compression engine. This is a grave disadvantage, as the fuel consumption per indicated horse-power rises rapidly with the reduction of compression.

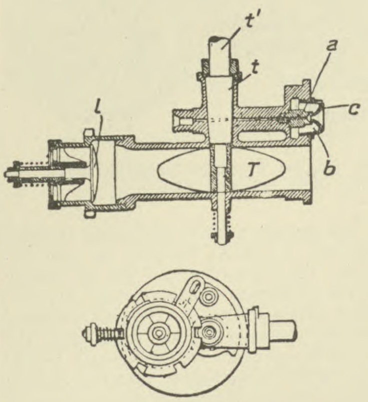


Fig. 12.—Priestman Oil Engine (section on a larger scale).

A test by Professor Unwin of a 4½ nominal horse-power Priestman engine, cylinder 8·5 inches diameter, 12 inches stroke, normal speed 180 revolutions per minute, showed the consumption of oil per indicated horse-power hour to be 1·066 lb, and per brake horse-power hour 1·243 lb. The oil used was that known as Broxburn Lighthouse, a Scottish paraffin oil produced by the destructive distillation of shale, having a density of ·81, and a flashing point about 152° F. With a 5 horse-power engine of the same dimensions, the volume swept by the piston per stroke being ·395 cubic feet, and the clearance space in the cylinder at the end of the stroke ·210 cubic feet, the principal results were :—

	Daylight Oil.	Russoline Oil.
Indicated Horse-Power . . .	9·369	7·408
Brake Horse-Power . . .	7·722	6·765
Mean Speed (revolutions per minute)	204·33	207·73
Mean available Pressure (revolutions per minute) . .	53·2	41·38
Oil consumed per Indicated Horse-Power per Hour . . .	·694 lb	·864 lb
Oil consumed per Brake Horse-Power per Hour . . .	·842 lb	·946 lb

With Daylight oil the explosion pressure was 151·4 lb per square inch above atmosphere, and with Russoline 134·3 lb. The terminal pressure at the moment of opening the exhaust valve with Daylight oil was 35·4 lb, and with Russoline 33·7 per square inch. The compression pressure with Daylight oil was 35 lb, and with Russoline 27·6 lb pressure above atmosphere. Professor Unwin calculated the amount of heat accounted for by the indicator as 18·8 per cent. in the case of Daylight oil and 15·2 in the case of Russoline oil.

Messrs Samuelson's engine is constructed under the Griffin patents, and it resembles Priestman's in subjecting the oil to the preliminary process of spraying before vaporizing; the vaporizer also is heated during the running of the engine by the exhaust gases. It differs, however, from the Priestman engine in the methods of igniting and governing. The tube igniter is used, and the governing device, instead of reducing the power of the explosions, so operates that when speed becomes too high the air supply is entirely cut off and the exhaust valve closed, after the combustion products of the last explosion have been discharged from the cylinder. The piston consequently moves out, expanding the contents of the compression space, while the oil valve is simultaneously shut off in the sprayer, so that no oil is injected. Fig. 13 is a section of the Griffin patent oil sprayer.

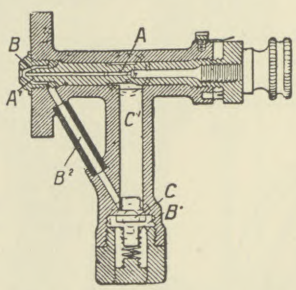


FIG. 13.—Section of Griffin Oil Sprayer.

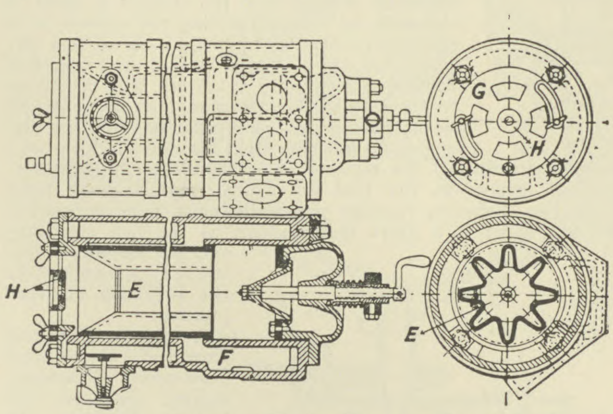


FIG. 14.—Samuelson Engine Vaporizer (longitudinal transverse section, plan and end elevation).

The air enters by way of the passage A, and discharges through the nozzle A^1, thereby causing a partial vacuum in the annular space B formed between the air nozzle and the oil nozzle. The passage B^2 connects to the oil-supply chamber B^1 by way of a spraying valve C attached to a plunger stem C^1. The air pressure, when admitted, forces down the plunger C^1, and thus opens the valve C against the pressure of the spring. Oil thus passes up the passage B^2 from the chamber B^1, and is discharged with the air from the nozzle A^1 in a state of fine spray. Whenever the air-pressure is removed from the plunger C^1, the spring forces the valve to its seat and cuts off the oil supply. The air pressure is maintained at from 12 to 15 lb above atmosphere by a pump driven from an eccentric on the valve shaft. The vaporizer is shown in longitudinal transverse section, plan and end elevation, in Fig. 14. The vaporizer E, corrugated in outline, is surrounded by the exhaust jacket F. The air is admitted from the atmosphere by the adjustable perforated plate G, and the spray nozzle, attached at a point H, discharges the spray into the centre of the vaporizer. Instead of the electric spark for igniting, an incandescent tube is adopted, heated and kept hot by an ingenious lamp shown in Fig. 15. In this lamp oil is admitted to the chamber J by the pipe K, and it is maintained at a constant level there by means of the overflow pipe L. A short piece of wire M is immersed in the oil, and the oil runs up the wire and covers the bent part by reason of capillary attraction. Air under pressure is admitted by way of the pipe N adjusted by the screw N^1, and it passes to the nozzle O, striking upon the bent part of the wire M. The air thus blows the oil off the wire, and at the same time the jet sucks in a

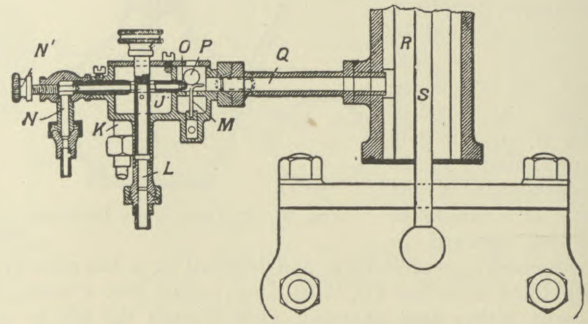


FIG. 15.—Samuelson Engine Spray Lamp.

further supply of air through holes P, and the mixed air and oil spray pass through the tube Q to the asbestos-lined funnel R. The mixture, on being ignited within this funnel, burns with a fierce blue flame, and heats up the igniter tube S; this opens into the engine cylinder, and ignites the mixture when it is compressed. To start the engine the air-pump is worked by hand until the required pressure is obtained; air is then turned on the sprayer, and the spray lighted. By this means the vaporizer is heated for about ten minutes from within, the burnt gases being discharged through a special valve opening into the exhaust, this valve being closed when sufficient heat is attained. The heating lamp of the incandescent tube is in the meantime lighted, and the engine is ready to start.

The Hornsby-Ackroyd engine is an example of the class in which the oil is injected into the cylinder and there vaporized. Fig. 16 is a section through the vaporizer and cylinder of this engine, and Fig. 17 shows the inlet and exhaust valves also in section placed in front of the vaporizer and cylinder section. Vaporizing is conducted in the interior of the combustion chamber, which is so arranged that the heat of each explosion maintains it at a temperature sufficiently high to enable the oil to be vaporized by mere injection upon the hot surfaces. The vaporizer A is heated up by a separate lamp, the oil is injected at the oil inlet B, and the engine is rotated by hand. The piston then takes in a charge of air by the air inlet valve into the cylinder, the air passing by the port directly into the cylinder without passing through the vaporizer chamber. While the piston is moving forward, taking in the charge of air, the oil thrown into the vaporizer is vaporizing and diffusing itself through the vaporizer chamber, mixing, however, only with the hot products of combustion left by the preceding explosion. During the charging stroke the air enters through the cylinder, and the vapour formed from the oil is almost entirely confined to the combustion chamber. On the return stroke of the piston air is forced through the somewhat narrow neck *a* into the combustion chamber, and is there mixed with the vapour contained in it. At first, however, the mixture is too rich in inflammable vapour to be capable of ignition. As the compression proceeds, however, more and more air is forced into the vaporizer chamber, and just as compression is completed the mixture attains proper explosive proportions. The sides of the chamber are sufficiently hot to cause explosion, under the pressure

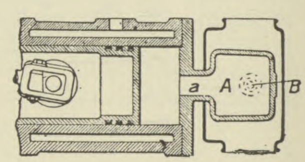


FIG. 16.—Hornsby-Ackroyd Engine (section through vaporizer and cylinder).

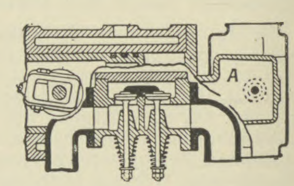


FIG. 17.—Hornsby-Ackroyd Engine (section through valves, vaporizer, and cylinder).

of which the piston moves forward. As the vaporizer A is not water-jacketed, and is connected to the metal of the back cover only by the small section or area of cast iron forming the metal neck *a*, the heat given to the surface by each explosion is sufficient to keep its temperature at about 700–800° C. Oil vapour mixed with air will explode by contact with a metal surface at a comparatively low temperature; this accounts for the explosion of the compressed mixture in the combustion chamber A, which is never really raised to a red heat. It has long been known that under certain conditions of internal surface a gas engine may be made to run with very great regularity, without incandescent tube or any other form of igniter, if some portion of the interior surfaces of the cylinder or combustion space be so arranged that the temperature can rise moderately; then, although the temperature may be too low to ignite the mixture at atmospheric pressure, yet when compression is completed the mixture will often ignite in a perfectly regular manner. It is a curious fact that with heavy oils ignition is more easily accomplished at a low temperature than with light

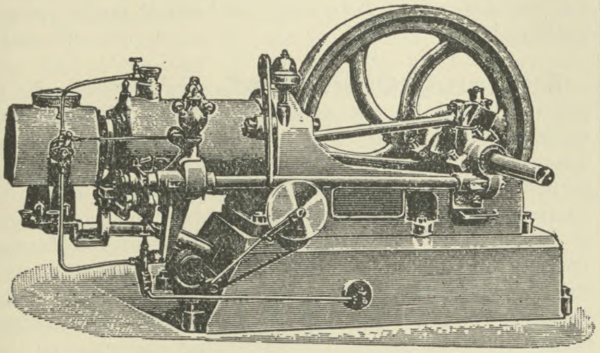


FIG. 18.—Hornsby-Ackroyd Oil Engine.

oils. The explanation seems to be that while in the case of light oils the hydrocarbon vapours formed are tolerably stable from a chemical point of view, the heavy oils very easily decompose by heat, and separate out their carbon, liberating the combined hydrogen, and at the moment of liberation the hydrogen, being in what chemists know as the *nascent* state, very readily enters into combination with the oxygen beside it. To start the engine the vaporizer is heated by a separate heating lamp, which is supplied with an air blast by means of a hand-operated fan. This operation should take about nine minutes. The engine is then moved round by hand, and starts in the usual manner. The oil tank is placed in the bed plate of the engine. The air and exhaust valves are driven by cams on a valve shaft. Fig. 18 is a general view of the external appearance of the engine, from which it will be seen that the governing is effected by a centrifugal governor. This governor

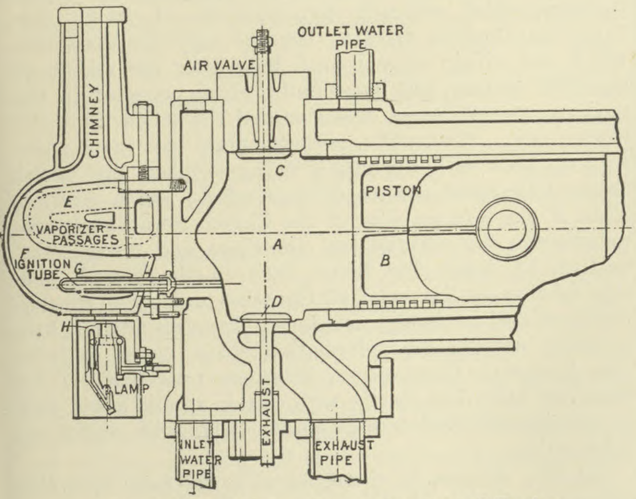


FIG. 19.—Vertical section of Crossley Oil Engine.

operates a bye-pass valve, which opens when the speed is too high, and causes the oil pump to return the oil to the oil tank. The fan and starting lamp will be seen in the lower part of the illustration. At a test of one of these engines, which weighed 40 cwts. and was given as of 8 brake horse-power, with cylinder 10 inches in diameter and 15 inches stroke, according to Professor Capper's report, the revolutions were very constant, and the power developed did not vary one quarter of a brake horse-power from day to day. The oil consumed, reckoned on the average of the three days over which the trial extended, was ·919 ℔ per brake horse-power per hour, the mean power exerted being 8·35 brake horse. At another full-power trial of the same engine a brake horse-power of 8·57 was obtained, the mean speed being 239·66 revolutions per minute, and

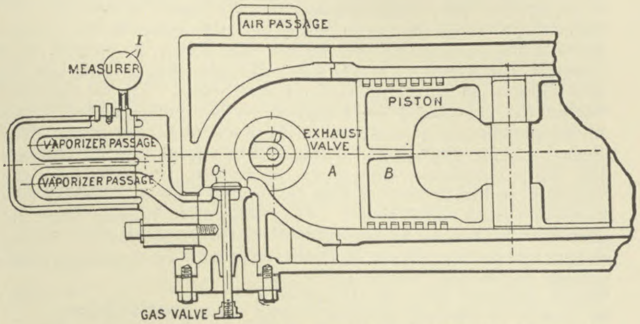


FIG. 20.—Sectional plan of Crossley Oil Engine.

the test lasting for two hours; the indicated power was 10·3 horse, the explosions per minute 119·83, the mean effective pressure 28·9 ℔ per square inch, the oil used per indicated horse-power per hour was ·81 ℔, and per brake horse-power per hour ·977 ℔. In a test at half power, the brake horse-power developed was 4·57 at 235·9 revolutions per minute, and the oil used per brake horse-power per hour was 1·48 ℔. On a four hours' test, without a load, at 240 revolutions per minute, the consumption of oil was 4·23 ℔ per hour.

Other engines of this class are those manufactured by Messrs Robey & Co. and one, a German engine, known as the Capitaine.

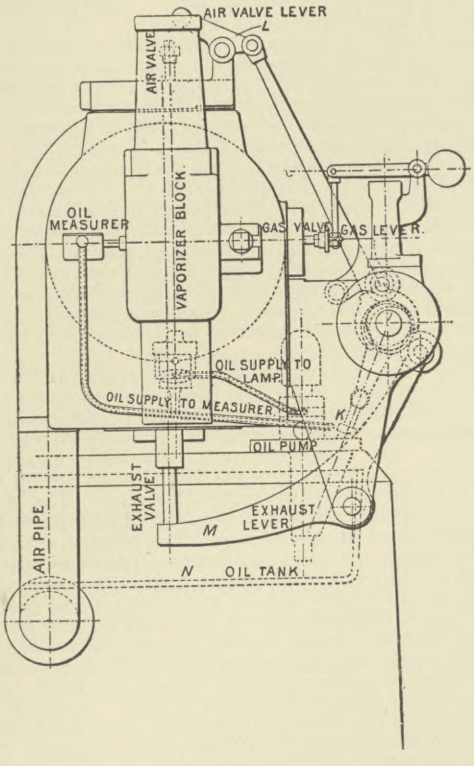


FIG. 21.—End elevation of Crossley Oil Engine.

The former vaporizes its charge by the injection of the oil against the heated walls of the combustion chamber, and ignition is accomplished also by contact with these hot walls. The Capitaine engine has a vaporizer and igniter placed within the combustion space of a cylinder; the oil is vaporized by injection upon the hot surfaces of the vaporizer, and ignition also takes place when compression is completed by contact with these hot surfaces. The late Mr Brayton also proposed and experimented with an engine somewhat of this type.

As a type of the engines in which the oil is vaporized in a device external to the cylinder, and introduced into the cylinder in a state of vapour, the Crossley oil engine may be described. Figs. 19, 20, and 21 show respectively vertical section, sectional plan, and end elevation of the combustion chamber and cylinder. Fig. 22 shows in elevation the oil pump on a larger scale. A is the combustion space, B the piston, C the air inlet valve, D the exhaust valve, E the vaporizer, F the vaporizer and igniter casing, G the igniter tube, H the heating lamp, I the oil measurer, J the valve shaft, K the oil pump, L the air valve lever, M the exhaust valve lever, and N the oil tank. The lamp H consists of a chamber into which oil is pumped. This chamber is heated in the first instance by burning a little oil upon waste. The oil vaporizes within the chamber when forced in by the pump, and it issues under pressure at a small nozzle at the foot of the lamp. The flame sucks air with it, and burns within a space passing through the lamp chamber. The flame so formed proceeds into the vaporizer casing F, heating first the igniter tube G, which is surrounded with a metal shield. The flame, after passing from the igniter tube, heats the vaporizer E, which consists of a casting having one passage within it, made continuous by a corresponding passage in the face shown in Fig. 20. Oil is pumped into the measurer I by means of the oil pump K. The measurer passes only a certain fixed volume at each stroke, the excess volume being sent back to the oil reservoir. The oil vaporizes in the vaporizer passage, and it is admitted to the engine by the oil valve O, which is operated by governor from the cam shaft J, as shown in Fig. 22. The advance of the piston B draws in a charge of air through the valve C. At the same time the oil valve O is opened, and the vapour of oil passes into the cylinder from the vaporizer passage. A small quantity of air is at the same time sucked through the passage. A vaporized charge of oil is thus passed into the cylinder with the air charge, and the piston B on its return stroke compresses the charge into the combustion space A. There it is ignited by the igniter tube G, and the engine makes its explosion or power stroke. This operation is repeated so long as power is required. When the speed of the engine exceeds the limit, the governor prevents the vapour valve O from opening, and no oil charge finds its way through the measurer to the vaporizer passage. One of these engines declared of 7½ brake horse-power developed on the brake 6·28 horse-power, and consumed ·90 lb of Russoline oil per brake horse-power per hour. The Tangye oil engine made under Pinkney's patents has also an external vaporizer, but all the air charge is dragged through the vaporizer to the cylinder, and the vaporizer is always opened to the cylinder, so that the port space is somewhat excessive. Many other oil engines are now upon the market, but all appear to be constructed in accordance with the types described.

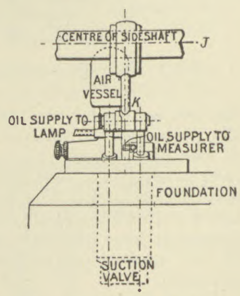


FIG. 22.—Oil Pump for Crossley Oil Engine (elevation).

Mr Diesel has, however, produced an engine which departs somewhat from other types. In it air alone is drawn into the cylinder on the charging stroke. The air is compressed on the return stroke to a very high pressure, generally over 700 lb per square inch. This compression raises the air to incandescence, and then oil is injected into the incandescent air by a small portion of air compressed to a still higher point. The oil ignites at once as it enters the combustion space, and so a power impulse is obtained, but without explosion. The pressure does not rise above the pressure of air and oil injection. The Diesel engine thus embodies two very original features: it operates at pressures very much higher than those used on any other internal combustion engines, and it dispenses with all the usual igniting devices by rendering the air charge incandescent by compression. The engine has been built both as an Otto cycle engine and as an impulse-every-revolution engine. One of the latter type was exhibited at the Glasgow Exhibition of 1901. So far the engine has not attained any commercial position. Although economical, it appears to be a heavy engine for the power developed.

The oil engine is at present in the development stage. Large alterations are continually being made, and in a few years great extensions may be looked for in the applications of oil engines to industrial purposes. At present, so far as dimensions are concerned, they are in the stage which the gas engine had attained about 1880. The difficulties have not been so thoroughly overcome as in gas engines, and especially the difficulties of constructing them of large size. An oil engine giving about 50 brake horse-power would at present be regarded as a large one, whereas now a large gas engine would be one giving about 300 brake horse-power. Great future developments may be expected both in gas and oil engines. So far as economy of heat is concerned, both have considerably surpassed the best steam engines, but much remains to be done before they equal the latter in frequency of impulses, in absolute steadiness of governing, and in power of control for cases where, for instance, reversing is required. As yet the applications of gas and oil to any but fixed engines have been limited, but ultimately they will be used with great advantage for propelling ships and for driving locomotives. Many engineers are now at work on the subject, and when the problem is further solved it will aid much in economizing fuel for all purposes where both large and small motive powers are required. (D. CL.)

England, Church of.—Subsequently to the period covered by the article in the 9th edition of this work, there has only been one material change in the constitutional status of the English Church. As a consequence of the disestablishment of the Irish Church, the "union created by Act of Parliament between the Churches of England and Ireland" was dissolved from 1st January 1871, although the Churches remain in full communion with one another. The projected disestablishment and disendowment of the four Welsh dioceses in 1893 would, if carried out, have had far more sweeping consequences; but it was rejected on an appeal to the country (see ESTABLISHMENT). There are other events, however, which must be recorded, both as being more important in themselves and as likely to lead to far-reaching consequences in the future. The so-called Catholic revival, of which the Oxford Movement was the most prominent feature, has, on the one hand, entirely remodelled the popular conception of the Church, and profoundly affected every side of its work; whilst, on the other hand, many of its developments have been stigmatized as popish, and have called forth strenuous opposition on this account. A more liberal cast of thought and a revival of exact scholarship have done much to assuage the apprehension with which natural science and Biblical criticism were formerly alike regarded; and a sounder and deeper theology, chief amongst the pioneers of which was Frederick Denison Maurice, has not only displaced that which was widely current until long after the middle of the 19th century, but has found a strong support in the modern conceptions of evolution and the solidarity of the human race. Meanwhile, resolute efforts have been made to keep pace with the ever-growing religious and social needs of the great centres of population; and a growing sense of the responsibility of the Church towards her own members in the colonies and elsewhere, and towards the heathen at large, has borne fruit in the growth and organization of the colonial Churches and in a greatly increased zeal for foreign missions. Recourse must be had to other articles for information upon these subjects (see ANGLICAN COMMUNION, MISSIONS); all that can be done here is to deal shortly with certain special heads, and to supplement what is said under these with statistical information.

(1) The changes in ritual, based in the main upon the express provisions of the Ornaments Rubric, or else upon an interpretation of it, as referring to the year before the introduction of the First Prayer-Book of Edward VI., have given rise to frequent legislation, the more important early cases being those of Westerton *v.* Liddell (1855–57), Martin *v.* Mackonochie (1867–68), and Elphinstone (afterwards Hebbert) *v.* Purchas (1869–70). Each

of these was carried to the Privy Council, the judgments of which not only varied in different cases, but showed no signs of being based upon an adequate knowledge of the facts under review. A Royal Commission on Ritual (1867–70) put forth valuable material, but did nothing to set matters at rest; and several unsuccessful efforts at legislation culminated at length, in 1874, in the passing of the Public Worship Regulation Act, in spite of strong opposition. This only made things worse, by constituting a new civil court in place of the ancient Court of Arches (see ARCHES, COURT OF), and facilitating litigation, without in any way conducing to a better interpretation or administration of the law. In the Folkestone case (1875–76) the defendant, the Rev. C. J. Ridsdale, only conformed to its judgment under a formal dispensation from his diocesan, Dr Tait, from the observance of the rubric as he interpreted it; and in six other cases, the last being that of the Rev. J. Bell Cox in 1887, clergymen went to prison for contempt of court rather than obey its monitions. Public opinion declared itself very strongly against this, however, and largely owing to the influence of Archbishop Tait (who bore witness that nothing of the kind had been intended by the promoters of the Act), it gradually came to an end. An entirely new departure was marked by the case of the Bishop of Lincoln, in which a purely spiritual judgment was given (LINCOLN JUDGMENT), which was very widely accepted by Churchmen. From 1898 there has been renewed agitation on the subject of ritual excesses, but the temper of Parliament was opposed to any introduction of legislation which should overrule the power of the bishops. The question of the meaning of the Ornaments Rubric was again raised in 1899, in regard to the ceremonial use of incense and the reservation of the Eucharist. At the request of the bishops concerned, the two Archbishops heard counsel and received evidence on both subjects (the Archbishop of York acting as assessor only as regards the former), and gave it as their opinion that both were forbidden (see INCENSE; RESERVATION). The directions of the bishops in accordance with these opinions have been very generally, but by no means universally, obeyed by the clergy; and an attempted prosecution of some of those who had not done so (by a non-parishioner) was stopped by the veto of the Bishop of London in December 1900. It was generally felt that action of some kind was desirable, but that it should be remedial rather than penal. Something has been done already by the restoration of the old Court of Arches; but the recommendations of the Ecclesiastical Courts Commission (1881–83) have not yet borne fruit, and nothing has yet been done to adapt to modern conditions the rigidity of an order of service which was largely moulded by the conditions of the 16th and 17th centuries.

(2) Closely connected with the subject of ritual is that of doctrine, of which it is in general the outward expression. As regards this, two things are noteworthy: on the one hand a tendency to permit the largest possible liberty of opinion, and on the other a fuller realization of the ancient doctrine of the Church as expressed in its formularies. The judgment of the Privy Council in the Gorham case (1847–50), to the effect that Mr Gorham's views were "not contrary or repugnant to the declared doctrine of the Church of England," is almost a dead letter excepting from the former point of view. Although the *Essays and Reviews*, published in 1860, caused a great sensation at the time of their publication, the condemnation of two of the essayists in the Court of Arches was reversed by the Privy Council, and a third became Archbishop of Canterbury in the person of Dr Temple. And whilst many of the views advanced would now be repudiated as contrary to sound learning, others are now on all hands accepted. Again, the Colenso controversy, if it showed that there was a rooted objection to the use of modern critical methods in the interpretation of Scripture, showed also that there was no Socinianism in the Church as a whole. Turning to the other side, the case of the Rev. W. J. E. Bennett (1870–72) vindicated for English Churchmen the right to hold and to teach the ancient doctrine of the Real Presence in the Eucharist. Naturally, changes such as these have not come about without much party feeling. The opposing tendencies are represented by (for the High Church party) the English Church Union, founded in 1859 "to defend and maintain unimpaired the doctrine, discipline, and ritual of the Church of England," and (for the Low Church party) the Church Association, founded in 1865 "to counteract the efforts now being made to pervert the teaching of the Church of England." The more aggressive spirits in the Low Church party (with whom the name of Mr Kensit was associated in their more violent outbreaks) have been active in making public protests against what they regarded as Roman tendencies; while similar tactics have been pursued by Father Black and others against the marriage of divorced persons in church, and other practices objectionable to the advanced High Church section.

(3) As regards corporate action, considerable advances have been made. The revival of the meeting of Convocation for business, if it has not given autonomy to the Church, has at least supplied it with a mouthpiece. In 1885 there was inaugurated a House of Laymen for the province by vote of both Houses of the Convocation of Canterbury. The Convocation of York followed suit in 1892, and the Houses of Laymen, although purely consultative bodies, have already done notable service. The Diocesan Synod is now a real bishop's council in some dioceses. A more popular element is supplied by the Church Congresses, held annually since 1861 at some selected centre, and presided over by the Bishop of the diocese, and by the various diocesan conferences; and the Lambeth Conferences (*q.v.*) have done very valuable work in keeping the Church at home in touch with its daughter Churches abroad. A widely felt need is being supplied by the Church House, proposed by Bishop Harvey Goodwin in 1886, founded as the Church's memorial of Queen Victoria's jubilee, and inaugurated by royal charter in 1888, to be a place of meeting for the Convocation of Canterbury, a home for Church organizations of all kinds, and a centre of operations for the whole Anglican communion.

(4) Nor can it be doubted that this enlarged corporate action has been accompanied by increased activity of the whole body. Without going into details here, one or two points may be noticed. A number of theological colleges have been founded which aim at supplying training for candidates for holy orders. New agencies for work of various kinds are supplied by brotherhoods and sisterhoods, and by institutions of deaconesses. The missionary activities of the Church of England are greater to-day than ever before. New interests are represented or stimulated by such societies as the Christian Social Union, the Church Historical Society, and the Church Reform League.

See also the articles ENGLAND AND WALES, CONFIRMATION OF BISHOPS, CHRISTIAN CHURCH, &c.; and the biographies of TAIT, BENSON, CREIGHTON, &c.

(W. E. CO.)

CHURCH WORK.

In summarized form the work and progress of the Church of England during the period 1875–1900 is treated on the next page from a statistical standpoint.

Home Missions.—The abnormal growth of population during the last quarter of the 19th century was met by the maintenance of exceptional agencies for ministering to the spiritual wants of the people. Bishops' Funds were established for creating new districts, building churches, and for the increase of parochial clergy, at a cost averaging not less than £80,000 a year. The Additional Curates Society, the Church Pastoral Aid, and kindred societies also provide for additional clergy, and otherwise assist in the extension and maintenance of Home Mission work, raising annually for this purpose about £275,000. To bring wealth and intellectual culture into closer touch with the needs of the masses, the late Bishop Walsham How took the initiative in the formation of Universities and Public Schools' Missions. Eight colleges and twenty-four public schools maintain such missions in populous centres. The Oxford House in Bethnal Green, the Cambridge House in South London, with the Inns of Court Mission in Drury Lane, have become permanent and active centres for the advancement of the religious and social welfare of the people. For the maintenance of these missions and settlements at least £35,000 is annually contributed. (See also CHURCH ARMY.) To supplement the work of the parochial clergy, systematic provision has been made for the holding of parochial missions. This work mainly originated with the Aitken Memorial Mission, now employing a staff of experienced preachers. In eighteen dioceses provision of a similar kind has been made by the appointment of diocesan missioners, or the creation of societies of mission clergy. The spiritual needs of the seafaring population have been vigorously ministered to by the missions to seamen and kindred societies. The increased activity of the military chaplains has been greatly aided by the work of the Soldiers' Institutes Association in establishing institutes at eight of the principal military depôts. At least £65,000 is annually contributed for the work of the Church among soldiers and sailors.

Foreign Missions.—The total sum contributed in voluntary offerings at home for the support of foreign missions in the year ending Easter 1900 was £831,093, 14s. 9d. To further corporate action, a Board of Missions has been established for the Provinces of Canterbury and York, and works in systematic connexion with the Houses of Convocation, collecting information, presenting reports upon the operations of various agencies, and organizing missionary unions and festivals. Associations of junior clergy have now been formed in almost every diocese: there are 91 such associations, representing a membership of 4921; they seek to promote an interest in missions by means of conferences, lectures, and services of intercession. (See also the article on MISSIONS.)

The Episcopate.—Since 1877 the sum of £533,909, 17s. 10d. has been contributed in voluntary offerings for the endowment of seven new sees, this sum being entirely independent of any assistance from the relieved dioceses or any sources of ecclesiastical income. These sees, with the date of creation and the amount contributed, are as follows:—Truro, 1877, £70,948; St Albans, 1877, £55,073; Liverpool, 1880, £94,676; Newcastle, 1882, £88,866; Southwell, 1884, £65,834; Wakefield, 1888, £83,510; Bristol, 1897, £75,000. The following suffragan bishops have been appointed since 1879: Bedford, 1879; Colchester, 1882; Marlborough, Shrewsbury, and Leicester, 1888; Richmond, Beverley, Reading, Derby, and Barrow-in-Furness, 1889; Swansea, 1890; Hull, Southwark, and Coventry, 1891; Thetford, 1894; Stepney and Southampton, 1895; Crediton, 1897; Islington, 1898; Ipswich, 1899; Kensington and Barking, 1901.

Colonial and Missionary Bishoprics.—There are now 99 Colonial and Missionary sees, and of these the following have been created since 1875:—

Asia.—Lahore and Rangoon in 1877; Travancore and Cochin, 1879; North China, 1880; South Tôkyô, 1883; Korea, 1889; Chhota Nagpur, 1890; Lucknow, 1893, Kiushiu, 1894; Western China, 1895; Tinnevelly, Osaka, and Hokkaido, 1896.

Africa.—Pretoria, 1878; Uganda, 1884; Lebombo and Mashonaland, 1891; Likoma, 1892.

Australia.—Ballarat, 1875; North Queensland, 1878; Riverina, 1883; Rockhampton, 1892; New Guinea, 1897; Carpentaria, 1899.

British North America.—Niagara, 1875; Athabasca and Qu' Appelle, 1884; Calgary, 1887; Selkirk, 1890; Ottawa, 1896; Keewatin, 1899; Kootenay, 1899; West Indies and South America, Windward Isles, 1878; Honduras, 1883.

The Clergy.—The number of deacons ordained 1875–1900 was 17,904; regarding these as additions to the ranks of the clergy, this will represent an average of 716 for each year. According to the official returns for the year ending Easter 1900, the parochial clergy numbered 21,750, representing 13,873 incumbents and 7877 assistant clergy. To these figures should be added the cathedral clergy, and a considerable number attached to the universities, public schools, hospitals, prisons, workhouses, and other institutions; with the army and navy chaplains. The official returns of the bishops for 1899–1900 report that there were 4625 clergy working in the Colonies, India, and the Missionary Dioceses.

Statistics of Parochial Work.—The following figures have been carefully registered in exact detail from the official returns of the clergy for the year ending Easter 1900:—Baptisms, infants 578,489, adults 12,244; communicants, 1,974,629; communicants' classes, 227,268; celebrations of the holy communion (monthly), before midday 32,293, at midday 23,045, after midday 2142; church accommodation, parish churches, appropriated 1,342,980, free 4,333,913; chapels of ease, appropriated 67,295, free 532,503; mission rooms, 609,307; other buildings systematically used for service, 114,377; total accommodation, appropriated 1,410,275, free 5,590,100; churches open for daily prayer, 4848; for private prayer, 6838; Sunday schools, infants 647,313, boys 805,453, girls 934,914; teachers, male 55,453, female 148,449; Bible classes, male 220,655, female 233,527; guilds, male 122,501, female 322,322; temperance work, adult abstainers 117,851, adult non-abstainers 45,798, juvenile abstainers 437,046; lay-help: district visitors, male 3406, female 67,376; lay-readers, licensed 2280, unlicensed 1959; sisters, 641; deaconesses, 379; nurses, 2030; mission women, 980; choir, male 251,192, female 86,278. With regard to confirmation, the number of candidates for 1900 were: males 79,058, females 116,511, total 195,569.

Church Extension.—During the last quarter of the 19th century 1712 churches were built or rebuilt, and 6325 churches restored; the cost of such work in the year 1899 was £1,183,739, practically representing the annual expenditure. Taking a period of sixteen years (1884–99), the following sums were contributed in purely voluntary offerings for these specific branches of Church extension: church building, £17,531,626; endowment of benefices, £2,348,611; burial-grounds, £410,572; parsonage houses, £1,567,739: making a total of £21,858,548. A parliamentary return shows that from 1868 to 1896, 1461 new parishes were constituted under Church Building Acts, providing for a population of 4,926,243.

Education.—The Church has vigorously maintained her voluntary schools. The accommodation increased from 2,011,434 in 1875 to 2,794,791 in 1899; the average attendance from 1,175,289 to 1,895,569; the number of assistant and certificated teachers from 15,763 to 45,823; the average cost per scholar was £1, 11s. 11d., increasing to £2, 4s. 11d. in 1899. In that year the sum of £42,880 was spent upon the maintenance of thirty training colleges for masters and mistresses, and the diocesan religious inspection of schools. For the year 1899, £996,808 was voluntarily contributed for the general maintenance of elementary schools, and the enlargement of school buildings. The total amount of voluntary expenditure on church schools and training colleges since 1870 was £27,352,967. The educational work of the Church has been immensely aided by the *National Society*, through its liberal grants for the building and maintenance of Church training colleges, the religious inspection of schools, and by the assistance it has given in grants of books and fittings. In the *Sunday Schools* of the Church of England there are now 2,387,680 children receiving instruction from 203,892 teachers. In adult Bible classes, more or less connected with Sunday schools, there are 454,182 members. The Sunday-school work is voluntarily maintained at an annual cost of about £150,000. For the instruction of children and adults of the higher and middle classes in the principles and teaching of the Church of England, reading societies have been formed in sixteen dioceses; by this provision courses of lectures are given at certain fixed centres, and examinations annually held. Seven schools have been established since 1875 in development of the Woodard scheme, making in all thirteen. Considerably over £500,000 has been voluntarily contributed for the foundation and maintenance of these schools. For the education of children above the class attending elementary schools, the Church Schools Company was formed in 1883, and in 1900 had 27 schools, educating about 2500. The *Society for Promoting Christian Knowledge* has, to a most valuable extent, advanced the higher education of the people by its publications and circulation of pure and popular literature, and its generous grants of books and tracts. In the British colonies and dependencies the work of the society has much assisted the bishops and clergy.

Philanthropic Work.—The extent of the efforts of the Church in this direction may be inferred from the following records of voluntary contributions during 1900: for industrial schools, penitentiaries, and preventive homes, £208,279, 18s.; orphanages, £124,792, 10s. 3d.; nursing institutions, convalescent homes, and cottage hospitals, £189,757, 0s. 5d.; making a total of £522,829, 8s. 8d. The figures relating to the Metropolitan Hospital Sunday Fund are especially instructive; the contributions between 1872 and 1900 represented a total of £922,116, 13s.; of this the Church of England contributed £715,552, 7s. in 24,282 separate collections out of a total of 41,199.

Clerical Incomes and Support of the Clergy.—The official returns for the year ending Easter 1900 represented the gross income of the clergy arising from all sources to be £4,386,451, 4s. 11d., the total deductions £973,611, 19s. 6d., leaving a net income of £3,412,839, 4s. 5d. This will give the average income of a benefice as £241, and to this figure should be generally added the value of the parsonage-house. Owing to the serious diminution in the value of tithe, with the consequent prevalence of poverty it has created, it has become necessary to organize provision for subsidizing diminished clerical incomes; this has been made by the inauguration of the Queen Victoria Clergy Fund, incorporated by Royal Charter in 1897; working in co-operation with this Fund, each diocese has its own distinct organization, and by this union of effort a sum averaging about £30,000 is annually raised. A large number of educational and charitable societies also exist for the assistance of the poorer clergy, their widows and orphans, representing an expenditure of about £140,000.

Voluntary Offerings.—The Church of England raised during the year ending Easter 1900 a sum total of £7,770,992, 15s. 1d. by purely voluntary effort and gifts, completely exclusive of any grants from the Ecclesiastical Commissioners, Queen Anne's Bounty, or anything in the nature of Government aid; nor does this amount embrace the contributions to societies supported by the co-operation of Churchmen and Nonconformists.

Brotherhoods.—There has been a growing recognition of the value of Brotherhoods, and of their work and life in the Church of England. Several new societies have been founded. The Society of Mission Priests of St John the Evangelist, otherwise known as the *Cowley Fathers*, was founded by the Rev. R. M. Benson in 1865 at Cowley St John, for the cultivation of a life dedicated to God, upon the principles of poverty, chastity, and obedience. It works by missionary and educational efforts for the advancement of Christ's kingdom at home and abroad; lay brothers are united with the clergy in dedication to the religious life, and generally assist in carrying out the aims of the society. The society has extended its labours to Bombay and Poonah in India, Cape Town in South Africa, and Boston in the United States.—The *Community of the Resurrection* had its origin in 1892 at Pusey House, Oxford, its founder being the Rev. Charles Gore. Subsequently it removed to Radley, then to Westminster, and it is now permanently located at Mirfield, in Yorkshire. The society consists of celibate clergy living under rule and with a common purse. As a condition of membership each priest must serve a period of probation with the intention of permanent association with the community, without binding himself, however, by any life vow. Taking the basis of study and prayer, each member is pledged to occupy himself in various works for the edification of the Church, pastoral, evangelistic, literary, and educational.—The *Society of the Sacred Mission* originated in the widely felt necessity for an agency which should train working-men and others who might be deterred by want of means or education for the foreign mission field. The work was begun in 1891, at the desire of Bishop Corfe of Korea, by the Rev. H. Kelly. The house is now located at Mildenhall, in Suffolk, and is recognized by the Bishop of Ely as a theological and missionary college. Each applicant for admission declares his intention (1) to serve for his whole life unpaid, receiving only the necessaries of life; (2) to remain unmarried; (3) not to seek ordination or undertake any work not assigned to him. The training varies from one to eight years; the life is of the simplest, the discipline that of a religious house.—The *Order of St Paul* is a community for priests and laymen "dedicated to God and our merchant seamen in holy religion." The house is at Alton, in Hampshire.—There is also a community, consisting of clerical and lay members, which has its headquarters in the mission district of St Philip's, Plaistow, E. The members are engaged in the work of the mission. (See also SISTERHOODS.) (F. BU.)

ENGLAND AND WALES.[1]

I. GEOGRAPHY.

THE object of this section is to give a physical description of England and Wales according to natural regions, which usually follow the geology of the country very closely. The lines of division thus do not correspond with the political or official divisions used for other purposes, and the general description which follows is intended to be supplemented by the statistics of the separate counties and towns, which will be found in separate articles. The southern portion of the island of Great Britain, to which alone the name of England is properly applied, extends from the mouth of the Tweed in 55° 48′ N. lat. to Lizard Head in 49° 58′ N., in a roughly triangular form. The base of the triangle runs from the South Foreland to Land's End W. by S., a distance of 316 miles in a straight line, but 545 miles following the larger curves of the coast. The east coast runs N.N.W. from the South Foreland to Berwick, a distance of 348 miles, or, following the coast, 640 miles. The west coast runs N.N.E. from Land's End to the head of Solway Firth, a distance of 354 miles, or, following the much-indented coast, 1225 miles. The total length of the coast-line may be put down as 2350 miles.[2] The most easterly point is at Lowestoft, 1° 46′ E., the most westerly is Land's End, in 5° 43′ W. The total area is given officially as 58,309 square miles, of which 50,867 square miles are assigned to England and 7442 square miles to Wales. The coasts are nowhere washed directly by the ocean, except in the extreme south-west; the south coast faces the English Channel, which is bounded on the southern side by the coast of France, converging from 100 miles apart at the Lizard to 21 at Dover. The east coast faces the shallow North Sea, which widens from the point where it joins the Channel to 375 miles off the mouth of the Tweed, the opposite shores being occupied in succession by France, Belgium, Holland, Germany, and Denmark. The west coast faces the Irish Sea, with a width varying from 45 to 130 miles. Except along the centre of the Irish Sea, at one point off the Tweed, and one between Devon and Normandy, the depth of water between England and the nearest land nowhere exceeds 50 fathoms. The east and south coasts show considerable stretches of uniform uninflected coast-line, and except for the Farne Islands and Holy Island in the extreme north, and the Isle of Wight in the south, they are without islands. The west coast, on the other hand, is minutely fretted into capes and bays, headlands and inlets of every size, and an island-group lies off every great headland. The coast-line, both on the west and east, is curved into numerous large inlets, which may be grouped in pairs—the Thames and Severn, the Wash and Cardigan Bay, the Humber and Mersey, the Tyne and Solway. In this way the land is so deeply penetrated by the water that no part is more than 75 miles from the sea.[3]

General Configuration and Geology.[4]—In their broad lines the configuration and geology of the country are

[1] See also UNITED KINGDOM, THE.

[2] Measurements made on a map on the scale of 12½ miles to 1 inch, the coast being assumed to run up estuaries until the breadth became 1 mile, and no bays or headlands of less than one mile across being reckoned. The coast-line of Anglesea and the Isle of Wight, but of no other islands, is included.

[3] Buckingham appears to be the most inland town in England, being 75 miles from the estuaries of the Severn, Thames, and Wash; Coleshill, near Birmingham, is also almost exactly 75 miles from the Mersey, Severn, and Wash.

[4] The work of the Ordnance Survey, the Geological Survey, and the Hydrographic Survey of the Admiralty suffices to delineate the configuration and the geology of England and the adjacent sea-beds with a completeness not surpassed in the case of any country. Statistics of every kind—of climate, agriculture, mining, manufactures, trade, population, births, marriages, deaths, disease, migration, education—are liberally furnished by Government agencies at the public expense; but the form in which they are compiled and published makes it impossible to utilize the data for the purpose of discussing general distributions in relation to the fixed geographical features. Hence this sketch is more imperfect than the space devoted to it necessitates. For a scheme for the complete geographical description of the British Islands and a specimen worked out in detail for a small area, see papers by H. R. Mill in *Geographical Journal*, vii., 1896, p. 345; xv., 1900, p. 205.

closely related, though the relationship is not so simple or so clearly marked as in Scotland. The land is highest in the west and north, where the rocks also are oldest, most disturbed, and hardest, and the land surface gradually sinks towards the east and south, where the rocks become successively less disturbed, more recent, and softer. The study of the scenery of England and Wales as a whole, or the study of orographical and geological maps of the country, allows a broad distinction to be drawn between the types of land-forms in the west and in the east. This distinction is essential, and applies to all the conditions of which geography takes account. The contrasted districts are separated by an intermediate area, which softens the transition between them, and may be described separately.

The Western Division is composed entirely of Archæan and Palæozoic rocks, embracing the whole range from pre-Cambrian up to Carboniferous. The outcrops of these rocks succeed each other in order of age in roughly concentric belts, with the Archæan mass of the island of Anglesea as a centre, but the arrangement in detail is much disturbed and often very irregular. Contemporary igneous outbursts are extremely common in some of the ancient formations, and add, by their resistance to atmospheric erosion, to the extreme ruggedness of the scenery. The hills and uplands of ancient rocks do not form regular ranges, but rise like islands in four distinct groups from a plain of New Red Sandstone (Permian and Triassic), which separates them from each other and from the newer rocks of the Eastern Division. Each of the uplands is a centre for the dispersal of streams; but with only one prominent exception (the Humber), these reach the sea without crossing into the Eastern Division of the country.

The Eastern Divison, lying to the east of the zone of New Red Sandstone, may be defined on the west by a slightly curved line drawn from the estuary of the Tees through Leicester and Stratford-on-Avon to the estuary of the Severn, and thence through Glastonbury to Sidmouth. It is built up of nearly uniform sheets of Mesozoic rock, the various beds of the Jurassic lying above the New Red Sandstone (Triassic), and dipping south-eastward under the successive beds of the Cretaceous system. In exactly the same way the whole of the south-east of the island appears to have been covered uniformly with gently dipping beds of Tertiary sands and clays, beneath which the Cretaceous strata dipped. At some period subsequent to this deposition there was a movement of elevation, which appears to have thrown the whole mass of rocks into a fold along an anticlinal axis running west and east, which was flanked to north and south by synclinal hollows. In these hollows the Tertiary rocks were protected from erosion, and remain to form the London and the Hampshire Basins respectively, while on the anticlinal axis the whole of the Tertiary and the upper Cretaceous strata have been dissected away, and a complex and beautiful configuration has been impressed on the district of the Weald. The general character of the landscape in the Eastern Division is a succession of steep escarpments formed by the edges of the outcropping beds of harder rock, and long gentle slopes or plains on the dip-slopes, or on the softer layers; clay and hard rock alternating throughout the series.

The contrast between the lower grounds of the Western and the Eastern Divisions is masked in many places by the general covering of the surface with glacial drift, a stiff clay composed on the whole of the detritus of the rocks upon which it rests, but usually containing fragments of rocks which have been transported from a considerable distance. This boulder clay covers almost all the low ground north of the Thames Basin, its southern margin fading away into washed sands and gravels.

The history of the origin of the land-forms of England, as far as they have been deduced from geological studies, is exceedingly complicated, and cannot be touched on here. The fact that every known geological formation (except the Miocene) is represented, proves of itself how long the history has been, and how multifarious the changes. It must suffice to say that the separation of Ireland from England was a comparatively recent episode, while the severance of the land-connection between England and the Continent by the formation of the Strait of Dover is so recent as probably to have come within the human period.

Climate.

Temperature.—The mean annual temperature of the whole of England and Wales (reduced to sea-level) is about 50° F., varying from something over 52° in the Scilly Isles to something under 48° at the mouth of the Tweed. The mean annual temperature diminishes very regularly from south-west to north-east, the west coast being warmer than the east, so that the mean temperature at the mouth of the Mersey is as high as that at the mouth of the Thames. During the coldest month of the year (January) the mean temperature of all England is about 40°. The influence of the western ocean is very strongly marked, the temperature falling steadily from west to east. Thus while the temperature in the west of Cornwall is 44°, the temperature on the east coast from north of the Humber to the Thames is under 38°, the coldest winters being experienced in the Fenland. In the hottest month (July) the mean temperature of England and Wales is about 61°·5, and the westerly wind then exercises a cooling effect, the greatest heat being found in the Thames basin immediately around London, where the mean temperature of the month exceeds 64°. The average temperature along the south coast is 62°, and that at the mouth of the Tweed a little under 59°. In the centre of the country along a line drawn from London to Carlisle the temperature is found to diminish gradually at an average rate of 1° per 60 miles. The coasts are cooler than the centre of the country, but the west coast is much cooler than the east, modified continental conditions prevailing over the North Sea. The natural effect of the heating of the air in summer and the cooling of the air in winter by contact with the land is largely masked in England on account of the strength of the prevailing south-westerly wind carrying oceanic influence into the heart of the country. This effect is well seen in the way in which the wind blowing directly up the Severn estuary is directed along the edges of the Oolitic escarpment north-eastward, thus displacing the centre of cold in winter to the east coast, and the centre of heat in summer to the lower Thames, from the normal position of both centres in a narrow strip running from Birmingham to Buckingham. As to how far the narrow portion of the North Sea modifies the influence of the European continent, there seems reason to believe that the prevailing winds blowing up the English Channel carry oceanic conditions some distance inland, along those parts of the Continent nearest to England. The Mersey estuary, being partly sheltered by Ireland and North Wales, does not serve as an inlet for modifying influences to the same extent as the Bristol Channel; and as the wind entering by it blows squarely against the slope of the Pennine Chain, it does not much affect the climate of the central plain.

Winds.—The average barometric pressure over England is about 29·940 inches, and normally diminishes from south-west to north-east at all seasons, the mean pressure on the south coast being 29·970, and that on the northern border 29·880. The pressure at any given latitude is normally highest in the centre of the country and on the east coast, and lowest on the west coast. The direction of the mean annual isobars shows that the normal wind in all parts of England and Wales must be from the south-west on the west coast, curving gradually until in the centre of the country, and on the east coast it is westerly, without a southerly component. The normal seasonal march of pressure-change produces a maximum gradient in December and January, and a minimum gradient in April; but for every month in the year the gradient is for winds from southerly and westerly quarters. In April the gradient is so slight that any temporary fall of pressure to the south of England, or any temporary rise of pressure to the north, which would suffice in other months merely to reduce the velocity of the south-westerly wind, is sufficient in that month to reverse the gradient and produce an east wind over the whole country. The liability to east wind in spring is one of the most marked features of the English climate, the effect being naturally most felt on the east coast. The southerly component in the wind is as a rule most marked in the winter months, the westerly component predominating in summer. The west end of a town receives the wind as it blows in fresh from the country at all seasons, and consequently the west end of an English town is with few exceptions the residential quarter, while smoke-producing industries are usually relegated to the east end.

Storms.—On account of the great frequency of cyclones passing in from the Atlantic, the average conditions of wind over the British Islands give no idea of the frequency of change in the direction and force of the wind. The chief cyclone paths are from south-west to north-east across England; one track runs across the south-east and eastern counties, and is that followed by a large proportion of the summer and autumn storms, thereby perhaps helping to explain the peculiar liability of the east of England to damage from hail accompanying thunderstorms. A second track crosses central England, entering by the Severn estuary and leaving by the Humber or the Wash; while a third crosses the north of England from the neighbourhood of Morecambe Bay to the Tyne. While these are tracks frequently followed by the centres of barometric depressions, individual cyclones may and do cross the country in all directions, though it is very rarely indeed that they move from east to west or from north to south.

Rainfall.—The rainfall of England, being largely due to passing cyclones, cannot be expected to show a very close relation to the physical features of the country, but looked at in a general way the relation between prevailing winds and orographic structure is not obscure. The western or mountainous division is the wettest at all seasons, each orographic group forming a centre of heavy precipitation. There are few places in the Western Division where the rainfall is less than 35 inches, while in Wales, the Cornwall-Devon peninsula, the Lake District, and the southern part of the Pennine Chain the precipitation exceeds 40 inches, and in Wales and the Lake District considerable areas have a rainfall of over 60 inches. In the Eastern Division, on the other hand, an annual rainfall exceeding 30 inches is rare, and in the low ground about the mouth of the Thames estuary and around the Wash the mean annual rainfall is less than 25 inches. In the Western Division and along the south coast the driest month is usually April or May, while in the Eastern Division it is February or March. The wettest month for most parts of England is October, the most noticeable exception being in East Anglia, where July is the month in which most rain falls, although October is not far behind. In the Western Division there is a tendency for the annual maximum of rainfall to occur later than October. It may be stated generally that the Western Division is mild and wet in winter, and cool and less wet in summer; while the Eastern Division is cold and dry in winter and spring, and hot and less dry in summer and autumn. The south coast occupies an intermediate position between the two as regards climate. Attention has been called to the fact that the bare rocks and steep gradients which are common in the Western Division allow of the heavy rainfall running off the surface rapidly, while the flat and often clayey lands of the Eastern Division retain the scantier rainfall in the soil for a longer time, so that for agricultural purposes the effect of the rainfall is not very dissimilar throughout the country.

Sunshine.—The distribution of sunshine is not yet fully investigated, but it appears that the sunniest part is the extreme south coast, where alone the total number of hours of bright sunshine reaches an average of 1600 per annum. The north-east, including the Pennine Chain and the whole of Yorkshire, has less than 1300 hours of sunshine, and a portion of North Wales is equally cloudy. Although little more than a guess, 1375 hours may be put down as approximately the average duration of bright sunshine for England as a whole, which may be compared with 2600 hours for Italy, and probably about 1200 hours for Norway.

For the purpose of forecasting the weather, the Meteorological Office divides England into six districts, which are known as England N.E., Midland Counties, England East, London and Channel, England N.W. and North Wales, and England S.W. and South Wales.

The western division.

Natural Divisions.—The four prominent groups of high land rising from the plain of the Red Rocks are: (1) the *Lake District*, bounded by the Solway Firth, Morecambe Bay, and the valleys of the Eden and the Lune; (2) the *Pennine Chain*, which stretches from the Scottish border to the centre of England, running due south; (3) *Wales*, occupying the peninsula between the Mersey and the Bristol Channel, and extending beyond the political boundaries of the principality to include Shropshire and Hereford; and (4) the peninsula of *Cornwall and Devon*. They are all similar in the great features of their land-forms, which have been impressed upon them by the prolonged action of atmospheric denudation rather than by the original order and arrangement of the rocks; but each group has its own geological character, which has imparted something of a distinctive individuality to the scenery. Taken as a whole, the Western Division depends for its prosperity on mineral products and manufactures rather than on farming; and the staple of the farmers is live-stock rather than agriculture. The people of the more rugged and remoter groups of this Division are by race survivors of the early Celtic stock, which, being driven by successive invaders from the open and fertile country of the Eastern Division, found refuges in the less inviting but more easily defended lands of the west. Even where, as in the Pennine region and the Lake District, the people have been completely assimilated with the Teutonic stock, they retain a typical character, marked by independence of opinion approaching stubbornness, and by great determination and enterprise.

Lake District.—The Lake District occupies the counties of Cumberland, Westmorland, and North Lancashire. It forms a roughly circular highland area, the drainage lines of which radiate outward from the centre in a series of narrow valleys, the upper parts of which cut deeply into the mountains, and the lower widen into the surrounding plain. Sheets of standing water are still numerous, and formerly almost every valley contained a single long narrow lake-basin; but some of these have been subdivided, drained, or filled up by natural processes. The existing lakes include Windermere and Coniston, draining south; Wastwater, draining south-west, Ennerdale water, Buttermere, and Crummock water (originally one lake, now divided by a delta), draining north-west; Derwent water and Bassenthwaite water (which were probably originally one lake), and Thirlmere, draining north; Ullswater and Haweswater, draining north-east. There are, besides, numerous mountain tarns of small size, most of them in hollows barred by the glacial drift which covers a great part of the district. The central and most picturesque part of the district is formed of great masses of volcanic ashes and tuffs, with intrusions of basalts and granite, all of Ordovician (Lower Silurian) age. Scafell and Scafell Pike (3210 feet and 3162 feet), at the head of Wastwater, and Helvellyn (3118), at the head of Ullswater, are the loftiest amongst many summits the grandeur of whose outlines is not to be estimated by their height. Sedimentary rocks of the same age form a belt to the north, and include Skiddaw (3054 feet); while to the south a belt of Silurian rocks, thickly covered with boulder clay, forms the finely wooded valleys of Coniston and Windermere. Round these central masses of early Palæozoic rocks there is a broken ring of Carboniferous Limestone, and several patches of Coal Measures, while the New Red Sandstone appears as a boundary belt outside the greater part of the district. Where the Coal Measures reach the sea at Whitehaven, there are coal-mines, and the hematite of the Carboniferous Limestones has given rise to the active ironworks of Barrow-in-Furness, now the largest town in the district. Except in the towns of the outer border, the Lake District is very thinly peopled; and from the economic point of view, the remarkable beauty of its scenery, attracting numerous residents and tourists, is the most valuable of its resources. The very heavy rainfall of the district, which is the wettest in England, has led to the utilization of Thirlmere as a reservoir for the water supply of Manchester, over 80 miles distant.

Pennine District.—The Pennine District, the centre of which forms the so-called Pennine Chain, occupies the country from the Eden valley to the North Sea in the north, and from the lower Tees, Yorkshire Ouse, and Trent, nearly to the Irish Sea, in the south. It includes the whole of Northumberland and Durham, the West Riding of Yorkshire, most of Lancashire and Derbyshire the north of Staffordshire, and the west of Nottinghamshire. The Pennine Chain forms a north and south watershed which determines the course of the rivers of the whole of the north. It is entirely composed of Carboniferous rocks, the system which transcends all others in the value of its economic minerals. The coal and iron have made parts of the region the busiest manufacturing districts, and the centres of densest population, in the country, or even in the world. The whole region may be looked upon as formed by an arch or anticline of Carboniferous strata, the axis of which runs north and south; the centre has been worn away by erosion, so that the Coal Measures have been removed, and the underlying Millstone Grit and Carboniferous Limestone exposed to the influences which form scenery. On both sides of the arch, east and west, the Coal Measures remain intact, forming outcrops which disappear towards the sea under the more recent strata of Permian or Triassic age. The northern part of the western side of the anticline is broken off by a great fault in the valley of the Eden, and the scarp thus formed is rendered more abrupt by the presence of a sheet of intrusive basalt. Seen from the valley, this straight line of lofty heights, culminating in Crossfell (2900 feet), presents the nearest approach in England to the appearance of a mountain range. In the north the Pennine region is joined to the Southern Uplands of Scotland by the Cheviot Hills, a mass of granite and Old Red Sandstone; and the northern part is largely traversed by dykes of contemporary volcanic or intrusive rock. The most striking of these dykes is the Great Whin Sill, which crosses the country from a short distance south of Durham almost to the source of the Tees, near Crossfell. The elevated land is divided into three masses by depressions, which furnish ready means of communication between east and west. The South Tyne and Irthing valleys cut off the Cheviots on the north from the Crossfell section, which is also marked off on the south by the valleys of the Aire and Ribble from the Kinderscout or Peak section. The numerous streams of the region carry off the rainfall down long valleys or dales to the east and the south, and by shorter and steeper valleys to the west. The dales are separated from each other by high uplands, which for the most part are heathery moorland or, at best, hill pastures. The agriculture of the region is confined to the bottoms of the dales, and is of small importance. Crossfell and the neighbouring hills are formed from masses of Carboniferous Limestone, which received its popular name of Mountain Limestone from this fact. Farther south, such summits as High Seat, Whernside, Bow Fell, Penyghent, and many others, all over 2000 feet in height, are capped by portions of the Grits and Sandstones, which rest upon the Limestone. The belt of Millstone Grit south of the Aire, lying between the great coal-fields of the North Riding and Lancashire, has a lower elevation, and forms grassy uplands and dales; but farther south, the finest scenery of the whole region occurs in the limestones of Derbyshire, in which the range terminates. The rugged beauty of the south-running valleys, and especially of Dovedale, is enchanced by the rich woods which still clothe the slopes. There are remarkable features underground as well as on the surface, the caverns and subterranean streams of Yorkshire and Derbyshire being amongst the deepest that have yet been explored. Compared with the rugged and picturesque scenery of the Lower Carboniferous rocks, that of the Coal Measures is, as a rule, featureless and monotonous. The coal-fields on the eastern side, from the Tyne nearly to the Trent, are sharply marked off on the east by the outcrop of Permian dolomite or Magnesian limestone, which forms a low terrace dipping towards the east under more recent rocks, and in many places giving rise to an escarpment facing westward towards the gentle slope of the Pennine dales. To the west and south the Coal Measures dip gently under the New Red Sandstone, to reappear at several points through the Triassic plain. The clear water of the upland becks and the plentiful supply of water-power led to the founding of small paper-mills in remote valleys before the days of steam, and many of these primitive establishments still exist. The prosperity and great population of the Pennine region dates from the discovery that pit-coal could smelt iron as well as charcoal; and this source of power once discovered, the people bred in the dales developed a remarkable genius for mechanical invention and commercial enterprise, which revolutionized the economic life of the world and changed England from an agricultural to an industrial country. The staple industry of the district in ancient times was sheep-rearing, and the villages in nearly all the dales carried on a small manufacture of woollen cloth. The introduction of cotton caused the woollen manufactures on the western side to be superseded by the working up of the imported raw material; but woollen manufactures, themselves carried on now almost entirely with imported raw material, have continued to employ the energies of the inhabitants of the east. Some quiet market-towns, such as Skipton and Keighley, remain, but most of them have developed by manufactures into great centres of population, lying, as a rule, at the junction of thickly peopled valleys, and separated from one another by the empty uplands. Such are Leeds, Bradford, Sheffield, Huddersfield, and Halifax on the great and densely peopled West Riding coal-field, which lies on the eastern slope of the Pennines. The iron ores of the Coal Measures have given rise to great manufactures of steel, from cutlery to machinery and armour-plates. High on the barren crest of the Pennines, where the rocks yield no mineral wealth, Harrogate, Buxton, and Matlock are types of health resorts, prosperous from their pure air and fine scenery. Across the moors, on the western side of the anticline, the vast and dense population of the *Lancashire coal-field* is crowded in the manufacturing towns which surround the great commercial centre, Manchester, which itself stands on the edge of the Triassic plain. Ashton, Oldham, Rochdale, Bury, Bolton, and Wigan form a nearly confluent semicircle of great towns, their prosperity founded on the underlying coal and iron, maintained by imported cotton. The Lancashire coal-field, and the portion of the bounding plain between it and the seaport of Liverpool, contains a population greater than that borne by any equal area in the country, the county of London and its surroundings not excepted. In the south-west of the Pennine region the coal-field of North Staffordshire supports the group of small but active towns known collectively from the staple of their trade as "The Potteries." On the north-east the great coal-field of Northumberland and Durham, traversed midway by the Tyne, supports the manufactures of Newcastle and its satellite towns, and leaves a great surplus for export from the Tyne ports.

Wales.—The low island of Anglesea, which is built up of the fundamental Archæan rocks, is important as a link in the main line of communication with Ireland, because it is separated from the mainland by a channel narrow enough to be bridged, and lies not far out of the straight line joining London and Dublin. The mainland of Wales rises into three main highlands, the mountain groups of North, Mid, and South Wales, connected together by land over 1000 feet in elevation in most places; but separated by valleys forming easy highways. The streams of the southern and western slopes are short and many, flowing directly to the Bristol Channel and the Irish Sea; but the no less numerous streams of the eastern slopes gather themselves into three river systems, and reach the sea as the Dee, the Severn, and the Wye. The mountain group of *North Wales* is the largest and loftiest; its scenery resembles that of the Scottish Highlands because of the juxtaposition of ancient Palæozoic rocks—Cambrian and Ordovician, often altered into slate—and contemporaneous volcanic outbursts and igneous intrusions. Here rises the peak of Snowdon (3560 feet), the culminating point of South Britain, and near it half a dozen summits exceed 3000 feet, while Cader Idris, farther south, though slightly lower, presents a singularly imposing outline. The mild winter climate has fringed the coast with seaside resorts; the rugged heights attract tourists in summer, and the vast masses of slate have given rise to the largest slate quarries in the world. The heavy rainfall of the upper valleys unfits them for agriculture, and the farms are poor. There are several lakes: that of Bala being the largest, except the old lake of Vyrnwy, reconstituted artificially to store the rainfall for the water supply of Liverpool, 68 miles distant. The Vyrnwy is tributary to the Severn; but north of it the streams gather into the Dee, and flow eventually northward. *Mid Wales* is built up, for the most part, of Silurian or Ordovician rocks, practically free from igneous intrusions except in the south-west. There the resistance of a series of igneous dykes gives prominence to the Pembroke peninsula, in which the fine fjord-like harbour of Milford Haven lies far out towards the Atlantic. The coast north of Pembroke and Merioneth has been worked into the grand sweep of Cardigan Bay, its surface carved into gently rounded hills, green with rich grass, which sweep downward into wide rounded valleys. Plynlymmon (2468 feet) is the highest of the hills, and forms a sort of hydrographic centre for the group, as from its eastern base the Severn and the Wye take their rise—the former describing a wide curve to east and south, the latter forming a chord to the arc in its southward course. Mid Wales is mainly a pastoral country, and very thinly peopled. The group of heights of *South Wales*, running on the whole from west to east, marks the outcrops of the Old Red Sandstone and Carboniferous strata which lie within a vast syncline of the Silurian rocks. The Brecon Beacons of Old Red Sandstone are the highest (2907 feet), but the Black Mountain bears a number of picturesque peaks carved out of Millstone Grit and Carboniferous Limestone, which rise frequently to over 2000 feet. Throughout Hereford, and in part of Monmouthshire, the Old Red Sandstone sinks to a great undulating plain, traversed by the exquisite windings of the Wye, and forming some of the richest pasture and fruit lands of England. This plain formed an easy passage from south to north, and since the time of the Romans was a strategical line of the greatest importance, a fact which has left its traces on the present distribution of towns. Around the western and northern edge of the Old Red Sandstone plain the underlying Silurian rocks (and even the Cambrian and Archæan in places) have been bent up so that their edges form hills of singular abruptness and beauty. Of these are the Malvern Hills, east of Hereford, and in particular the hills of Shropshire. Wenlock Edge, running from south-west to north-east, is an escarpment of Silurian limestone, while the broad upland of Long Mynd, nearly parallel to it on the north, is a mass of Archæan rock. The Wrekin, the Caradoc and Cardington Hills, are isolated outbursts of pre-Cambrian volcanic rocks. The outer rim of the Welsh area contains a broken series of coal-fields, where patches of Carboniferous strata come to the surface on the edge of the New Red Sandstone plain. Such are the coal-fields of Flint in the north, the Forest of Wyre and the Forest of Dean, close to the Severn, on the east. The great coal-field on the south is a perfect example of a synclinal basin, the Millstone Grit and Carboniferous Limestone which underlie the Coal Measures appearing all round the margin. This coal-field occupies practically the whole of Glamorgan and part of Monmouth, and its surface slopes from the Black Mountain and Brecon Beacons to the sea as a gently inclined plateau, scored by deep valleys draining south. Each chief valley has a railway connecting a string of mining villages, and converging seaward to the busy ports of Newport, Cardiff, and Barry Dock (a town created on a sandy island to form an outlet for the mines). In the north of the field, where the limestone crops out and supplies the necessary flux, Merthyr Tydfil has become great through iron-smelting; and in the west Swansea is the chief centre in the world for copper and tin smelting. The unity and ruggedness of the highlands of Wales have proved sufficient to isolate the people from those of the rest of South Britain, and to preserve a purely Celtic race, still very largely of Celtic speech.

Cornwall and Devon.—The peninsula of Cornwall and Devon may be looked upon as formed from a synclinal trough of Devonian rocks, which appear as plateaux on the north and south, while the centre is occupied by Lower Carboniferous strata at a lower level. The northern coast, bordering the Bristol Channel, is steep, with picturesque cliffs and deep bays or short valleys running into the high land, each occupied by a little seaside town or village. The plateau culminates in the barren heathy upland of Exmoor, which slopes gently southward from an elevation of

1600 feet, and is almost without inhabitants. The Carboniferous rocks of the centre form a soil which produces rich pasture under the heavy rainfall and remarkably mild and equable temperature, forming a great cattle-raising district. The Devonian strata on the south do not form such lofty elevations as those on the north, and are in consequence, like the plain of Hereford, very fertile and peculiarly adapted for fruit-growing and cider-making. The remarkable features of the scenery of South Devon and Cornwall are due to a narrow band of Archæan rock which appears in the south of the peninsulas terminating in Lizard Head and Start Point, and to huge masses of granite and other eruptive rocks which form a series of great bosses and dykes. The largest granite boss forms the wild upland of Dartmoor, culminating in Yes Tor at 2000 feet. The clay resulting from the weathering of the granite has formed marshes and peat bogs, and the desolation of the district has been emphasized by the establishment in its midst of a great convict prison. The Tamar flows from north to south on the Devonian plain, which lies between Dartmoor on the east and the similar granitic boss of Bodmin Moor (where Brown Willy rises to 1345 feet) on the west. There are several smaller granite bosses, of which the mass of Land's End is the most important. Most of the Lizard peninsula, the only part of England stretching south of 50° N., is a mass of serpentine. The great variety of the rocks which meet the sea along the south of Cornwall and Devon has led to the formation of a singularly picturesque coast—the headlands being carved from the hardest igneous rocks, the bays cut back in the softer Devonian strata. The fjord-like inlets of Falmouth, Plymouth, and Dartmouth are splendid natural harbours, which would have developed great commercial towns but for their remoteness from the centres of commerce and manufactures. China clay from the decomposing granites; tin and copper ore, once abounding at the contacts between the granite and the rocks it pierced, were the former staples of wealth, and the mining largely accounts for the exceptional density of population in Cornwall. Fishing has always been important, the numerous good harbours giving security to fishing-boats; and the fact that this coast is the mildest and almost the sunniest, though by no means the driest, part of Great Britain has led to the establishment of many health resorts, of which Torquay is the chief. The old Cornish language of the Celtic stock became extinct only in the 18th century, and the Cornish character remains as a heritage of the time when the land had leisure to mould the life and the habits of the man. Projecting farthest of all England into the Atlantic, it is not surprising that the West country has supplied a large proportion of the great naval commanders in British history, and of the crews of the navy.

The central plain.

Between the separate uplands there extends a plain of Permian and Triassic rocks, which may conveniently be considered as an intermediate zone between the two main divisions. To the eye it forms an almost continuous plain with the belt of Lias clays, which is the outer border of the Eastern Division; for although a low escarpment marks the line of junction, and seems to influence the direction of the main rivers, there is only one plain so far as regards free movement over its surface, and the construction of canals, roads, and railways. The plain usually forms a distinct border along the landward margins of the uplands of more ancient rock, though to the east of the Cornwall-Devon peninsula it is not very clear, and its continuity in other places is broken by inliers of the more ancient rocks, which everywhere underlie it. One such outcrop of Carboniferous Limestone in the south forms the Mendip Hills; another of the Coal Measures increases the importance of Bristol, where it stands at the head of navigation on the southern Avon. In the north-west a tongue of the Red rocks forms the Eden valley, separating the Lake District from the Pennine Chain, with Carlisle as its central town. Farther south, these rocks form the low coastal belt of Lancashire, edged with the longest stretches of blown sand in England, and dotted here and there by pleasure towns, like Blackpool and Southport. The plain sweeps round south of the Lancashire coal-field, forms the valley of the Mersey from Stockton to the sea, and farther south in Cheshire the salt-bearing beds of the Keuper marls give rise to a characteristic industry. The plain extends through Staffordshire and Worcester, forming the lower valley of the Severn. The greater part of Manchester, all Liverpool and Birkenhead, and innumerable busy towns of medium size, which in other parts of England would rank as great centres of population, stand on this soil. Its flat surface and low level facilitate the construction of railways and canals, which form a closer network over it than in other parts of the country. The great junction of Crewe, where railways from south-east, south-west, east, west, and north converge, is thus explained. South of the Pennines, the Red rocks extend eastward in a great sweep through the south of Derbyshire, Warwick, the west of Leicestershire, and the east of Nottingham, their margin being approximately marked by the Avon, flowing south-west, and the Soar and Trent, flowing north-east. South and east of these streams the very similar country is on the Lias clay. Several small coal-fields rise through the Red rocks—the largest, between Stafford and Birmingham, forms the famous "Black Country," with Wolverhampton and Dudley as centres, where the manufacture of iron has preserved a historic continuity, for the great Forest of Arden supplied charcoal until the new fuel from the pits took its place. This coal-field, ministering to the multifarious metal manufactures of Birmingham, constitutes the centre of the Midlands. Smaller patches of the Coal Measures appear near Tamworth and Burton, while deep shafts have been sunk in many places through the overlying Triassic strata to the coal below, thus extending the mining and manufacturing area beyond the actual outcrop of the Coal Measures. A few small outcrops occur where still more ancient strata have been raised to the surface, as, for instance, in Charnwood Forest, where the Archæan rocks, with intrusions of granite, create a patch of highland scenery in the very heart of the English plain; and in the Lickey Hills, near Birmingham, where the prominent features are due to volcanic rocks of very ancient date. The "Waterstones," or Lower Keuper Sandstones,—forming gentle elevations above the softer marls, and usually charged with an abundant supply of water, which can be reached by wells,—form the site of many towns, such as Birmingham, Warwick, and Lichfield, and of very numerous villages. The plain as a whole is fertile and undulated, rich in woods and richer in pasture: the very heart of rural England. Cattle-grazing is the chief farm industry in the west, sheep and horse-rearing in the east; the prevalence of the prefix "Market" in the names of the rural towns is noticeable in this respect. The manufacture of woollen and leather goods is a natural result of the raising of live stock; Leicester, Coventry, and Nottingham are manufacturing towns of the region. The historic castles, the sites of ancient battles, and the innumerable mansions of the wealthy, combine to give to Central England a certain æsthetic interest which the more purely manufacturing districts of the west and north fail to inspire. The central plain curves northward between the outcrop of the Dolomite on the west and the Oolitic heights on the east. It sinks lowest where the estuary of the Humber gathers in its main tributaries, and the greater part of the surface is covered with recent alluvial deposits. The Trent runs north in the southern half of this plain, the Ouse runs south through the northern half, which is known as the Vale of York, lying low between the Pennine heights on the west and the Yorkshire moors on the east. Where the plain reaches the sea, the soft rocks are cut back into the estuary of the Tees, and there Middlesbrough stands at the base of the Moors. The quiet beauty of the rural country in the south, where the barren Bunter pebble-beds have never invited agriculture, and where considerable vestiges of the old woodland still remain in and near Sherwood Forest, has attracted so many seats of the landed aristocracy as to earn for that part the familiar name of "the Dukeries." The central position of York in the north made it the capital of Roman Britain in ancient times, and an important railway junction in our own.

The eastern division.

Five natural regions may be distinguished in the Eastern Division of England, by no means so sharply marked off as those of the west, but nevertheless quite clearly characterized. The first is the Jurassic Belt, sweeping along the border of the Triassic plain from the south coast at the mouth of the Exe to the east coast at the mouth of the Tees. This is closely followed on the south-east by the Chalk country, occupying the whole of the rest of England except where the Tertiary Basins of London and Hampshire cover it, where the depression of the Fenland carries it out of sight, and where the lower rocks of the Weald break through it. Thus the Chalk appears to run in four diverging fingers from the centre or palm on Salisbury Plain, other formations lying wedge-like between them. Various lines of reasoning unite in proving that the Mesozoic rocks of the south rest upon a mass of Palæozoic rocks, which lies at no very great depth beneath the surface of the anticlinal axis that runs from the Bristol Channel to the Strait of Dover. The theoretical conclusion has been confirmed by the discovery of Coal Measures, with workable coal seams, at Dover at a depth of 2000 feet below the surface.

The Eastern Division is built up of parallel strata, the edges of the harder rocks forming escarpments, the sheets of clay forming plains; and on this account similar features are repeated in each of the successive geological formations. The rivers exhibit a remarkably close relation to the geological structure, and thus contrast with the rivers of the Western Division. There are two main classes of rivercourse—those flowing down the dip-slopes at right angles to the strike, and cutting through opposed escarpments by deep valleys, and those following the line of strike along a bed of easily eroded rock. A third class of streams, tributary to the second, flows down the steep face of the escarpments. By the study of the adjustment of these rivers to their valleys, and of the relation of the valleys to the general structure, Professor W. M. Davis has elaborated a theory of river classification, and a scheme of the origin of surface-features which is attractive in its simplicity. The Thames is the one great river of the division, rising on the Jurassic Belt, crossing the Chalk country, and finishing its course in the Tertiary London Basin, towards which, in its prevailing west-to-east direction, it draws its tributaries from north and south. The other rivers are shorter, and flow either to the North Sea on the east, or to the English Channel on the south. With the exception of the Humber, they all rise and pursue their whole course within the limits of the Eastern Division itself.

The Eastern Division is the richest part of England agriculturally, it is the part most accessible to trade with the Continent, and that least adapted for providing refuges for small bodies of men in conflict with powerful invaders. Hence the latest of the conquerors, the Saxon and other Germanic tribes, obtained an easy mastery, and spread over the whole country, holding their own against marauding Northmen, except on the northern part of the east coast; and even after the political conquest by the Normans, continuing to form the great mass of the population, though influenced not a little by the fresh blood and new ideas they had assimilated. The present population is so distributed as to show remarkable dependence on the physical features. The chalk and limestone plateaux are usually almost without inhabitants, and the villages of these districts occur grouped together in long strings, either in drift-floored valleys in the calcareous plateaux, or along the exposure of some favoured stratum at their base. In almost every case the plain along the foot of an escarpment bears a line of villages and small towns, and on a good map of density of population the lines of the geological map may be readily discerned.[1]

The Jurassic Belt.—The Jurassic belt is occupied by the counties of Gloucester, Oxford, Buckingham, Bedford, Northampton, Huntingdon, Rutland, Lincoln, and the North Riding of Yorkshire. The rocks of the belt may be divided into two main groups: the Lias beds, which come next to the Triassic plain, and the Oolitic beds. Each group is made up of an alternation of soft marls or clays and hard limestones or sandstones. The low escarpments of the harder beds of the Lias are the real, though often scarcely perceptible, boundary between the Triassic plain and the Jurassic belt. They run along the right bank of the Trent in its northward course to the Humber, and similarly direct the course of the Avon southward to the Severn. The great feature of the region is the long line of the Oolitic escarpment, formed in different places by the edges of different beds of rock. The escarpment runs north from Portland Island on the English Channel, curves north-eastward as the Cotswold Hills, rising abruptly from the Severn plain to heights of over 1000 feet; it sinks to insignificance in the Midland counties, is again clearly marked in Lincolnshire, and rises in the North Yorkshire moors to its maximum height of over 1500 feet. Steep towards the west, where it overlooks the low Lias plain as the Oolitic escarpment, the land falls very gently in slopes of Oxford Clay towards the Cretaceous escarpments on the south and east. Throughout its whole extent it yields valuable building stone, and in the Yorkshire moors the great abundance of iron ore has created the prosperity of Middlesbrough, on the plain below. The Lias plain is rich grazing country, the Oxford Clay forms valuable agricultural land, yielding heavy crops of wheat. The towns of the belt are comparatively small, not one attains a population of 75,000, and the favourite site is on the Lias plain below the great escarpment. They are for the most part typical rural market-towns, the manufactures, where such exist, being usually of agricultural machinery, or woollen and leather goods. Bath, Gloucester, Oxford, Northampton, Bedford, Rugby, Lincoln, and Scarborough are amongst the chief. North of the gap in the low escarpment in which the town of Lincoln stands, a close fringe of villages borders the escarpment on the west; and throughout the belt the alternations of clay and hard rock are reflected in the grouping of population.

The Chalk Country.—The dominating surface-feature formed by the Cretaceous rocks is the Chalk escarpment, the northern edge of the great sheet of chalk that once spread continuously over the whole south-east. It appears as a series of rounded hills of no great elevation running in a curve from the mouth of the Axe to Flamborough Head, roughly parallel with the Oolitic escarpment. Successive portions of this line of heights are known as the Dorset Downs, the Marlborough Downs, the Chiltern Hills, the East Anglian Heights, the Lincolnshire Wolds, and the Yorkshire Wolds. The rivers from the gentle southern slopes of the Oolitic heights pass by deep valleys through the Chalk escarpments, and flow on to the Tertiary plains within. The typical scenery of the Chalk country everywhere is unrelieved by small streams of running water; the hills rise into rounded downs, often capped with fine clumps of beech, and usually covered with thin turf, affording pasture for sheep. The chalk, when exposed on the surface, is an excellent foundation for roads, and the lines of many of the Roman roads were probably determined by this fact. The Chalk country extends over part of Dorset, most of Wiltshire, a considerable portion of Hampshire and Oxfordshire, most of Hertfordshire and Cambridgeshire, the west of Norfolk and Suffolk, the east of Lincoln, and the East Riding of Yorkshire. From the upland of Salisbury Plain, which corresponds to the axis of the anticline marking the centre of the double fold into which the strata of the south of England have been thrown, the great Chalk escarpment runs north-eastward; fingers of Chalk run eastward on each side of the Weald, forming the North and South Downs, while the southern edge of the Chalk sheet appears from beneath the Tertiary strata at several places on the south coast, and especially in the Isle of Wight. Flamborough Head, the South Foreland, Beachy Head, and the Needles are examples of the fine scenery into which chalk weathers where it fronts the sea, and these white cliffs gave to the island its early name of Albion. The Chalk is everywhere very thinly peopled, except where it is thickly covered with boulder clay, and so becomes fertile, or where it is scored by drift-filled valleys, in which the small towns and villages are dotted along the high roads. The thickest covering of drift is found in the Holderness district of Yorkshire, where, from the chalk cliffs of Flamborough Head to the sandspit of Spurn Point, the whole coast is formed of boulder-clay resting on chalk. Of the few towns in the Chalk country, the interest of which is largely historical or scholastic, Salisbury, Winchester, Marlborough, and Cambridge are the most distinguished. Reading flourishes from its position on the edge of the London Tertiary Basin, Croydon is a suburb of London, and Hull, though on the Chalk, derives its importance from the Humber estuary, which cuts through the Chalk and the Jurassic belts, to drain the Triassic plain and the Pennine region. The narrow strip of Greensands appearing from beneath the Chalk escarpment on its northern side is crowded with small towns and villages on account of the plentiful water supply.

The Weald.—The dissection of the great east and west anticline in the south-east of England has resulted in a remarkable piece of country, occupying the east of Hampshire and practically the whole of Sussex, Surrey, and Kent, in which each geological stratum produces its own type of scenery, and exercises its own specific influence on every natural distribution. The sheet of Chalk shows its cut edges in the escarpments facing the centre of the Weald, and surrounding it in an oval ring, the eastern end of which is broken by the Strait of Dover, so that its completion must be sought in France. From the crest of the escarpment, all round on south, west, and north, the dip-slope of the Chalk forms a gentle descent outwards, the escarpment a very steep slope inwards. The cut edges of the escarpment forming the Hog's Back and North Downs on the north, and the South Downs on the south, meet the sea in the fine promontories of the South Foreland and Beachy Head. The Downs are almost without population, waterless and grass-covered, with patches of beech wood. Their only important towns are on the coast, *e.g.*, Brighton, Eastbourne, Dover, Chatham, or in the gaps where rivers from the centre pierce the Chalk ring, as at Guildford, Rochester, Canterbury, Lewes, and Arundel. Within the Chalk ring, and at the base of the steep escarpment, there is a low terrace of the Upper Greensand, seldom so much as a mile in width, but in most places crowded with villages scarcely more than a mile apart, and ranged like beads on a necklace. Within the Upper Greensand an equally narrow ring of Gault is exposed, its stiff clay forming level plains of grazing pasture, without villages, and with few farmhouses even; and from beneath it the successive beds of the Lower Greensand rise towards the centre, forming a wider belt, and reaching a considerable height before breaking off in a fine escarpment, the crest of which is in several points higher than the outer ring of Chalk. Leith Hill and Hindhead are parts of this edge in the west, where the exposure is widest. Several towns have originated in the gaps of the Lower Greensand escarpment which are continuous with those through the Chalk: such are Dorking, Reigate, Maidstone, and Ashford. Folkestone and Pevensey stand where the two ends of the broken ring meet the sea. It is largely a region of oak and pine trees, in contrast to the beech of the Chalk Downs. The Lower Greensand escarpment looks inwards in its turn over the wide plain of Weald Clay, along which the Medway flows in the north, and which forms a fertile soil, well cultivated, and particularly rich in hops and wheat. The primitive forests have been largely cleared, the primitive marshes have all been drained, and now the Weald Clay district is fairly well peopled and sprinkled with villages. From the middle of this plain the core of Lower Cretaceous sandstones, known as the Hastings Beds, emerges steeply, and reaches in the centre an elevation of 796 feet at Crowborough Beacon. It is on the whole a region with few streams, and a considerable portion of the ancient woodland still remains in Ashdown Forest. The greater part of the area is almost without inhabitants. Towns are found only round the edge bordering the Weald Clay, such as Tonbridge, Tunbridge Wells, and Horsham; and along the line where it is cut off by the sea, *e.g.*, Hastings and St Leonards. The broad low tongue of Romney Marsh running

[1] See F. Bosse's Map of Density of Population in Bartholomew's "Handy Royal Atlas of England." London (Newnes), 1899.

out to Dungeness is a product of shore building by the Channel tides, attached to the Wealden area, but not essentially part of it.

The London Basin.—The London Basin occupies a triangular depression in the Chalk which is filled up with clays and gravels of Tertiary and later age. It extends from the eastern extremity of Wiltshire in a widening triangle to the sea, which it meets along an irregular line from Deal to Cromer. It thus occupies parts of Wiltshire, Hampshire, Surrey, Kent, Berkshire, Hertfordshire, the whole of Middlesex, the county of London and Essex, and the eastern edge of Suffolk and Norfolk. The scenery is quiet in its character, but the gravel hills are often prominent features, as at Harrow and in the northern suburbs of London; the country is well cultivated, and many parts, of which Epping Forest is a fine example, are still densely wooded, the oak being the prevailing tree. The coast is everywhere low and deeply indented by ragged and shallow estuaries, that of the Thames being the largest. Shallow lagoons formed along the lower courses of the rivers of Norfolk have given to that part of the country the name of the Broads, a district of low and nearly level land. Apart from the huge area of urban and suburban London, the London Basin has few large towns. Norwich and Ipswich, Yarmouth, Harwich, and Colchester may be mentioned in the north-eastern part, all depending for their prosperity on agriculture or on the sea; and a fringe of summer resorts on the low coast has arisen on account of the bracing climate. Reading and Windsor lie in the western portion, beyond the suburban sphere of London. The Bagshot Beds in the west form infertile tracts of sandy soil, covered with heath and pine, where space is available for the great camps and military training grounds round Aldershot, and for the extensive cemeteries at Woking. The London Clay in the east is more fertile and crowded with villages, while the East Anglian portion of the basin consists of the more recent Pliocene sands and gravels, which mix with the boulder clay to form the best wheat-growing soil in the country.

The Hampshire Basin.—The Hampshire Basin forms a triangle with Dorchester, Salisbury, and Worthing near the angles, and the rim of Chalk to the south appears in broken fragments in the Isle of Purbeck, the Isle of Wight, and to the east of Bognor. On the infertile Bagshot Beds the large area of the New Forest remains untilled under its ancient oaks. The London Clay of the east is more fertile, but the greatness of this district lies in its coast-line, which is deeply indented, like that of the London Basin. Southampton and Portsmouth have gained importance through their fine natural harbours, improved by engineering works and fortifications; Bournemouth and Bognor, from their favourable position in the sunniest belt of the country, as health resorts.

The Fenland.—The continuity of the belts of Chalk and of the Middle and Upper Oolites is broken by the shallow depression of the Wash and the Fenland. The Fenland comprises a strip of Norfolk, a considerable part of Cambridgeshire, and the Holland district of Lincoln. Formerly a great inlet with vague borders of lagoons and marshes, the Fenland has been reclaimed partly by natural processes, partly by engineering works patiently continued for centuries. The whole district is flat and low, for the most part within 15 feet of sea-level; the seaward edge in many places is below the level of high tide, and is protected by dykes as in Holland, while straight canals and ditches carry the sluggish drainage from the land. The soil is composed for the most part of silt and peat. A few small elevations of gravel, or of underlying formations, rise above the level of 25 feet; these were in former times islands, and now they form the sites of the infrequent villages. Boston and King's Lynn are memorials of the maritime importance of the Wash in the days of small ships. The numerous ancient churches and the cathedrals of Ely and Peterborough bear evidence to the share taken by religious communities in the reclamation and cultivation of the land.

Communications.—The configuration of England, while sufficiently pronounced to allow of the division of the country into natural regions, is not strongly enough marked to exercise any very great influence upon lines of communication. The navigable rivers are all connected by barge-canals, even across the Pennine Chain. Although the waterways are much neglected, compared with those of France or of Germany, they could easily be made very useful if they were developed by free competition with railways. The main roads developed as arteries of intercommunication by the Romans, suffered to fall into neglect, and revived in the coaching days of the beginning of the 19th century, fell into a second period of comparative neglect when the railway system was completed; but they are now recovering a considerable share of their old importance in consequence of the development of cycling and the use of motor-cars. Following the Roman roads, the high roads of the Eastern Division very frequently run along the crests of ridges or escarpments; but in the Western Division they are, as a rule, forced by the more commanding relief of the country to keep to the river valleys and cross the rougher districts through the dales and passes.

General.

The railways themselves, radiating from the great centres of population, and especially from London, are only in a few instances much affected by configuration. The Pennine Chain has always separated the traffic from south to north into an east coast route through the Vale of York, and a west coast route by the Lancashire plain. The Midland Railway, running through the high and rugged country between the two, was the last to be constructed. The most notable bridges over navigable water affording continuous routes are those across Menai Strait, the Tyne at Newcastle, the Severn at Severn Bridge, and the Manchester Ship Canal. It is more usual to tunnel under such channels, and the numerous Thames tunnels, the Mersey tunnel between Liverpool and Birkenhead, and the Severn tunnel, the longest in the British Islands (4½ miles), on the routes from London to South Wales, and from Bristol to the north of England, are all important. The Humber estuary is neither bridged nor tunnelled below Goole.

Density of Population.—The present distribution of population over England and Wales shows a dense concentration at all large seaports, in the neighbourhood of London, and on the coal-fields where manufactures are carried on. Agricultural areas are very thinly peopled; purely pastoral districts can hardly be said to have any settled population at all. There are very few dwellings situated at a higher level than 1000 feet, and on the lower ground the Chalk and the Oolitic limestones, where they crop out on the surface, are very thinly peopled, and so as a rule are areas of alluvial deposits and the Tertiary sands. But, on the other hand, the broad clay plains of all formations, and the Triassic plain, are peopled more densely than any other districts without mineral wealth or sea trade.

Political Divisions.—In the partition of England and Wales into counties, physical features play but a small part. The forty ancient counties, remnants of various historical groupings and partings, are occasionally bounded by rivers. Thus the Thames divides counties along nearly its whole length, forming the southern boundary of four and the northern boundary of three. Essex and Suffolk, Suffolk and Norfolk, Cornwall and Devon, Durham and Yorkshire, Lancashire and Cheshire, are all separated by rivers, while rivers form some part of the boundaries of almost every county. Still, it is noteworthy that the Severn and Trent nowhere form continuous county boundaries. Watersheds are rarely used as boundaries for any distance; but, although slightly overlapping the watershed on all sides, Yorkshire is very nearly coincident with the basin of the Ouse. The boundaries of the parishes, the fundamental units of English political geography, are very often either rivers or watersheds, and they frequently show a close relation to the strike of the geological strata. The hundreds, or groups of parishes, necessarily share their boundaries, and groups of hundreds are often aggregated to form larger subdivisions of counties. A wide grouping according to natural characteristics may be recognized still only in the cases of Wales, East Anglia, Wessex, and such less definite groups as the Home Counties around London, or the Midlands around Birmingham. Configuration is only one out of many conditions modifying distributions, and its effects on England as a whole appear to be suggestive rather than determinative.

For detailed descriptions of parts of England and Wales, see the articles on individual counties, towns, rivers, etc. For more general references, see EUROPE, GEOLOGY, METEOROLOGY.

AUTHORITIES.—A. J. JUKES-BROWN. *The Building of the British Islands.* London, 1888.—SIR A. C. RAMSAY. *Physical Geography and Geology of Great Britain.* Edited by H. B. Woodward. London, 1894.—SIR A. GEIKIE. *Geological Map of England and Wales* (scale, 10 miles to 1 inch). Edinburgh, 1897.—E. RECLUS, *Universal Geography*, vol. iv. *The British Isles.* Edited by E. G. Ravenstein. London, 1880.—G. G. CHISHOLM. "On the Distribution of Towns and Villages in England," in *Geographical Journal*, vol. ix. (1897), pp. 76–87; vol. x. (1897), pp. 511–530.—A. HAVILAND. *The Geographical Distribution of Disease in Great Britain.* London, 1892.—A. BUCHAN. "The Mean Atmospheric Temperature and Pressure of the British Islands" (with maps), *Journal of the Scottish Meteorological Society*, vol. xi. (1898), pp. 3–41.—W. M. DAVIS. "The Development of Certain English Rivers," *Geographical Journal*, vol. v. (1895), pp. 127–148.

(H. R. M.)

II. STATISTICS.

Area and Population.

The area of England and Wales, exclusive of 840,448 acres of tidal water and foreshore, consists of 37,317,885 acres or 58,309 square miles, 37,106,272 acres or 57,979 square miles being land, and 216,613 acres or 330 square miles being water. The population at the date of the census of March 31, 1901, was returned (preliminary report) at 32,526,075. The increase since 1871, and the decennial rate of increase, are shown in the following table :—

Date of Enumeration.	Population.	Decennial Increase.	Decennial Increase per cent.
1871, April 3	22,712,266	2,646,042	13·20
1881, April 4	25,974,439	3,262,173	14·36
1891, April 6	29,002,525	3,028,086	11·65
1901, March 31	32,526,075	3,523,550	12·17

The increase of population took place chiefly in the commercial centres and in the industrial and mining districts, there having been little or no increase, or even in some places in the west of England and in North Wales a considerable decrease, of the agricultural population. The following table shows the population of each of the eleven registration divisions of England and Wales in 1891 and 1901, and the increase per cent. in the intercensal period :—

Registration Divisions.	Population.		Increase per cent.
	1891.	1901.	1891–1901.
I. London	4,228,317	4,536,063	7·2
II. S.E. counties (Surrey, Kent, Sussex, Hampshire, Berkshire)	2,867,078	3,312,163	15·5
III. S. Midland (Middlesex, Hertfordshire, Buckinghamshire, Oxfordshire, Northamptonshire, Huntingdonshire, Bedfordshire, Cambridgeshire)	1,847,309	2,181,105	18·1
IV. Eastern (Essex, Suffolk, Norfolk)	1,575,311	1,891,922	20·1
V. S.W. (Wiltshire, Dorsetshire, Devonshire, Cornwall, Somersetshire)	1,855,262	1,913,082	3·1
VI. W. Midland (Gloucestershire, Herefordshire, Shropshire, Staffordshire, Worcestershire, Warwickshire)	3,305,841	3,679,264	11·3
VII. N. Midland (Leicestershire, Rutlandshire, Lincolnshire, Nottinghamshire, Derbyshire)	1,808,494	2,042,151	12·9
VIII. N.W. (Cheshire, Lancashire)	4,664,749	5,230,261	12·1
IX. Yorkshire	3,212,188	3,596,395	11·9
X. Northern (Durham, Northumberland, Cumberland, Westmorland)	1,863,166	2,128,633	14·2
XI. Monmouthshire and Wales	1,774,810	2,015,036	13·5
England and Wales	29,002,525	32,526,075	12·1

The total number of males and of females, and the number of females to 1000 males, at the last four enumerations were as follows :—

Year.	Population.	Males.	Females.	Females to 1000 Males.
1871	22,712,266	11,058,934	11,653,332	1054
1881	25,974,439	12,639,902	13,334,537	1055
1891	29,002,525	14,052,901	14,949,624	1064
1901	32,526,075	15,721,728	16,804,347	1069

The areas and population of the ancient counties of England and Wales in 1891 and 1901 (preliminary report), with the number of inhabited houses in 1901, were as follows :—

Counties.	Area. Statute Acres.	Inhabited Houses, 1901.	Population.	
			1891.	1901.
Bedford	298,494	38,356	160,704	171,249
Berks	462,224	53,889	238,709	254,931
Buckingham	475,694	43,476	185,284	195,534
Cambridge	549,749	44,430	188,961	190,687
Chester	657,068	169,191	730,058	814,555
Cornwall	868,208	72,601	322,571	322,957
Cumberland	970,161	54,823	266,549	266,921
Derby	658,876	128,039	528,033	620,196
Devon	1,667,097	123,598	631,808	660,444
Dorset	632,272	43,474	194,517	202,962
Durham	647,281	201,099	1,016,559	1,187,324
Essex	987,028	201,059	785,445	1,085,576
Gloucester	795,734	128,514	599,947	634,666
Hants	1,037,764	155,743	690,097	798,756
Hereford	537,363	25,579	115,949	114,401
Hertford	406,161	53,272	220,162	250,350
Huntingdon	234,218	13,620	57,761	57,773
Kent	995,344	249,139	1,142,324	1,351,849
Lancaster	1,207,605	888,261	3,926,760	4,406,787
Leicester	527,124	94,545	373,584	433,994
Lincoln	1,693,547	113,738	472,878	498,781
Middlesex	181,301	463,038	3,251,671	3,585,139
Monmouth	341,688	54,533	252,416	292,327
Norfolk	1,308,440	106,821	454,516	460,040
Northampton	641,992	74,039	302,183	338,064
Northumberland	1,289,756	93,717	506,030	602,859
Nottingham	539,752	111,594	445,823	514,537
Oxford	483,614	41,089	185,669	182,768
Rutland	97,273	4,595	20,659	19,708
Shropshire	859,516	51,484	236,339	239,321
Somerset	1,043,485	108,154	484,337	508,104
Stafford	749,601	247,976	1,083,408	1,234,382
Suffolk	952,709	86,334	371,235	384,198
Surrey	485,128	311,761	1,731,343	2,008,923
Sussex	933,269	116,518	550,446	605,052
Warwick	577,462	188,963	805,072	897,678
Westmorland	500,906	13,737	66,098	64,305
Wiltshire	880,248	61,321	264,997	273,845
Worcester	480,560	104,238	413,760	488,401
York, E. Riding	753,104	96,688	408,530	445,112
,, N. Riding	1,361,465	81,820	360,383	393,143
,, W. Riding	1,768,279	601,974	2,439,895	2,746,867
Total England	32,538,560	5,916,840	27,483,490	30,805,466
Anglesey	175,836	12,269	50,098	50,590
Brecknock	475,224	12,745	57,031	59,906
Cardigan	440,630	15,136	62,630	60,237
Carmarthen	587,816	29,137	133,566	135,325
Carnarvon	361,097	29,041	118,204	126,835
Denbigh	423,477	27,758	117,872	129,935
Flint	164,050	17,978	77,277	81,725
Glamorgan	516,959	157,634	687,218	860,022
Merioneth	427,810	11,324	49,212	49,130
Montgomery	510,111	12,282	58,003	54,892
Pembroke	395,151	19,469	89,133	88,749
Radnor	301,164	4,883	21,791	23,263
Total Wales	4,779,325	349,656	1,519,035	1,720,609
Total England	32,538,560	5,916,840	27,483,490	30,805,466
Total England and Wales	37,317,885	6,266,496	29,002,525	32,526,075

At the census of 1891 the number of inhabited houses was 5,451,497, so that there was an increase of 814,999 in the ten years. The average number of occupants to a house was 5·32 in 1891, as against 5·38 in 1881, and 5·33 in 1871. The proportion was highest in the larger towns: in London it was 7·72 per inhabited house; in Newcastle-on-Tyne, 7·73; in Sunderland, 7·00. The number of tenements (*i.e.*, houses or parts of houses separately occupied) was 6,131,001 in 1891. This gives an average of 4·7 persons to each tenement, and 1·12 tenements to each house. The density of population in England and Wales, and the average number of persons to an inhabited house, at the last four census enumerations, were as follows:—

Census Years.	Persons per Square Mile.	Acres per Person.	Persons to a House.
1871 . . .	390	1·64	5·33
1881 . . .	445	1·44	5·38
1891 . . .	497	1·29	5·32
1901 . . .	558	1·14	5·19

The density of population, and the average number of persons to a house in England and in Wales, as compared with Scotland and Ireland, in 1891 and 1901 were:—

	Persons per Square Mile.		Acres to a Person.		Persons to an Inhabited House.	
	1891.	1901.	1891.	1901.	1891.	1901.
England . .	540	606	1·18	1·05	5·33	5·21
Wales . . .	203	230	3·14	2·78	5·01	4·94
Scotland . .	135	150	4·73	4·26	4·92	4·83
Ireland . . .	148	140	4·32	4·56	5·40	5·19

The following table gives the Registrar-General's estimate of the population of England and Wales in the middle of every fifth year from 1871 to 1911, the estimates from 1901 to 1911 being provisional and based on the assumption that the rate of increase from 1891 to 1901 will be continued to 1911:—

Years.	Population.	Years.	Population.
1871 . .	22,788,594	1896 . .	30,799,461
1876 . .	24,370,267	1901 . .	32,619,410
1881 . .	26,046,142	1906 . .	34,546,904
1886 . .	27,522,532	1911 . .	36,588,288
1891 . .	29,081,053		

The population of the administrative county of London (comprising the 29 metropolitan boroughs), that of the 1121 urban districts (of which 67 are county boroughs, 248 municipal, but not county boroughs, and 806 non-municipal districts), and that of the 666 rural districts of England and Wales in 1901, with the population on the same groups of areas in 1891, are given as follows:—

Groups of Areas.	Population.		Increase 1891-1901.
	1891.	1901.	
Administrative county of London . .	4,228,317	4,536,063	307,746
Urban districts . .	17,515,660	20,518,205	3,002,545
Rural districts . .	7,258,145	7,471,242	213,097
Areas neither in urban nor in rural districts	403	565	162
England and Wales .	29,002,525	32,526,075	3,523,550

In 1901 there were 75 large towns (including London) each of which had over 50,000 inhabitants, their total population being 14,506,273; on the same areas in 1891 the total population amounted to 12,729,545, the increase in the ten years having been 13·96 per cent. The following is a list of 40 of the largest county boroughs with the population of each in 1901 and the population on the same areas in 1891:—

County Boroughs.	Enumerated Population.		County Boroughs.	Enumerated Population.	
	1891.	1901.		1891.	1901.
Liverpool . .	629,548	684,947	Brighton . .	115,873	123,478
Manchester . .	505,368	543,969	Preston . .	107,573	112,982
Birmingham . .	478,113	522,182	Norwich . .	100,970	111,728
Leeds . . .	367,505	428,953	Birkenhead . .	99,857	110,926
Sheffield . .	324,243	380,717	Gateshead . .	85,692	109,887
Bristol . . .	289,280	328,842	Plymouth . .	88,926	107,509
Bradford . .	265,728	279,809	Derby . . .	94,146	105,785
West Ham . .	204,903	267,308	Halifax . .	97,714	104,933
Hull . . .	200,472	240,618	Southampton .	82,126	104,911
Nottingham . .	213,877	239,753	South Shields .	78,391	97,267
Salford . .	198,139	220,956	Burnley . .	87,016	97,044
Newcastle - upon-Tyne . . .	186,300	214,803	Huddersfield .	95,420	95,008
Leicester . .	174,624	211,574	Swansea . .	90,349	94,514
Portsmouth .	159,278	189,160	Wolverhampton .	82,662	94,179
Bolton . . .	146,487	168,205	Middlesbrough .	75,532	91,317
Cardiff . . .	128,915	164,420	Northampton .	75,075	87,021
Sunderland . .	131,686	146,565	Walsall . .	71,789	86,440
Oldham . .	131,463	137,238	St Helens . .	72,413	84,410
Croydon . .	102,695	133,885	Rochdale . .	76,161	83,112
Blackburn . .	120,064	127,527	Stockport . .	70,263	78,871

Movement of Population.—The number of marriages, births, and deaths in England and Wales in 1871, in every succeeding fifth year, and in 1898 and 1899, was as follows:—

Years.	Marriages.	Births.	Deaths.
1871 . . .	190,112	797,428	514,879
1876 . . .	201,874	887,968	510,315
1881 . . .	197,290	883,642	491,935
1886 . . .	196,071	903,760	537,276
1891 . . .	226,526	914,157	587,925
1896 . . .	242,764	915,331	526,727
1898 . . .	255,379	923,165	552,141
1899 . . .	262,334	928,646	581,799

In the same years the number of persons married, of births, and of deaths per 1000 persons living was:—

Years.	Persons Married in 1000 Living.	Births to 1000 Living.	Deaths to 1000 Living.
1871 . . .	16·7	35·0	22·6
1876 . . .	16·5	36·3	20·9
1881 . . .	15·1	33·9	18·9
1886 . . .	14·2	32·8	19·5
1891 . . .	15·6	31·4	20·2
1896 . . .	15·8	29·7	17·1
1898 . . .	16·3	29·4	17·6
1899 . . .	16·5	29·3	18·3

The marriage-rate is evidently closely associated with the general prosperity of the country. In the period embraced by the table given above, it was highest in 1873, when it was 17·6 per 1000 living, and lowest in 1886, when it fell to 14·2. In the former year the value of the total imports and exports per head of population of the United Kingdom was also at its highest, and in the latter year, at its lowest. The following figures for recent years illustrate this connexion:—

Years.	Marriage-Rate.	Value per Head of Population of United Kingdom.		
		Exports of British Produce.	Imports.	Total Exports and Imports.
		£ s. d.	£ s. d.	£ s. d.
1895 . . .	15·0	5 15 8	10 13 1	17 19 3
1896 . . .	15·8	6 1 8	11 3 11	18 14 1
1897 . . .	16·0	5 17 7	11 6 6	18 14 3
1898 . . .	16·3	5 16 2	11 14 1	19 0 5
1899 . . .	16·5	6 10 5	11 19 2	20 1 8

Since 1871 there has been a steady decline in the number of marriages of minors. Among the persons who married in the five years 1871–75, 81·6 per 1000 of the husbands and 223·2 per 1000 of the wives were under 21 years of age; in the five years 1891–95 the proportions were, 56·2 per 1000 of husbands, and 182·6 of wives; in the year 1899, 50 per 1000 of husbands, and 165 per 1000 of wives.

For the 29 years 1871–99 the average birth-rate of England and Wales was 31·1 to 1000 persons living. The rate was highest in 1876, when it rose to 36·3, and lowest in 1899, when it fell to 29·3, the lowest rate on record. In 1899 the birth-rate was highest in Durham (35·3), Staffordshire (35·1), and Northumberland (33·4); it was lowest in Westmorland (22·7) and Rutland (22·9). Within the period 1871–98 the proportion of illegitimate births has steadily decreased. In 1871 it was 56 to 1000 births; in 1881, 49; in 1891, 42. This proportion continued down to 1898, except that in 1894 the number rose temporarily to 43; in 1899 it fell to 40. The proportion varies widely in different parts of the country. In 1899 the lowest proportions were 28 per 1000 births in Essex, where the average of the preceding 10 years was 29, 29 in Monmouthshire, 30 in Warwickshire, 31 in Middlesex (average of 10 years, 31), 31 in South Wales (average 35). The highest proportions in 1899 were 60 per 1000 births in North Wales, where the average of the preceding 10 years was 66, 61 in Norfolk and in Huntingdon, 62 in Westmorland (average 63), 64 in Cumberland (average 71), 65 in Shropshire (average 73), and 66 in Herefordshire (average 71). Though, as already shown, the female population is considerably in excess of the male, yet the number of male births exceeds that of the female. During the 29 years 1871–99 the average number of male to 1000 female births was 1038; the highest was 1043 in 1875, and the lowest was 1032 in 1898; in 1899 the number was 1039. The variations in the proportion over the whole country range within comparatively narrow limits, but in particular localities they are considerable. In 1899 the lowest proportions of male to female births were 929 in Huntingdonshire, where the average of the preceding ten years was 1042, 933 in Rutland (average 1059), and 991 in Monmouthshire (average 1041). The highest were 1063 male to 1000 female births in South Wales (average of ten years, 1038), 1064 in Oxford (average 1037), 1064 in Buckinghamshire (average 1031), 1065 in Essex (average 1029), and 1094 in Dorsetshire (average 1051).

The average annual death-rate of England and Wales for the 29 years 1871–99 was 19·0 per 1000 persons living; the highest was 22·7 in 1875; the lowest was 16·6 in 1894. For the 5 years 1871–75 the average was 22·0; for 1891–95, 18·7. In the 5 years 1871–75 the average death-rate of males was 23·3 per 1000 living; of females, 20·7; in 1891–95, of males 19·8, and of females 17·7 per 1000 living. In 1899, 19·5 males died per 1000 living, and 17·3 females per 1000. In 1899 the lowest death-rates were 12·9 in Westmorland, where the average of the preceding 10 years was 14·9 per 1000 living, 14·7 in Middlesex (average 14·7), 4·9 in Cambridgeshire (average 16·4); the highest were 19·6 in Staffordshire (average 19·8), 20·1 in Northumberland (average 19·3), and 21·1 in Lancashire (average 21·4).

For the purpose of comparison the following table is given, showing for the United Kingdom and its several parts, and for various continental countries, the average number of births and of deaths per 1000 living in the 25 years 1874–98:—

Countries.	Births.	Deaths.	Countries.	Births.	Deaths.
United Kingdom	31·4	19·3	Austria	38·1	29·0
England and Wales	32·6	19·4	Hungary	43·0	33·2
Scotland	32·6	19·7	Switzerland	28·9	20·9
Ireland	24·0	18·1	Prussia	37·8	24·1
Denmark	31·4	18·6	Netherlands	34·4	20·9
Norway	30·7	16·7	Belgium	30·3	20·3
Sweden	28·9	17·2	France	23·8	22·0
			Italy	36·8	27·1

The increase of population is retarded and obscured by the large outflow and inflow of passengers to and from the United States and the British Colonies. In the 25 years 1876–1900 the gross number of emigrants, British and foreign, to countries out of Europe amounted to 7,172,800, of whom 5,010,707 were of British or Irish origin. On the other hand, the immigrants, British and foreign, from non-European countries numbered 3,123,025, of whom 2,122,150 were of British or Irish origin The net number of emigrants was thus 4,049,775, of whom 2,888,557 were of British or Irish origin. The following table shows the gross numbers and the percentages of emigrants, English, Scots, and Irish, who left the United Kingdom for non-European countries in quinquennial periods 1876–1900:—

Periods.	English. Number.	Per c.	Scots. Number.	Per c.	Irish. Number.	Per c.	Total. Number.
1876–80	425,550	60	70,596	10	213,236	30	709,382
1881–85	760,124	59	133,527	10	398,658	31	1,292,309
1886–90	788,841	62	141,568	11	335,817	27	1,266,226
1891–95	617,869	63	100,878	10	259,827	27	978,574
1896–00	478,022	63	85,104	11	201,090	26	764,216
1876–00	3,070,406	61	531,673	10	1,408,628	28	5,010,707

The following summary shows the movement of emigration and immigration between the United Kingdom and the United States, British North America, and Australasia in 25 years, 1876–1900:—

1876–1900.	To and from United States.	To and from British N. America.	To and from Australasia.	Total (including others).
Total Emigration	4,973,292	810,872	684,450	7,172,800
Total Immigration	2,230,206	226,810	214,312	3,123,025
Net Emigration	2,743,086	584,062	470,138	4,049,775
British and Irish Emigration	3,272,962	555,459	664,381	5,010,707
British and Irish Immigration	1,351,171	211,469	197,820	2,122,150
Net British and Irish Emigration	1,921,791	343,990	466,561	2,888,557

The total number of emigrants to Cape Colony and Natal, 1876–1900, was 339,334; the immigrants therefrom, 1882–1900, numbered 183,335. The number of British and Irish emigrants to these colonies, 1877–1900, was 268,729; of British and Irish immigrants therefrom, 1882–1900, 155,015. The net emigration of persons of British and Irish origin in quinquennial periods 1876–95 and in the 5 years 1896–1900 was as follows:—

Periods.	Emigrants.	Immigrants.	Balance of Emigrants.
1876–80	709,382	275,181	434,201
1881–85	1,292,309	358,046	934,263
1886–90	1,266,226	472,166	794,060
1891–95	978,574	530,663	447,911
1896	161,925	101,742	60,183
1897	146,460	95,221	51,239
1898	140,644	91,248	49,396
1899	146,362	100,246	46,116
1900	168,825	97,637	71,188
1876–1900	5,010,707	2,122,150	2,888,557

In the 25 years 1876–1900 the rate of British and Irish emigration fluctuated between wide limits. The smallest net emigration was in 1877, when the number was 31,305, or 0·09 per cent. of the population of the United Kingdom; the largest was in 1883, when the net number of emigrants was 246,314, or 0·69 per cent. of the whole population. The following table shows the rate of the net British and Irish emigration in recent years:—

Years.	Per cent. of Population.	Years.	Per cent. of Population.	Years.	Per cent. of Population.
1886	0·42	1891	0·31	1896	0·15
1887	0·54	1892	0·29	1897	0·13
1888	0·50	1893	0·28	1898	0·12
1889	0·41	1894	0·10	1899	0·11
1890	0·29	1895	0·19	1900	0·17

Aliens.—Regarding the increase of the foreign element in the population of the United Kingdom there is no precise information, but a rough estimate is formed on the basis of the figures showing the passenger movement between the United Kingdom and the Continent of Europe. The excess of the inward over the outward passengers is assumed to represent foreigners not returning to the Continent; from this excess the number of foreigners known to have emigrated within the year to places out of Europe, and the number of foreign sailors, coming as passengers but departing as crews of vessels, are deducted, and the remainder is taken to represent approximately the increase to the foreign population of the United Kingdom within the year. For 1898, 1899, and 1900 the figures are given as follows:—

	1898.	1899.	1900.
Inwards from Europe	620,123	666,230	748,725
Outwards to Europe	590,226	609,570	669,292
Excess inwards	29,897	56,660	79,433
Net foreign emigrants	14,801	31,231	50,685
Foreign sailors	12,299	13,362	14,950
Total to be deducted	27,100	44,593	65,635
Net foreign increase	2,797	12,067	13,798

The increase consists largely of Russian, Polish, and Rumanian Jews, who, arriving in a state of destitution, are assisted by Jewish Boards of Guardians and Relief Committees in London and other large towns.

Local Government.

Political divisions.

For most practical purposes the ancient counties of England and Wales have been superseded by the administrative counties created by the Local Government Act of 1888. The ancient division, however, forms the basis on which the system of distribution of parliamentary representation now in force was constructed. After the Representation of the People Act, 1884, had extended to householders and lodgers in counties the franchise which in 1867 had been conferred on householders and lodgers in boroughs, the Redistribution of Seats Act, 1885, made a new division of the country into county and borough constituencies. All the English counties, with the exception of Rutland, are now divided into two or more constituencies, each returning one member, the number of English county parliamentary areas being 234. In Wales the eight smaller or less populous counties form each one parliamentary constituency, while the four larger are divided, the number of Welsh county parliamentary areas being 19. The number of county areas for parliamentary purposes in England and Wales is thus 253, and the total number of their representatives is the same. Outside the county constituencies are the parliamentary boroughs. Of these there are 135 in England, one of them, Monmouth district, being made up of three contributory boroughs, while many are divided into several constituencies, the number of borough parliamentary areas in England being 205, of which 61 are in the metropolis. Of the 205 borough constituencies, 184 return each one member, and 21 return each two members, so that the total number of English borough members is 226. Besides the county and borough members there are in England five university members, namely, two for Oxford, two for Cambridge, and one for London. In Wales there are 10 borough parliamentary areas, all of which, except Merthyr Tydfil and Swansea town division, consist of groups of several contributory boroughs. Each Welsh borough constituency returns one member, except Merthyr Tydfil, which returns two, so that there are eleven Welsh borough members.

The following summary shows the population (1891), the registered electors (1901), the numbers, and representation of the various classes of constituencies in England and Wales:—

Description of Constituencies.	Population, 1891.	Electors, 1901.	Constituencies Number.	Representatives in Parliament.
England—				
County	13,848,294	2,835,019	234	234
Borough	13,636,100	2,232,278	205	226
University	...	17,702	3	5
Total England	27,484,394	5,084,999	442	465
Wales—				
County	999,957	211,881	19	19
Borough	518,174	92,985	10	11
Total Wales	1,158,131	304,866	29	30
England and Wales	29,002,525	5,389,865	471	495

At the general parliamentary election of 1895 the total number of votes recorded was 3,190,826. If the university constituencies are left out of account, the average representation, according to the census returns of 1901, is one member of parliament for every 66,380 inhabitants of England and Wales. The distribution, however, is still very unequal, ranging from one representative for 14,935 inhabitants in Durham, to one for 167,679 in the Cardiff district of boroughs. This inequality is shown by the following statement from the preliminary report on the census of 1901:—

Population to one Representative.	Number of Constituencies. 1891.	1901.
100,000 and upwards	7	41
90,000 and under 100,000	19	34
80,000 ,, ,, 90,000	26	47
70,000 ,, ,, 80,000	66	69
60,000 ,, ,, 70,000	108	82
50,000 ,, ,, 60,000	128	102
40,000 ,, ,, 50,000	79	56
30,000 ,, ,, 40,000	23	28
20,000 ,, ,, 30,000	19	19
10,000 ,, ,, 20,000	15	12
	490	490

Administrative divisions.

Under the Local Government (England and Wales) Act, 1888, which established a new system of county administration, 62 administrative counties have been created, each having a county council. Of the new counties, 14 coincide in area with ancient counties, and 7 others, together with county boroughs situated within their boundaries but now under separate administration, have areas coinciding with ancient counties of the same name. Generally, however, the areas of the new counties are different from those of the ancient. (1) In some cases portions of ancient counties are now administrative counties. Thus, the Isle of Ely in Cambridgeshire; the Parts of Holland, the Parts of Kesteven, the Parts of Lindsey, in Lincolnshire; the Soke of Peterborough in Northamptonshire; the Isle of Wight in Hampshire; the East Riding, the West Riding, and the North Riding of Yorkshire; the eastern portion and the western portion of Suffolk; and the eastern portion and the western portion of Sussex, have been formed each into a separate administrative county. The Scilly Islands, which form part of the ancient county of Cornwall, without being ranked as an administrative county, are provided with a county council and have separate administration. (2) The administrative county of London has an area taken entirely from the counties of Middlesex, Kent, and Surrey.

(3) All boroughs which on June 1, 1888, had a population of not less than 50,000, boroughs which were already counties having a population of not less than 20,000, and a few others, were formed into separate administrative areas, with the name of county boroughs. Of these there were originally 61, but their number has been increased to 67. (4) Provision was made for including entirely within one administrative county each of such urban districts (then called urban sanitary districts) as were situated in more than one ancient county.

The councils of the administrative counties consist of councillors chosen for three years by duly qualified electors in electoral divisions, aldermen chosen for six years by the councillors, either from among themselves or from outside, and a chairman chosen by the council, either from its own members or from outside. Municipal boroughs of sufficient importance to have separate representation on the councils form one or more electoral divisions, according to population. The county council of each administrative county is a body corporate, having perpetual succession and a common seal, and has power to acquire and hold land for the purposes of its constitution. The administrative business of the county councils is generally that formerly managed by the Quarter Sessions, with the exception of judicial business. Their powers relate principally to the levying of rates, the borrowing of money, the management of county buildings and property, the licensing of places for music and dancing and of racecourses, the maintenance of asylums for pauper lunatics, reformatories, and industrial schools, the management of bridges and roads, the regulation of fees of county officials and of salary and fees of coroners, the appointment of polling districts for parliamentary elections, and arrangement for the registration of electors and revision of electoral lists. County coroners, formerly chosen by popular election, are now elected by the county council. The county police is under the control of a standing committee of magistrates and members of the council in equal numbers, except in the county of London, where the police is under the Home Secretary. In the county boroughs the town councils have powers similar to those of the county councils.

Municipal boroughs.

The number of municipal boroughs in England and Wales has largely increased since the passing of the Municipal Reform Act of 1835. That Act applied to 178 boroughs, while 68 places (including London) with municipal powers of various origin were left outside its scope. These were mostly unimportant, and have either been reincorporated under the Municipal Corporations Act, 1883, or have ceased to exist as boroughs. The municipal boroughs in 1881 numbered 243; in 1891, 295; in 1901, 315 (exclusive of metropolitan boroughs). In 1900, under the London Government Act, 1899, the administrative county of London, exclusive of the City, was divided into 28 boroughs, the councils of which, with some additions and some limitations, took over the property, powers, and duties of the vestries.

The governing bodies in boroughs are the councils, consisting of the mayor, aldermen, and councillors. Their constitution and powers were amended by the Municipal Corporations Act, 1882, and to a large extent formed the models on which those of the county and district councils were framed in 1888 and 1894. The councillors are elected by the burgesses (in cities, citizens) for three years; the mayor and aldermen are elected by the council, either from within or from those outside who are qualified to be elected councillors, the mayor for one year and the aldermen for six years. The basis of the municipal franchise is ratepaying residence, and women may be enrolled and vote. The powers of the town councils comprise the levying of rates, the borrowing of money, management of borough property, police, markets, lighting, cleansing, water-supply, paving, bridges, and powers under various Acts relating to artizans' dwellings, cemeteries, free libraries, and matters affecting public health. As the urban district council the town council holds separate sittings.

Urban and rural district councils.

The areas into which England and Wales were divided under the Public Health Act of 1875 were called Urban and Rural Sanitary Districts. By the Local Government Act of 1894 this division was retained, but its purpose was greatly extended. In the designation the word "sanitary" was dropped, and, in urban and rural districts, district councils were established. In the boroughs this involved no change, but in Improvement Act districts, and in Local Government districts, the Improvement Commissioners and the Local Boards, respectively, were superseded by the new councils. In the rural districts the Boards of Guardians were formerly the sanitary authorities, but while such boards, under new regulations, continue to exist in urban districts, they are entirely abolished in rural districts, and their place is filled by rural district councils.

These councils, urban and rural, consist of councillors chosen for three years by the electors in wards or parishes, and a chairman chosen by the council for one year, either from within or outside this body, provided he have the qualification necessary for election as councillor. No disqualification for elector or councillor arises from sex. To the councils have been transferred powers formerly exercised by sanitary and highway authorities, and others exercised by justices out of session, and by Quarter Sessions, and they have duties relating to right of way, the Adoptive Acts, the compulsory purchase of land, and various other matters. Under the same Act every parish with a population of more than 300 has a *parish council*; parishes with smaller population may either be grouped together, or each have a council. Among other business, these councils appoint overseers and, except with respect to church affairs and ecclesiastical charities, exercise the powers formerly possessed by the vestries. In every rural parish there is a parish meeting held at least once a year, with powers relating to election of parish councillors, parish finance, and other matters.

Among the county, district, and parish councils there is much interdependence, and all of them are under the administrative and financial control of the central authority, the Local Government Board.

Poor Law.

Parishes, for local government purposes, are *poor-law parishes*, areas for each of which a separate poor-rate is or can be levied. In 1891 there were in England and Wales 14,684 such parishes, but under various Acts their boundaries and their number are subject to alteration. *Poor-law unions*, formed under an Act of 1834, are groups of parishes for the local administration of the Poor Laws. In 1898 the number of unions and of separate parishes was 649. *Registration districts* are generally, but not invariably, coextensive with unions of the same name. These districts are divided into sub-districts, within which the births and deaths are registered by registrars appointed for that purpose. *Registration counties* are groups of registration districts, and their boundaries differ more or less from those both of the ancient and the administrative counties. In England and Wales there are eleven registration divisions, consisting of groups of registration counties. Within the unions the local poor-law authorities are the *Boards of Guardians*. In rural districts the functions of these boards are, under the Local Government Act of 1894, performed by the district councils, and in other places their constitution is now similar to that of the urban and district councils. The guardians, elected for three years by the parochial electors, may choose two additional guardians, and the chairman, appointed annually, may be chosen either from within or from outside. There are now no *ex officio* or nominated guardians, and no disqualification for the office of guardian arises from sex or marriage. The principal duties of the guardians are the preparation or revision of the valuation lists on which the poor-rate is assessed, though the rates are levied not in union but in parish areas, and the administration of relief to the poor, involving the appointment of officers and the supervision of their work. The action of the guardians, however, in many cases requires the confirmation of the Local Government Board.

Pauperism.—The total number of paupers in England and Wales relieved, either within the union workhouses or outside, on January 1st of each fifth year from 1881 to 1896, and of each of the last three years, is given below. The few who received both indoor and outdoor relief are in the total counted only once:—

January 1.	Indoor Paupers.	Outdoor Paupers.	Total.
1881	195,286	614,232	809,341
1886	199,641	613,532	813,014
1891	198,218	582,413	780,457
1896	229,721	610,904	840,456
1899	230,915	590,323	821,096
1900	226,871	580,724	807,471
1901	227,148	574,312	801,460

The following table shows for entire parochial years, ending March 25th, the mean number per 1000 of estimated population of England and Wales:—(1) of indoor and outdoor paupers, (2) of in- and outdoor paupers, exclusive of vagrants and insane, (3) of adult able-bodied paupers only:—

Year ending March 25.	Paupers per 1000 of Estimated Population.		
	Total In- and Outdoor.	Exclusive of Vagrants and Insane.	Adults, able-bodied only.
1882 . .	30·3	27·0	3·9
1887 . .	28·9	26·2	3·7
1892 . .	25·6	22·8	3·2
1897 . .	26·5	23·3	3·3
1899 . .	26·5	23·2	3·4
1900 . .	25·0	21·7	3·0

The paupers relieved on January 1, 1901, exclusive of vagrants, were as follows:—

Description.	Male.	Female.	Children (under 16).	Total.
Indoor—				
Able-bodied . .	19,470	18,100	13,267	50,837
Not able-bodied . .	65,587	44,110	37,561	147,258
Insane . . .	7,486	8,959	1,083	17,528
Total indoor .	92,543	71,169	51,911	215,623
Outdoor—				
Able-bodied . .	10,632	48,456	130,696	189,748
Not able-bodied . .	77,109	201,120	27,417	305,646
Insane . . .	34,857	43,249	643	78,749
Total outdoor .	122,598	292,825	158,756	574,179
Total . .	215,141	363,994	210,667	789,802

The total number of vagrants relieved was 11,658 (11,525 indoor and 133 outdoor), and, including these, the total number of paupers relieved was 801,460, of whom 113 received both indoor and outdoor relief. Of the 10,632 "able-bodied" outdoor male paupers, the great majority were relieved on account of sickness or accident; of the 48,456 "able-bodied" female outdoor paupers, 34,082 were widows, 7588 were wives of "able-bodied" men relieved, 4183 were wives of non-resident males, 2374 were single women without children, and 229 were mothers of illegitimate children. The great majority of the children relieved out-of-doors were children of widows relieved.

The cost of poor-relief steadily increases. The gross expenditure, with the amount per head of population, and the relief expenditure from rates, with the average rate per £ of rateable value, in the parochial years 1891 and 1899 (ending March 25), were as follows:—

Years.	Gross Expenditure.	Per Head of Population.	Expenditure from Rates	Per £ of Rateable Value.
	£	s. d.	£	s. d.
1891 .	8,643,318	6 0	5,857,436	0 9¼
1899 .	11,286,973	7 2¼	8,161,532	1 0·2

In these years the sums expended on in-maintenance, out-relief, and on lunatics in asylums, etc., were:—

Years.	In-maintenance.	Out-relief.	Lunatics in Asylums, &c.
	£	£	£
1891 .	1,951,486	2,400,089	1,284,656
1899 .	2,462,008	2,764,854	1,748,558
Increase	510,522	364,765	463,902

Other expenditure in 1899 consisted of £919,313 for interest and repayment of workhouse loans, £1,971,614 for salaries, &c., and £1,420,626 for other purposes, bringing the total expenditure up to £11,286,973.

The number of paupers and the cost of poor-relief are very unequally distributed over England and Wales. The following table shows, for January 1, 1901, the number of in- and outdoor paupers per 1000 of estimated population, and for 1899 the gross expenditure on poor-relief per head of estimated population, in each of the eleven registration divisions:—

Divisions.	Per 1000 of Population.			Expenditure per Head of Population
	Indoor Paupers.	Outdoor Paupers.	Total, including Asylums, &c.	s. d.
London	14·9	8·7	26·9	15 3½
South-Eastern . .	7·3	15·0	24·7	6 10¾
South Midland . .	5·2	17·8	25·4	6 2¾
Eastern . . .	6·0	23·0	31·2	6 10¾
South-Western . .	5·5	27·2	35·5	6 11½
West Midland . .	6·8	17·6	26·8	6 0½
North Midland . .	4·7	20·2	26·9	6 2½
North-Western . .	6·9	10·1	19·0	4 10½
Yorkshire . .	4·4	13·4	19·6	4 11
Northern . . .	4·5	13·8	20·0	4 4¼
Welsh	3·9	23·8	29·8	6 6½
Total . .	7·1	15·6	25·0	7 2¼

Justice.

The highest court of appeal is the House of Lords, where the Lord Chancellor presides, the other judges being ex-Lords of Appeal in Ordinary (appointed under the Appellate Jurisdiction Act, 1887) and such other peers of Parliament as hold or have held high judicial office. The Judicial Committee of the Privy Council is concerned chiefly with appeals from Colonial and Indian Courts, but it has also ecclesiastical and other jurisdiction, and it decides concerning petitions for extension of letters patent. Its judgments are given in the form of reports to the King. Members of this court are the Lord Chancellor and the four Lords of Appeal, but the Lord Chief Justice, the Lords Justices, and others who hold or have held high judicial office, and are members of the Privy Council, are qualified to sit. One member of the court is a specially appointed expert in Indian law; and in 1897, under an Act of 1895, three colonial judges, the Chief Justices of Cape Colony, Canada, and South Australia, were added.

In the Supreme Court of Judicature there is a Court of Appeal, where the Master of the Rolls and five Lords Justices usually sit, the Lord Chancellor, the Lord Chief Justice, and the President of the Probate, Divorce, and Admiralty Division being also judges in this court.

In the Chancery Division of the High Court of Justice there are six judges, besides the Lord Chancellor; in the King's Bench Division are the Lord Chief Justice and fourteen other judges; in Probate, Divorce, and Admiralty Division are two judges; and in the Bankruptcy Division, one. The Court of Arches for ecclesiastical cases has one judge.

Assize courts, in which the the judges of the High Court try civil and criminal cases, are held in eight circuits, which at present are constituted as follows:— The South-Eastern, in two divisions—the Home Division (Sussex, Kent, Essex, Hertford) and the Norfolk Division (Norfolk, Suffolk, Huntingdon, Cambridge); the Midland (Buckingham, Bedford, Northampton, Leicester, Rutland, Lincoln, Derby, Nottingham, Warwick); the Northern (Westmorland, Cumberland, Lancashire); the North-

Eastern (Northumberland, Durham, York); the Oxford (Berkshire, Worcester, Gloucestershire, Monmouth, Hereford, Stafford, Shropshire, Oxford); the Western (Hampshire, Wiltshire, Somerset, Dorsetshire, Devonshire, Cornwall); the North Wales (Chester and the six northern Welsh counties); South Wales (the six southern Welsh counties).

Courts with jurisdiction in special matters are the Lunacy Commission, the Railway and Canal Commission, the Lancaster and Durham Chancery Courts. For the determination of civil cases in which the value in dispute is of small amount, there are County Courts, England and Wales being divided into sixty County Court circuits. Other civil courts which may be mentioned are the Lord Mayor's Court, London, Bankruptcy Courts, and Borough Courts of Record. The number of civil cases in which proceedings were commenced in courts of first instance in England and Wales in 1899 was 1,272,143. Of these 78,326 were in the High Court, and 1,159,062 in County Courts, the remainder being mostly in the Lord Mayor's Court, London, in Borough Courts of Record, and in Bankruptcy Courts. In the same year there were 446 appeals in the High Court from inferior courts; 826 in the Court of Appeal; 76 in the Judicial Committee of the Privy Council; and 75 in the House of Lords.

Crime.—The Queen's Bench Division of the High Court has power to try criminal cases, but this power is seldom used (in two cases in 1898), and, practically, the principal criminal courts are the Assize courts, and the Central Criminal Court, which, in law, is included in the assizes. Assize courts are usually held three times (in some cases four times) a year, by judges on circuit, or by commissioners appointed for the purpose. The Central Criminal Court holds twelve sessions a year. Courts with less extensive jurisdiction are Quarter Sessions, held by two or more justices of the peace in counties, and by the recorder in boroughs which have a separate court. These courts, sitting four times (in London thirty-six times) a year, dispose of the less serious cases, while more serious charges, *e.g.*, treason, murder, perjury, are tried at assizes. Neither from Assize courts nor from Quarter Sessions is there any appeal, but the judges or magistrates may reserve doubtful points of law for decision by the Court for Crown Cases Reserved, consisting of five or more judges of the High Court. At Assizes and Quarter Sessions all trials are by jury.

Courts of summary jurisdiction consist of at least two justices of a petty sessional division of a county or of a borough sitting in petty sessions, but in large towns the stipendiary magistrate may sit alone. In these courts there is no jury; the decisions are in most cases subject to appeal, but appeals are rare. The magistrates conduct the preliminary investigation of cases afterwards tried at Quarter Sessions or Assizes, and they have also certain civil jurisdiction.

The number of persons committed for trial at the Assizes and at Quarter Sessions, the number convicted, and the number acquitted (including those not proceeded against), in 1881, in each fifth year to 1896, and in 1898 and 1899, were as follows:—

Years.	Committed for Trial.	Convicted.	Acquitted.
1881 . .	14,786	11,353	3401
1886 . .	13,974	10,686	3245
1891 . .	11,695	9,055	2585
1896 . .	11,214	8,856	2317
1898 . .	11,594	9,273	2267
1899 . .	11,044	8,749	2240

The decrease in the number of persons annually convicted of serious crime since 1880 is evident, and is the more remarkable when it is considered that this absolute decrease has been concurrent with a large increase in the population.

The different classes of offences for which prisoners were committed, and of which they were convicted or acquitted, at Assizes and Quarter Sessions in the years 1897–1899, were as follows:—

Classes of Offences.	Years.	Persons Committed.	Persons Convicted.	Persons Acquitted, &c.
I. Against the person .	1897	2,606	1750	856
	1898	2,629	1800	829
	1899	2,649	1785	864
II. Against property, with violence .	1897	1,997	1762	235
	1898	2,136	1888	248
	1899	1,908	1702	206
III. Against property, without violence .	1897	5,524	4527	997
	1898	5,657	4625	1032
	1899	5,334	4340	994
IV. Malicious offences against property .	1897	277	209	68
	1898	251	189	62
	1899	259	180	79
V. Forgery and offences against the currency . . .	1897	304	275	29
	1898	351	317	34
	1899	311	275	36
VI. Other offences .	1897	507	344	163
	1898	430	314	116
	1899	441	326	115
Total . .	1897	11,215	8867	2348
	1898	11,454	9133	2321
	1899	10,902	8608	2294

In 1899, 39,592 persons were tried summarily for indictable offences, and 31,879 were convicted, the total number of convictions for indictable offences within the year having thus been 40,487.

The criminal statistics since 1895 show a slight increase in the number of cases, but this is due to increase not of the number of criminals, but of offences. Sentences of imprisonment are now for shorter terms than formerly; old offenders are more frequently at large, are oftener brought to justice, and thus swell the numbers in the statistical returns. This view is borne out by the following figures, showing for the years 1893–1898 the number of receptions of convicted prisoners into the prisons of England and Wales, and also the number and percentage that had been previously convicted:—

Years.	Number of Convicted Prisoners.	Number having Previous Convictions.	Percentage of the whole.
1893 . .	151,462	75,867	58·1
1894 . .	155,132	84,603	54·9
1895 . .	143,441	79,711	55·6
1896 . .	149,000	85,405	57·3
1897 . .	148,962	85,890	57·7
1898 . .	158,323	94,972	60·0
1899 . .	154,754	93,250	60·0

The total number of receptions into the various prisons, and the number of criminal and non-criminal prisoners, in 1899, were as follows:—

Prisoners.	Male.	Female.	Total.
Convicted on indictment .	6,718	787	7,505
Convicted summarily . .	102,657	44,592	147,249
Total convicted criminals	109,375	45,379	154,754
Convicted by court-martial	1,626	—	1,626
Remanded and discharged .	12,629	3,165	15,794
Total criminal prisoners .	123,630	48,544	172,174
Surety prisoners . .	1,248	648	1,896
Debtors	10,247	462	12,706
Others	56	8	64
Total . . .	137,178	49,662	186,840

In 1899 sentence of death was passed in 29 cases, and carried out in 15. Of the prisoners received into prisons, 735 were under sentence of penal servitude.

Of the 154,754 convicted prisoners received in 1899, 93,250 were old offenders. These, classed according to the number of their previous convictions, were:—

Previously Convicted.	Males.	Females.	Total.
Once	19,422	6,023	25,445
Twice	8,755	3,436	12,191
Three times . . .	5,557	2,606	8,163
Four times . . .	3,952	1,925	5,877
Five times	2,953	1,636	4,589
Six to ten times. . .	8,834	5,468	14,302
Above ten times . .	10,468	12,215	22,683
Total . .	59,941	33,309	93,250

The condition of the convicted criminals received into prisons in 1899 with respect to education, is shown in the subjoined statement:—

Prisoners.	Male.	Female.	Total.
Not able to read or write .	17,703	11,483	29,186
Per cent. of whole .	16·18	25·30	18·86
Able to read and write imperfectly . . .	84,854	33,114	117,968
Per cent. of whole	77·58	72·98	76·23
Able to read and write well	5,658	740	6,398
Per cent. of whole .	5·17	1·63	4·14
Superior instruction . .	84	6	90
Per cent. of whole .	0·08	0·01	0·05
Instruction not described .	1,075	37	1,112
Per cent. of whole .	0·99	0·08	0·72
Total . . .	109,374	45,380	154,754

With respect to age, the prisoners received in 1899 were as follows:—

Ages.	Male.	Female.	Total.
Under 16	1,286	72	1,358
16 and under 21 . .	12,826	2,386	15,212
21 ,, ,, 30 . .	29,777	12,006	41,783
30 ,, ,, 60 . .	57,352	28,856	86,208
60 and upwards . .	8,056	2,042	10,098
Age not ascertained . .	77	18	95
Total . . .	109,374	45,380	154,754

In 1899, 1134 offenders under 16 years of age were committed to reformatory schools, 44 being from Assize and Quarter Sessions, and 1090 from courts of summary jurisdiction. In the great majority of the cases the offence was larceny or other form of dishonesty. In 131 cases a preliminary term of imprisonment was imposed. In the same year 7245 offenders under 16 years of age were sent to industrial schools, many of them for such offences as begging and absenting themselves from school. The following are the figures showing receptions into reformatory and industrial schools in 1899:—

	Boys.	Girls.	Total.
Reformatory schools . . .	987	147	1134
Industrial schools . . .	2422	617	3039
Truant industrial schools .	2323	—	2323
Truant indus rial day schools .	1405	478	1883
Total, industrial schools .	6150	1095	7245

Police.—The average number of men employed daily in police duties in England and Wales in 1900, and the net cost of the police force in the same year, were as follows:—

	Average Number.	Net Cost.
		£
Counties	13,080	1,127,350
Cities and boroughs . .	13,296	1,225,595
Metropolitan police . .	13,588	1,291,070
City of London police . .	1,001	99,007
Total	40,965	3,743,022

Education.

The Board of Education, which was formed April 1, 1900, under an Act of 1899, is charged with the superintendence of all matters relating to education in England and Wales. It consists of a president, the Lord President of the Council (unless he is appointed president), the principal Secretaries of State, the First Lord of the Treasury, and the Chancellor of the Exchequer. This board has taken the place of the Education Department and the Department of Science and Art, and, under the Act by which it was created, Orders in Council have been made whereby it will exercise, concurrently with the Charity Commissioners, certain powers relating to educational endowments in England and Wales, and there have been transferred to it from those Commissioners powers relating to educational endowments in Wales and Monmouth, regulated by schemes under the Endowed Schools Acts. A consultative committee has been appointed to frame regulations for a register of teachers, and to advise the board on any matter on which the board may request advice. The Education Office has been organized in two branches, one concerned chiefly with elementary, and the other with secondary education, the administration of science and art instruction being intrusted to the latter. Arrangements are in progress to enable the board, with the Charity Commissioners, to undertake the complete inspection, administrative and educational, of schools which desire it.

The Elementary Education Act of 1870 has been amended, and its purpose extended, by several important Acts. By an Act of 1876 it was made a punishable offence for a parent to neglect the education of his child; and the employment of children at work under the age of ten, and of children over ten unless they should have reached a certain standard of proficiency, was made illegal. The age of exemption from attendance at school on account of proficiency was in 1893 raised to eleven, and in 1899 to twelve. The Act of 1876 further required that attendance at school should be enforced by school boards or, where there are no school boards, by school attendance committees appointed annually for the purpose; and it empowered the authorities to send neglected children to industrial schools. An Act of 1891 provided for the payment of a fee grant of ten shillings *per annum* for each child (over three and under fifteen years of age) of average attendance at day schools, the grant being made conditional on the abolition or reduction of school fees. The Voluntary Schools Act, 1897, provided that an aid grant, not exceeding in the aggregate five shillings per scholar, should be paid to public elementary schools not provided by school boards, and it also exempted such schools from the payment of rates. This Act contemplated the formation of associations of voluntary schools, and a school may be required to belong to an association to receive the grant. A separate Act of the same year provided for an increase in the grants to school boards, thus reducing the school board rates. Among other educational Acts passed in recent years are those of 1893 and 1899, providing for the instruction of blind and deaf, and of epileptic children.

The progress of elementary education in the country is roughly shown by the following table, which gives the annual average proportion of persons signing the marriage register with marks :—

Years.	Proportion signed by Mark in 1000 Marriages.		
	Husbands.	Wives.	Both.
1881–85 . .	123·4	154·8	54·4
1886–90 . .	84·0	98·2	30·2
1891–95 . .	51·2	59·6	16·6
1896 . .	37	43	11
1897 . .	33	40	10
1898 . .	31	36	10
1899 . .	29	34	9

The average proportion of persons who signed the marriage register by mark in 1889–98, and the proportion in 1899, in the registration counties, are given as follows :—

Registration County.	In 1000 Marriages signed by Mark.			
	1889–98.		1899.	
	Men.	Women.	Men.	Women.
London . . .	32	43	25	33
Surrey	30	19	17	12
Kent	41	28	23	17
Sussex	42	19	22	12
Hampshire . . .	36	24	18	15
Berkshire . . .	47	24	28	15
Middlesex . . .	36	26	21	16
Hertfordshire . .	75	45	36	20
Buckinghamshire . .	69	36	30	22
Oxfordshire . . .	56	29	29	21
Northamptonshire .	47	42	24	25
Huntingdonshire . .	69	36	27	18
Bedfordshire . .	67	65	37	28
Cambridgeshire . .	82	47	38	30
Essex	52	38	28	25
Suffolk	83	46	41	20
Norfolk . . .	74	46	38	22
Wiltshire . . .	58	30	29	19
Dorsetshire . . .	56	28	29	24
Devonshire . . .	36	35	17	22
Cornwall . . .	83	76	49	47
Somerset . . .	62	47	42	25
Gloucester . . .	51	49	27	29
Hereford . . .	75	43	26	26
Shropshire . . .	76	58	41	35
Staffordshire . . .	76	89	39	44
Worcestershire . .	63	71	33	30
Warwickshire . .	51	67	30	39
Leicestershire . .	38	42	19	20
Rutland . . .	48	20	38	23
Lincolnshire . . .	48	37	23	24
Nottinghamshire . .	53	60	23	34
Derbyshire . . .	46	46	22	26
Cheshire . . .	47	55	25	24
Lancashire . . .	49	81	25	43
York, W. Riding . .	56	78	32	45
,, E. Riding . .	39	49	21	25
,, N. Riding . .	51	52	32	43
Durham . . .	63	82	35	46
Northumberland . .	39	61	22	37
Cumberland . . .	42	56	27	31
Westmorland . .	21	23	15	4
Monmouthshire . .	93	102	56	65
South Wales. . .	72	102	41	57
North Wales . .	87	94	50	53

According to this test, the illiteracy of both men and women is greater in the northern than in the southern counties; in the southern, except London, there are more illiterate men than women married, while in the northern and London, the women are the more illiterate.

Elementary Schools.—The number of elementary schools (both voluntary and board schools) inspected, the number of children for whom accommodation was provided in these schools, and the average attendance in years ending August 31, 1881, 1891, and in 1897–1900 were :—

Years.	Schools Inspected.	Accommodation.	Average Attendance.
1881 . .	18,062	4,389,633	2,863,535
1891 . .	19,508	5,628,201	3,749,956
1897 . .	19,958	6,215,199	4,488,543
1898 . .	19,937	6,316,866	4,554,165
1899 . .	20,064	6,417,514	4,636,938
1900 . .	20,100	6,509,611	4,666,130

Voluntary schools are Church of England (National), Roman Catholic, British, Wesleyan, and Jewish. The number of voluntary schools of various denominations, and of board schools inspected, and the average attendance at the schools in 1881, 1891, and 1900 were :—

Denomination and Year (ending August 31).		Schools Inspected.	Average Attendance.
Church of England .	1881	11,589	1,490,429
	1891	11,908	1,675,634
	1900	11,804	1,882,854
British, Wesleyan, &c.	1881	1,992	544,113
	1891	1,893	384,597
	1900	1,553	350,899
Roman Catholic . .	1881	789	152,641
	1891	955	195,663
	1900	1,052	255,124
Board schools . .	1881	3,692	856,351
	1891	4,779	1,498,599
	1900	5,691	2,177,253

In 1901 there were in England and Wales 2545 school boards and 788 school attendance committees. The voluntary school associations formed up to March 31, 1901, numbered 75, of which 46 were Church of England, 17 British and Wesleyan, 11 Roman Catholic, and 1 Jewish. There were 181 unassociated voluntary schools.

The increase in the number of teachers in elementary schools is shown thus :—

Years.	Certificated Teachers.	Assistant and Additional.	Pupil Teachers.
1881 . .	33,562	11,018	33,639
1891 . .	47,823	29,189	28,131
1900 . .	64,038	49,948	29,393

Of the certificated teachers in 1900, 24,557 were men, and 39,481 women. Of the assistant and additional teachers, 5121 were men. There are 44 residential training colleges, of which 30 belong to the Church of England, 11 are British, Wesleyan, &c., and 3 are Roman Catholic. They contained in 1899, 3866 students. There were also 1334 students in 16 day training colleges. In addition to the day schools there were, in 1900, 5263 evening continuation schools, with an average attendance of 206,335.

For the building of schools and for permanent structural improvements, loans are advanced to school boards by the Public Works Loan Commissioners, and are obtained otherwise on the security of the rates. Up to April 1, 1900, the loans amounted to £39,428,860; the outstanding balance on September 29, 1899, amounted to £29,352,590.

The income of public elementary schools is derived partly from Government grants and partly from local sources. The local income is mainly from endowment, voluntary contributions, school pence, rates, and county council grants. The local income, the total income, and the total expenditure of elementary schools in 1881, 1891, and 1900 were as follows :—

Years.	Revenue.		Expenditure.
	Local.	Total.	
	£	£	£
1881 . .	3,194,175	5,349,840	5,336,979
1891 . .	4,480,162	7,813,706	7,829,655
1900 . .	4,334,005	12,336,986	12 453,006

In the school year ending August 31, 1900, the income and expenditure of voluntary and board schools were :—

Schools.	Revenue.		Expenditure.
	Local.	Total.	
	£	£	£
Church of England .	937,609	4,345,148	4,418,988
British, Wesleyan, &c. .	223,607	881,758	909,248
Roman Catholic . .	93,835	556,327	572,555
Board	3,078,954	6,553,753	6,552,215
Total . .	4,334,005	12,336,986	12,453,006

Of the amount expended in 1900, £407,960 was devoted to evening continuation schools. In 1899 the average rate per £ on the rateable value for school purposes was in England 10·9d. In London it was 12·9d.; in boroughs, 10·1d.; and in rural parishes, 9·7d. In Wales the average rate was 11·1d.; in boroughs, 10·3d. ; in parishes, 11·5d.

Secondary Schools.—Many school boards maintain higher grade schools, with an upper portion arranged as an organized science school. Of these schools there were 54 in 1897. In 38 towns there were 43, with an average attendance of 681 pupils each. In 1901 an Act was passed obviating the effect of the legal decision in what was known as the Cockerton Case, and enabling school boards (with the sanction of county councils or other local authorities) to support from the rates higher or technical instruction in their schools. With respect to secondary schools in England, there are no comprehensive official statistics, but in 1897 the Committee of Council on Education instituted an inquiry into their number, and the numbers of their teaching staff and pupils. The great majority of the schools owe their existence to private enterprise, their administration and the instruction given in them being in the hands of the owners. Others are supported by subscriptions, and are controlled by committees of subscribers. A considerable number belong to companies, formed under articles of association with limited liability. The endowed schools are variously regulated—some under the Charitable Trusts Acts, others under the Endowed Schools Acts, while a few are regulated by their charters, special Acts of Parliament, and in other ways. A small number of secondary schools is under local public authority. The number of secondary schools in England, exclusive of Monmouthshire, and the number of their pupils on June 1, 1897, according to the results of the inquiry, are set forth as follows :—

Form of Control.	For Boys.		For Girls.		Mixed.	
	Schools.	Pupils.	Schools.	Pupils.	Schools.	Pupils.
Private enterprise	1311	46,617	2886	80,286	970	26,027
Subscribers .	70	8,719	99	6,321	28	3,626
Companies .	48	5,188	99	13,238	3	308
Endowed, &c. .	502	59,517	86	14,119	31	3,035
Local authority .	27	2,272	3	3,275	46	6,996

Of the 6209 schools to which the return relates, 1958 were for boys, 3173 were for girls, and 1078 were mixed. The total number of boys at the schools was 158,502, and of girls 133,042, or, respectively, 5·4 and 4·5 per 1000 of the total population of England (exclusive of Monmouthshire) in 1897. Of the pupils, 68,785, or 24·8 per cent. of the whole, were boarders. The teaching staff of the schools consisted of 8362 attached male teachers, and 14,980 female, with 6874 visiting male teachers, and 5204 female. Of the male teachers (attached and visiting), 5821 were university graduates ; of the female, 2323.

By the Board of Education Act, 1899, provision was made for the inspection of secondary schools desiring to be inspected, except those under the Welsh Intermediate Education Board. This board, constituted under the Welsh Intermediate Education Act, 1889, consists of 80 members appointed by councils of counties and county boroughs, school-governing bodies and other bodies interested, and it provides for the inspection and examination of secondary schools in Wales and Monmouthshire. In 1899, 93 schools were examined, of which 22 were for boys, 21 for girls, 43 dual, and 7 mixed. The teaching staff consisted of 241 male and 204 female attached teachers, besides 204 visiting teachers. Of 7390 pupils examined, 3877 were boys, and 3513 were girls.

In England and Wales technical instruction has made great progress, and technical schools have been multiplied. In London the City and Guilds Technical Institute has a central college, an intermediate college, and 2 schools, employing in all about 76 professors and teachers, and giving instruction to over 1600 students. The metropolis contains many other institutions of a similar nature, among them being the Northampton Institute, the Regent Street Polytechnic, the Bolt Court Technical School, the Camberwell School of Arts and Crafts, the Central School of Arts and Crafts, the Hackney Technical Institute, the Crafts School, Mile End, Herold's Institute, the Shoreditch Municipal Technical School, and the National Training School of Cookery. But in addition to such institutions primarily intended for technical instruction, over 100 schools and colleges and institutes in London have been turned to account for the same purpose. Throughout the counties and boroughs of England and Wales similar development has taken place. Municipal and other technical institutes have been founded in great numbers, while already-existing colleges, grammar schools, and board schools are encouraged and assisted in the work of technical instruction. The amount expended by local authorities on technical instruction in the year 1897–98 in England and Wales was : from grant under Local Taxation (Customs and Excise) Act, £756,717 ; from rates, £97,739 ; total, £854,456. The estimated total for the year 1898–99 was £870,087.

In 1899 the Board of Education had 2056 science schools in England and Wales and Ireland, the number of science pupils being 174,670, while the number of its art schools and classes was 1745, with 130,126 pupils. For the year 1901–02 the parliamentary vote for art and science schools amounted to £321,295.

Colleges.—In England, in 1900, there were 11 university colleges, receiving annual parliamentary grants amounting in the aggregate to £24,000 ; in Wales there were 3, each receiving annually a grant of £4000. Among the subsidized English colleges is Bedford College, London, for ladies ; similar institutions not receiving grants are Newnham College and Girton College, Cambridge ; Lady Margaret Hall and Somerville Hall, Oxford ; and the Royal Holloway College, Egham.

New Universities.—In 1878 the University of London received a supplemental charter whereby women are admitted equally with men to its degrees and honours, and in 1900 it was reconstituted so as to have teaching as well as examining functions. The first schools of the university are University College and King's College, London, 6 theological colleges, 2 colleges for ladies, 10 medical schools, and 4 other schools and colleges. Provision is also made for the admission from time to time of other institutions as schools of the university. Victoria University was created by charter in 1880, with power to grant degrees to men and women who have studied in its colleges ; in 1883 it was empowered to confer medical degrees. Its colleges are Owen's College, Manchester ; University College, Liverpool ; and the Yorkshire College, Leeds. The University of Wales was created in 1895, with power to grant degrees (but not medical degrees) to men and women. Its constituent colleges are those of Aberystwith, Bangor, and Cardiff. The University of Birmingham, created by charter of May, 1900, is a teaching and examining university, and confers degrees on persons of either sex.

University and College Attendances.—The University of Oxford in 1899 had 3446 undergraduates, 814 students having matriculated during the year. The University of Cambridge in 1900 had 2985 undergraduates ; in 1899–1900 there were 932 matriculations. The University of Durham had in 1899, 170 students. In 1900 the 2 Colleges for ladies at Oxford contained 141 students, and the 2 at Cambridge, 286 ; that in London had 183, and that at Egham, 120. At other university colleges (except those at Aberystwith, Bangor, and Lampeter, and the Medical College at Newcastle), the attendance of students is largely in the evening, and in the following figures, referring to the winter session of 1900, both day and evening students are included. University College and King's College, London, had together 2565 students. The 3 colleges associated together in the Victoria University had 2400 ; the 3 within the University of Wales had 2730 ; the 2 at Newcastle (1 of medicine and the other of science), connected with Durham University, had 1700 students ; Mason College, Birmingham, had 935 ; and the 4 colleges at Nottingham, Sheffield, Bristol, and Lampeter had altogether 3600 students.

Charities.

The information concerning the endowed charities of England and Wales contained in the Reports of the Commission of 1818 to 1837 has been and is being supplemented by digests compiled by the Charity Commissioners, and, since 1892, by the results of local inquiries, towards the cost of which the County Councils are authorized to contribute. As yet, however, there is no complete account of the income of these charities. According to a return laid before Parliament in 1898, the amount applicable for alms-people and pensioners, and the amount applicable to gifts of money and in kind, were at that date, as far as had been ascertained, as follows:—

	For Alms-people and Pensioners.	For Distribution.
	£	£
I. Results of Local Inquiry—		
West Riding of Yorkshire . .	37,918	13,330
Part of Wales	3,156	3,739
II. According to Digests, 1868–76, and Supplementary Digests, 1890–97	301,887	218,790
III. According to Digests, 1868–76 .	268,504	91,796
Total	611,465	327,655
	£939,120	

In the 48th Report of the Commissioners it is stated that the number of returns of accounts of charities made to their office in 1900 was 36,754; in 1899, 38,516; in 1898, 29,478; but according to the 46th Report the number of charities from which accounts were annually due in 1898 was 70,547. The stock and investments which had been transferred to the official trustees of charitable funds (exclusive of retransferments) from 1854 to December 31, 1900, amounted to £20,829,650.

The number and value of endowed charities is rapidly increasing. In the 20 years 1875–94 charities of £1000 and upwards subject to the Charitable Trusts Acts were founded, amounting to over £8,000,000, and in the 5 years 1895–99 the new charities in the aggregate amounted to over 2½ millions sterling. On the average, about 500 new charities are created annually, and the average amount annually so given is estimated at a capital value of about £1,000,000, of which about half is permanent, or subject to a perpetual trust for investment, and the remainder is not so subject.

Of the large amount annually raised by voluntary contribution for charitable purposes in England and Wales, no trustworthy estimate can be formed. In the metropolis the income of charitable institutions (exclusive of the amount devoted to religious purposes) is probably not much less than £4,000,000, of which about £950,000 goes to the hospitals, general and special. The number of hospitals in London and its suburbs is about 126; 23 are general and 76 are for special diseases, and there are about 27 suburban and cottage hospitals. Of the general hospitals, 13 are provided with medical schools. St Bartholomew's Hospital in 1899 had an income, from all sources, amounting to £72,454; treated 6343 in-patients and 14,017 out-patients, besides 125,233 cases of accident, &c. The income of St Thomas's Hospital was £72,841, of which £46,792 was from estates; the in-patients during 1899 numbered 5831; the out-patients, 18,417; and the cases of accident, &c., 44,920. In the same year the London Hospital had a total income of £93,679, of which £61,521 was ordinary income; the in-patients numbered 13,234, and the out-patients, 189,638. Guy's Hospital had an ordinary income of £41,541, and to meet current expenditure £38,479 was transferred from permanent funds; it had 7548 in-patients and 85,198 out-patients during the year. St George's Hospital had a total income of £29,692; St Mary's Hospital, £32,513; and the Royal Free Hospital, £11,930. The Bethlehem Hospital for lunatics had in 1899 a revenue of £39,000; the patients cared for during the year were 179 men and 259 women, besides 47 men and 63 women at the Witley convalescent estate. Owing to the decrease in the value of land and from other causes, the permanent income of several of the hospitals has decreased in recent years, and consequently many of the beds have been unoccupied. The amount raised by the Hospital Sunday Fund in 1901 was £51,000; in 1900, £49,500; in 1899, £53,504. The Hospital Saturday Fund in each of those years raised about £20,000. The Prince of Wales's Hospital Fund for London amounted, at the beginning of 1900, to £315,364, of which £176,015 remained in hand.

Religion.

There are no comprehensive statistics showing the population of England and Wales according to religious denominations. In the Registrar-General's Report for 1899 the number of churches and chapels of the Established Church in which marriages could be solemnized was stated to be 15,309, and the number of buildings on the register for marriages by rites other than those of the Church of England was 12,578. The latter number comprised 2551 Congregationalist buildings, 2195 Baptist, 2695 Wesleyan, 1124 Primitive Methodist, 533 United Methodist Free Church, 203 Methodist New Connexion, 96 other Wesleyan Methodist, 665 Calvinistic Methodist, 397 Presbyterian, 177 Unitarian, 149 Bible Christian, and 678 belonging to other bodies. Of 1000 marriages solemnized in each of the years 1881, 1891, 1898, and 1899, the proportion solemnized according to the rites of the Church of England, and of those solemnized otherwise was as follows:—

	1881.	1891.	1898.	1899.
Established Church .	715	699	685	678
Roman Catholic . .	45	42	40	41
Various other Christian .	111	118	121	124
Friends	0·3	0·3	0·4	0·3
Jews	2·5	4·6	5·7	6·4
In Registrar's office .	126	136	148	150

Judged by this test, the Church of England predominates over the length and breadth of England and Wales, except in the northern counties of Wales.

Established Church.—In 1900 the Established Church was governed by 2 archbishops, 33 bishops, 17 suffragan and 5 assistant bishops in England and Wales. Since the year 1880 five bishoprics have been founded or reconstituted, one of them, that of Bristol, being in the province of Canterbury, and the others in the province of York. These new dioceses, with the year of their foundation and the amount of annual income, are as follows:—Liverpool, 1880, income, £4000; Newcastle, 1882, income, £3500; Southwell, 1884, income, £3500; Wakefield, 1888, income, £3000; Bristol, 1897, income, £3000. The see of Bristol was originally founded in 1542, but in 1836 it was united with that of Gloucester. In 1897, however, it was, by Order in Council, reconstituted as a separate diocese. Steps were being taken in 1901 towards the foundation of a bishopric of Southwark, with an endowment of £4000 a year. Under the bishops are 31 deans, 91 archdeacons, and 810 rural deans. The total number of bishops and clergymen at work in 1899 was approximately 22,800, of whom 13,873 were beneficed, the remainder being curates and unbeneficed clergymen. Church extension is steadily progressing, churches and chapels being built, new districts and parishes formed, and the incomes of the poorer clergy increased. This work is being advanced with the assistance of diocesan funds, and by the labours of 31 diocesan Church extension societies. The number of new districts, parishes, &c., formed in the year 1898–99, under the Church Building and New Parishes Acts, was 26, and in the years 1818 to 1899, 3725. The voluntary contributions alone which were applied to this purpose in the 16 years 1884–99 amounted to £21,858,548, of which £17,531,626 was applied to church building and restoration, £2,348,611 to endowments, £1,567,739 to parsonages, and £410,572 to burial-grounds. Through the instrumentality of the Ecclesiastical Commissioners, assisted by private liberality, the incomes of the underpaid clergy have been largely increased, 5800 benefices having been augmented during the years 1840 to 1898, the total annual income being increased by £1,032,300. Within the Church there are many clerical and lay agencies for school work, for home and foreign mission work, and for many other purposes, for which voluntary contributions of large amount are received. The gross annual income of the Church of England, according to a return of the Ecclesiastical Commissioners in 1891, was as follows, from ancient endowments and from benefactions since 1703:—

	Ancient Endowments.	Private Benefactions since 1703.
	£	£
Archiepiscopal and Episcopal sees .	87,827	11,081
Cathedral and Collegiate churches	192,460	—
Ecclesiastical benefices . . .	3,941,057	272,605
Ecclesiastical Commissioners .	1,247,827	—
Queen Anne's bounty . . .	—	700
Total	£5,469,171	£284,386

The income from voluntary contributions for church purposes, raised by offertories in church and by parochial organization, in 1897–98 was £5,919,706, in 1898–99, £5,954,738, and in 1899–1900, £5,504,395. If to these sums be added the money contributed for general purposes, the total for 1898–99 rises to £7,464,430, and for 1899–1900, £7,770,993; but this is exclusive of many contributions devoted to church or parish purposes through other channels. The Church House at Westminster is regarded as a centre for the many societies within the Church of England. It contains a large hall, library, and offices, and though not yet complete, it began to be used by Convocation in 1896. It is intended that the building shall contain a hall for the use of the House of Laymen.

Roman Catholics.—The number of Roman Catholics in England and Wales in 1891 was estimated at about 1,500,000, but there are no trustworthy statistics on the subject. The Roman Catholic hierarchy in England in 1900 consisted of 1 archbishop and 14 bishops, besides 2 auxiliary bishops and a coadjutor bishop. In Wales there was a bishop, vicar-apostolic. At the same date the number of officiating Roman Catholic clergy in England and Wales was 2837, and of their chapels and stations, 1536.

Protestant Dissenting Bodies.—The Protestant Dissenting bodies are numerous and active, possessing organizations for charitable work and for home and foreign mission work, their efforts for the last-named purpoes being made largely through the London Missionary Society, while they raise large amounts annually for congregational purposes. The following list, which shows the number of members (communicants), of ministers, of local preachers, and of sittings in the churches and chapels of the several bodies, refers in general to the year 1900:—

	Members.	Ministers.	Local Preachers.	Sittings.
Congregational . .	398,741	2509	5,050	1,643,400
Baptist . . .	346,083	1855	5,074	1,273,325
Presbyterian . .	74,541	336	—	164,491
Wesleyan . . .	552,933	1858	17,834	2,224,057
Primitive Methodist .	185,075	1060	15,730	962,720
Calvinistic Methodist	156,058	626	409	451,200
United Methodist Free Church . . .	78,692	355	3,028	426,500
Meth. New Connexion	35,962	193	1,029	137,478
Bible Christian . .	29,150	169	1,473	153,600
Friends . . .	16,611	—	400	—
Churches of Christ .	11,939	—	397	20,000
Independent Methodist	8,599	—	495	33,000
Wesleyan Reform Union . . .	7,192	18	—	43,834
Moravians . . .	3,371	51	—	—
Lady Huntingdon Connexion . . .	2,355	29	—	13,347
Free Church of England . . .	1,500	27	—	6,500
Reformed Episcopal .	1,500	28	—	7,200

The Unitarians have about 345 chapels. Smaller bodies are the Catholic Apostolic Church, with about 80 churches, and the New Jerusalem Church, with about 75 societies. The Salvation Army, a religious body with a quasi-military organization, has carried on since 1865 active work, both of a spiritual and social nature, and has extended its labours to the colonies and to many foreign countries. In the United Kingdom alone it has 1610 corps and societies, with 4854 officers and others wholly engaged in its work, and it maintains 142 institutions for assisting the destitute, or for rescuing those who have lapsed into crime or immorality. At these institutions, in 1899, work was obtained for 12,460 applicants; over 2½ million cheap meals and nearly 1¾ million cheap lodgings were provided, for which (combined) the recipients paid £33,610. There were received into homes in the same year 2129 women and girls, of whom 1820 were sent to situations or restored to their friends.

The number of Jews in England and Wales in 1899 was estimated at 97,350, the great majority of them being in London. They have about 80 synagogues, and about 100 ministers.

Agriculture.

The land area of England and Wales extends over 37,120,000 acres, of which, on the average of the three years 1897–99, 27,591,000 acres are under crops and grass, 3,427,000 acres consist of mountain and heath land used for grazing, and 1,848,000 acres (according to an estimate of 1895) are under woods and plantations; the area which is not arable, nor pastoral, nor woodland, thus extends to 4,254,000 acres. The following statement shows the distribution of these areas in England and in Wales, and the proportion which each bears to the total land area:—

Description of Land.	England.		Wales.	
	Area.	Per cent.	Area.	Per cent.
	Acres.		Acres.	
Under crops and grass (1897–99) . .	24,763,000	76·6	2,828,000	59·6
Mountain and heath land used for grazing (1897–99) . .	2,243,000	6·9	1,184,000	24·9
Woods and plantations (1895) . . .	1,666,000	5·1	182,000	3·9
Other land areas .	3,703,000	11·4	551,000	11·6
Total land area .	32,375,000	100·0	4,745,000	100·0

The area under crops and grass in England and Wales in 1881, 1891, 1896, and 1900 was as follows:—

	1881.	1891.	1896.	1900.
	Acres.	Acres.	Acres.	Acres.
Corn crops—				
Wheat . .	2,731,071	2,253,983	1,656,228	1,796,210
Barley . .	2,171,817	1,889,533	1,886,481	1,750,070
Oats . .	1,870,548	1,906,890	2,087 372	2,076,960
Rye . .	34,277	39,167	66,387	47,566
Beans . .	420,327	339,377	238,115	250,116
Peas . .	215,233	203,181	195,251	155,837
Total corn crops	7,443,273	6,632,131	6,129,834	6,076,759
Green crops—				
Potatoes .	390,173	392,844	433,952	430,161
Turnips and swedes .	1,545,038	1,438,567	1,408,218	1,223,372
Mangold .	346,771	353,348	336,399	411,755
Cabbage, &c.	139,437	147,666	151,244	181,705
Vetches		216,370	167,598	168,263
Other green crops	383,084	103,840	131,560	139,611
Total green crops	2,806,503	2,652,635	2,628,971	2,554,867
Grasses, &c., under rotation—				
For hay	2,880,353	1,762,851	1,778,992	1,795,558
Not for hay		1,323,914	1,245,473	1,369,162
Total .	2,880,353	3,086,765	3,024,465	3,164,720
Flax . .	6,243	1,791	1,765	466
Hops . .	64,943	56,145	54,249	51,308
Small fruit .	—	54,077	70,885	67,858
Fallow . .	776,167	420,041	424,505	301,230
Total arable	13,977,662	12,903,585	12,334,674	12,217,207
Permanent pasture—				
For hay	13,471,238	4,349,685	4,467,991	4,241,343
Not for hay		10,747,864	10,862,960	11,079,579
Total . .	13,471,238	15,097,549	15,330,951	15,320,922
Total—Crops and grass	27,448,900	28,001,134	27,665,625	27,538,130

The horses (used for agriculture), cattle, sheep, and pigs in the same years were in number as follows :—

	1881.	1891.	1896.	1900.
	Number.	Number.	Number.	Number.
Horses . .	1,231,870	1,293,236	1,346,003	1,305,605
Cattle . .	4,815,430	5,629,524	5,286,582	5,607,084
Sheep . .	17,849,801	21,108,658	19,238,820	19,277,229
Pigs . .	1,925,072	2,731,267	2,734,186	2,249,519

In 1900 the agricultural animals were thus distributed between England and Wales :—

	Horses.	Cattle.	Sheep.	Pigs.
England . .	1,152,321	4,848,698	15,844,713	2,021,422
Wales . .	153,284	758,386	3,432,516	228,097

The figures given above show that between 1881 and 1900 the arable area of England and Wales decreased nearly 13 per cent., while the permanent pasture increased nearly 14 per cent. The acreage under wheat contracted 34 per cent., while that under oats extended 11 per cent. Flax cultivation, never extensive, shrank almost out of existence, while the cultivation of small fruit increased. It should be mentioned, also, that the orchard area of England and Wales, yielding grass or other produce, besides fruit, expanded from 183,033 acres in 1881 to 208,069 in 1891, 219,319 in 1896, and 226,378 in 1899.

The area of England (apart from Wales) is divided into two sections, "arable" and "grass," corresponding with the old division into "corn counties" and "grazing counties," except that the county of Leicester is included not in the "grass" but in the "arable" section." Most of the eastern part of England is "arable," while the western and northern part is "grass," the boundary between the sections being the western limit of the counties of Hants, Berks, Oxford, Warwick, Leicester, Nottingham, and of the East Riding of Yorkshire. The difference between the agricultural conditions of the sections is shown by the following table, giving the acreage under crops and grass, and the number of agricultural animals, with the proportion per cent. in each section in 1899 :—

	Acreage.		Percentage.	
	Arable Section.	Grass Section.	Arable Section.	Grass Section.
	Acres.	Acres.		
Arable land—				
Corn crops . .	3,692,240	2,063,236	64·2	35·8
Green crops . .	1,436,936	973,020	59·6	40·4
Clover, grass, &c. (rotation) . .	1,340,891	1,465,719	47·8	52·2
Hops, small fruit, &c.	88,686	28,489	69·8	30·2
Fallow . . .	236,144	86,440	73·2	26·8
Total arable . .	6,794,897	4,616,904	59·5	40·5
Permanent pasture—				
For hay . . .	1,481,219	2,272,648	39·5	60 5
Not for hay . .	3,606,044	5,964,249	37·7	62·3
Total permanent pasture .	5,087,263	8,236,897	38·2	61·8
Total crops and grass . .	11,882,160	12,853,801	48·0	52·0
Orchards . . .	70,581	152,131	31·7	68·3
Woods and plantations (1895) . . .	825,266	840,475	49·5	50·5
Mountain and heath, for grazing . . .	216,509	2,055,254	9·5	90·5
Farm animals—	Number.	Number.		
Horses . . .	576,555	587,157	48·8	51·2
Cattle . . .	1,815,258	3,026,595	37·5	62·5
Sheep . . .	7,314,478	8,946,939	45·6	55·0
Pigs	1,018,650	1,143,770	48·6	51·4

The yield of the principal crops in England and in Wales in 1891, 1896, and 1900, and the yield per acre in the same years, are shown in the following statement :—

Crops.	England.			Wales.		
	1891.	1896.	1900.	1891.	1896.	1900.
	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.
Wheat .	68,694,456	54,523,269	49,528,385	1,461,740	1,078,090	1,332,299
Barley .	60,900,824	59,843,547	50,977,265	3,438,620	2,823,170	3,341,872
Oats . .	69,786,175	69,402,150	73,604,178	7,698,529	7,179,786	7,238,305
Beans . .	9,965,524	5,974,472	6,928,152	54,834	30,631	32,643
Peas . .	5,702,714	4,911,734	3,995,030	30,633	25,580	33,391
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Potatoes .	2,050,923	2,539,363	1,986,103	207,851	218,264	153,162
Turnips, &c.	17,703,675	14,656,350	15,855,318	1,010,162	956,958	965,943
Mangold .	6,597,827	4,968,364	8,243,735	130,485	98,754	170,947
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Hops . .	436,716	453,188	347,894	—	—	—
Hay . .	140,646,306	105,860,449	138,619,980	12,902,192	9,726,309	14,130,322
	Per Acre.	Per Acre.	Per Acre.	Per Acre.	Per Acre.	Per Acre.
	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.
Wheat. .	31·33	33·88	28·39	23·73	22·95	25·79
Barley. .	34·36	33·64	30·99	29·36	26·21	31·81
Oats . .	41·72	37·60	39·56	32·89	29·71	33·44
Beans . .	29·54	25·27	27·88	29·11	20·68	25·34
Peas . .	28·31	25·40	25·94	19·98	16·64	21·65
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Potatoes .	5·78	6·35	5·00	5·44	5·45	4·61
Turnips .	12·94	10·96	13·66	14·31	13·47	15·34
Mangold .	19·10	15·10	20·51	16·55	13·28	17·37
	Cwt.	Cwt.	Cwt.			
Hops . .	7·78	8·36	6·78	—	—	—

The number of agricultural holdings in England and Wales arranged in 4 classes according to their size, and the acreage comprised in each class, in 1885 and in 1895, are given in the subjoined table. The first class includes holdings of 1 acre and not over 5 acres ; the second, those over 5 and not over 50 ; the third, those over 50 and not over 300 ; while the fourth class comprehends all over 300 acres :—

Holdings.		England.		Wales.	
Acres.		Number.	Acreage.	Number.	Acreage.
1–5	1885	103,229	286,526	11,044	34,352
	1895	101,428	279,641	11,763	36,633
5–50	1885	170,431	3,262,033	29,715	620,651
	1895	170,591	3,288,669	30.969	635,024
50–300	1885	104,073	13,571,338	17,888	1,969,045
	1895	106,955	13,837,899	18,113	1,988,034
Over 300	1885	16,148	7,761,654	460	193,789
	1895	15,578	7,452,852	443	179,668
Total	1885	393,881	24,881,551	59,107	2,817,837
	1895	394,552	24,859,061	61,288	2,839,359

In 1895 the number of allotments under 1 acre in size in England was 522,163; in Wales, 12,179. It would appear that between 1885 and 1895 the small holdings of 1 to 5 acres decreased in number and in acreage in England, but increased in Wales, and that the tendency was towards increase in the number and area of holdings from 5 up to 300 acres, but towards decrease in the case of those over 300 acres.

Most of the agricultural holdings in England and Wales are rented, but the acreage of those farmed by the owners is considerable. In the following table the holdings are grouped in 8 classes according to size, the first class consisting of those over 1 acre and not over 5 acres. The figures show for 1895 the aggregate area of the cultivated land, and the percentage of owner-farmed land in each class. For large farms this percentage is high ; it is at its lowest in the class embracing holdings of from 50 to 100 acres, and it slowly rises as the holdings decrease in size :—

Holdings of Acres.	England.		Wales.	
	Total Area.	Owner-Farmed. Per cent. of total.	Total Area.	Owner-Farmed. Per cent. of total.
	Acres.		Acres.	
1–5	265,268	17·5	35,633	11·8
5–20	1,210,716	15·3	211,267	12·6
20–50	2,077,953	13·0	423,757	11·0
50–100	3,403,761	11·5	749,465	10·8
100–300	10,434,138	11·6	1,238,569	11·0
300–500	4,188,651	15·8	142,925	12·8
500–1000	2,570,684	25·3	32,818	42·8
Over 1000	693,517	40·8	3,925	69·4
Over 1 .	24,844,688	14·9	2,838,359	11·6

Thus it appears that in England and Wales, in 1895, of the total acreage under crops and grass, 14·5 per cent. belonged to owner-farmed holdings.

In 1881, according to the census returns, there were in England and Wales 1,278,624 persons (including 64,171 females) engaged in agriculture, those who worked "in fields and pastures" being to the number of 1,196,836 (including 61,073 females). In 1891 there were 1,311,720 persons (including 51,696 females) engaged in agriculture, but the number of those who worked "in fields and pastures" had fallen to 1,096,362 (including 45,999 females).

Communications.

Roads.—In England and Wales the high-roads, or roads on which wheeled vehicles can travel, are of two classes: (1) the main roads, or the great arteries along which the main traffic of the country passes; and (2) ordinary highways, which are by-roads serving only local areas. The length of the former in 1882 was stated to be 12,199 miles; in 1899, 22,025 miles. The mileage of the ordinary highways in 1882 was stated to be 102,615; in 1899, 96,573. By the Local Government Act of 1888 the duty of maintaining main roads was imposed on county councils, but these bodies were enabled to make arrangements with the respective highway authorities for their repair. Under the Local Government Act of 1894 the duties of all the highway authorities were transferred to the rural district councils on or before March 31, 1899.

For the year 1898–99 the total receipts of all the highway authorities (exclusive of £29,721 from loans) amounted to £2,217,703, of which £1,410,931 was from rates, the remainder being chiefly from Local Taxation Account and County Council contributions. The expenditure (exclusive of £23,587 from loans) amounted to £2,188,422, of which £350,228 was spent on repairs of main roads, and £1,632,070 on repairs of ordinary highways. In England and Wales the assessable value for the purposes of highway authorities was £40,508,545, and on this value the rates levied for highway purposes were equivalent to 8·4d. on the £. The last turnpike trust ceased to exist on November 5, 1895, and the final accounts in connexion with its debt were closed in the year 1898–99.

Railways.—In the period from 1880 to 1899 the mileage of the railways of the United Kingdom increased by 21 per cent., while their paid-up capital was augmented to the extent of 58 per cent. In 1880 their total length was 17,933 miles; in 1890, 20,073 miles; in 1900, 21,855 miles. Their authorized capital in 1880 amounted to £802,014,004; in 1890, to £1,004,529,164; in 1900, to £1,302,674,079. The paid-up capital rose from £728,316,848 in 1880 to £897,472,026 in 1890, and £1,176,001,890 in 1900. The growth of the railway systems of England and Wales alone during the same period is shown by the following figures, giving the length of line, double (or more) and single, the authorized capital and the paid-up capital on December 31 of the years named :—

Years.	Length of Line.			Capital.	
	Double or More.	Single.	Total.	Authorised.	Paid-up.
	Miles.	Miles.	Miles.	£	£
1880	8,105	4551	12,656	663,067,719	602,242,578
1890	9,094	5025	14,119	833,049,003	740,033,907
1895	9,481	5170	14,651	924,256,307	825,195,880
1899	9,933	5111	15,044	1,071,417,937	950,179,607
1900	10,101	5086	15,187	1,095,042,057	970,147,581

The English and Welsh railways for their whole length, except 124 miles, have a gauge of 4 ft. 8½ in.

The number of passengers carried in the course of a year on the railways of the United Kingdom increased between 1880 and 1900 by 88 per cent., and the weight of goods carried, by 81 per cent., while the receipts from passenger traffic had an increase of 67 per cent., and those from goods traffic an increase of 49 per cent. The number of passengers conveyed (exclusive of season ticket-holders) in 1880 was 603,885,025; in 1890, 817,744,046; in 1900, 1,142,276,686. The total weight of goods carried in 1880 was 235,305,629 tons; in 1890, 303,119,427 tons; in 1900, 424,929,513 tons. The receipts from passenger traffic in 1880 amounted to £27,200,464; in 1890, to £34,327,965; in 1900, to £45,383,988. The receipts from goods traffic in 1880 reached £35,761,303; in 1890, £42,220,382; in 1900, £53,470,564. The number of season ticket-holders in 1880 was 502,174; in 1900, 1,749,804. In 1880 the goods traffic comprised 165,670,304 tons of minerals; in 1900, 306,389,083 tons, the receipts for the carriage of which amounted to £22,870,694. The expansion of the passenger and goods traffic and of the receipts therefrom in England and Wales alone are shown in the following statement:—

Years.	Passengers Conveyed.	Goods Carried.	Receipts for Carriage of	
			Passengers.	Goods.
	Number.	Tons.	£	£
1880 .	540,669,175	200,393,357	23,141,055	30,457,932
1890 .	721,114,781	259,150,132	29,207,694	35,976,180
1895 .	816,921,056	280,324,042	31,687,774	37,014,948
1899 .	959,601,776	350,070,663	37,225,740	44,186,881
1900 .	992,425,769	359,524,742	38,633,679	45,339,962

The number of season ticket-holders (not included in the number of passengers in the table) was, in 1880, 449,823; in 1900, 1,610,754. The weight of minerals carried on the English and Welsh railways in 1880 was 140,965,835 tons; in 1900, 256,895,900 tons, the receipts for the carriage of minerals in the latter year having amounted to £19,528,603. Of the railway passengers in the United Kingdom in 1900, 34,318,809 travelled in first-class carriages; 69,804,629 in second-class; and 1,038,873,248 in third-class. Of the passengers on the English and Welsh railways alone, 27,446,980 travelled in first-class, 65,157,076 in second-class, and 899,821,713 in third-class carriages. The total receipts of the railways of the United Kingdom for the year 1880 amounted to £65,491,625; the working expenses to £33,601,124; and the net receipts to £31,890,501, or 4·38 per cent. of the paid-up capital. For 1900 the total receipts reached the sum of £104,801,858; the working expenses, £64,743,520; and the net receipts, £40,058,338, or 3·41 per cent. of the paid-up capital. Of the railways in England and Wales alone, the total receipts, the working expenses, and the net receipts, with their proportion per cent. of paid-up capital, were as follows in various years. The receipts include not only those from traffic, but also those from rents, tolls, &c. :—

Years.	Receipts.	Working Expenses.	Net Receipts.	
			Amount.	Per cent. of Paid-up Capital.
	£	£	£	
1880 .	55,795,186	28,577,111	27,218,075	4·52
1890 .	68,272,908	36,964,577	31,308,331	4·23
1895 .	72,791,758	41,126,298	31,665,460	3·83
1899 .	86,708,006	51,922,103	34,785,903	3·65
1900 .	89,392,501	55,882,810	33,509,691	2·89

In 1880 the railways of the United Kingdom had 13,384 locomotive engines; in 1900, 21,195. In 1880 they had 29,565 carriages for passengers; in 1900, 47,433. In 1880 the waggons, &c., numbered 402,901; in 1900, 727,784. The increase in the rolling stock of the English and Welsh railways is shown as follows:—

Years.	Locomotives.	Passenger Carriages.	Waggons, &c.
1880	11,172	24,658	301,921
1890	13,731	31,374	426,791
1895	15,901	35,773	486,394
1899	17,411	38,805	537,786
1900	18,040	40,115	559,917

In England and Wales there are about 190 railway companies, but most of them are small, and of 81 companies the lines have been leased to, or are worked by, the great companies named in the subjoined table. The mileage and traffic include those of the absorbed companies' lines. The figures relate to the year 1900:—

Companies.	Miles Open.	Goods Carried.	Passengers Carried.
		Tons.	Number.
Great Western	2627	37,500,510	80,944,483
London and N.-Western	1937	44,465,277	82,069,743
North-Eastern	1654	53,126,913	57,573,747
Midland	1437	40,937,111	51,932,911
Great Eastern	1110	11,642,386	116,103,401
London and S.-Western	898	6,411,400	63,710,860
Great Northern	825	17,548,466	37,671,162
S.-E. and Chatham	609	6,655,824	73,834,089
Lancashire and Yorks	556	21,795,887	64,665,969
Great Central	494	20,779,795	18,443,272
London, Brighton, and S. Coast	448	4,262,974	55,770,005

On the Metropolitan Railway of 73 miles there were 77,126,753 passengers; on the Metropolitan District, 19 miles, 40,444,073 passengers; and on the North London, 12 miles, 38,382,728 passengers in 1900, the numbers being in each case exclusive of season ticket-holders.

Light Railways.—The railway statistics given above do not include those relating to light railways, for the construction of which in Great Britain encouragement was offered by the Light Railways Act, 1896, with a view to benefiting agricultural, fishing, and other interests. A Commission which is continued under the Expiring Laws Continuance Act (1901), examines schemes and submits its Orders to authorize light railways for confirmation by the Board of Trade. Local authorities, as well as companies or individuals, may apply for Orders, and may make advances for light railways, as the Treasury also, under certain conditions, is empowered to do. Up to December 31, 1900, out of 309 applications, 167 had been approved by the Commission, the aggregate length of the approved lines amounting to 1360 miles, and their estimated construction cost to £8,824,275. Those actually submitted to the Board of Trade numbered 133, and they related to 1063 miles of line, and a construction cost of £6,517,311. Of these Orders the Board of Trade had confirmed 71, of which 12 were for Scotland. Of the projected lines, about three-fourths in length resemble ordinary railways, the remainder being road or street railways.

Tramways.—On June 30, 1900, there were in the United Kingdom 177 tramway undertakings, with altogether 1177 miles of tramway line. Of these undertakings, 70 with 585 miles of line belonged to local authorities, while 107 with 592 miles of line belonged to others than local authorities. The capital expenditure on the former amounted to £10,203,604, on the latter to £11,532,384. The development of tramway enterprise in England and Wales, as shown by the mileage open, the paid-up capital, gross receipts, working expenses, and number of passengers carried, has been as follows:—

Years ending June 30.	Miles Open.	Paid-up Capital.	Gross Receipts.	Working Expenses.	Passengers carried during year.
		£	£	£	Number.
1880	269	4,206,637	972,513	812,876	118,218,415
1890	753	10,994,341	2,573,535	1,932,444	418,399,936
1895	774	11,312,338	3,038,804	2,344,302	525,838,417
1899	881	13,964,628	3,860,701	2,962,039	700,436,783
1900	933	15,901,923	4,347,142	3,316,590	816,768,639

For the whole of the United Kingdom in 1899–1900 the paid-up capital amounted to £20,582,692; the gross receipts, to £5,445,620; the working expenses to £4,075,352; and the number of passengers carried was 1,065,374,347. In the same year, in England and Wales the tramway cars numbered 5051, and they were drawn by 29,827 horses and 526 locomotive engines. In the United Kingdom there were 6410 cars, drawn by 37,481 horses and 558 locomotive engines.

Canals.—Of the canals and navigations in the United Kingdom in 1898, the total length reached 3907 miles, of which 2768 miles did not, and 1139 miles did, belong to railway companies. The total length in 1888 was given as 3813 miles, of which 2608 miles did not, and 1204 miles did, belong to railway companies. The canal returns for 1898 are more complete than those for 1888, but the figures as they stand indicate an increase of 160 miles in the length of the canals not belonging to railway companies, and a decrease of 66 miles in that of the railway canals, the net increase thus reaching 94 miles. In 1898 the total paid-up capital (from all sources) of the canals not belonging to railway companies amounted to £37,929,280; in 1888 it amounted to £24,285,175. Of the total paid-up capital in 1898, the sum of £35,091,404 stood against the names of canal companies in England and Wales. The development in canal enterprise in England and Wales between 1888 and 1898, according to Board of Trade Returns, is shown by the following figures, giving the mileage, the traffic conveyed, the gross revenue, and the expenditure in the respective years of A, canals and navigations not belonging to railway companies, and B, of those belonging to railway companies:—

A. *Non-Railway Canals and Navigations.*

Years.	Length.	Traffic.	Revenue.	Expenditure.
	Miles.	Tons Conveyed.	£	£
1888	2026	27,715,875	1,439,343	861,068
1898	2208	32,513,800	1,895,506	1,322,201
		B. *Railway Canals and Navigations.*		
1888	1024	6,609,304	437,080	335,503
1898	959	4,913,085	331,305	309,025

The increase in the length of the English canals is due mainly to the construction of the Manchester Ship Canal, which was opened in 1894. From its commencement at Eastham, where it joins the Mersey, to its termination in the city of Manchester, it has a length of 35½ miles, while, including the Bridgewater canals and the Mersey and Irwell navigations, the whole system has a length of about 110 miles. From Eastham to Manchester the canal may be used by vessels 550 feet in length and 60 feet wide, with 25 feet of draught and 70 feet of headway. The bottom width at the full depth is in general 120 feet, but at several places it exceeds this; while between Latchford Locks and Partington Canal Basin it does not exceed 90 feet. At Eastham there are three locks, and the Latchford, Irlam, Barton, and Modewheel locks are in pairs. A junction with the Shropshire Union Canal is made at Ellesmere Port; with the Weaver Navigation, at Weston Point; with the Bridgewater canals, at Runcorn; and with the Runcorn and Latchford Canal, at Stockton Heath Bridge. The paid-up capital (from all sources) of the canal up to December 31, 1898, amounted to £15,459,369. The traffic (not sea-borne) using the company's canals, &c., in the year 1898 reached 3,548,894 tons, while the sea-borne traffic to and from Manchester amounted to 2,540,961 tons. The receipts during the same year reached the sum of £551,039, and the working expenses amounted to £447,356. Many of the old canals are of importance for the development of the industries of the country. The Birmingham Canal Navigations consist of the Birmingham and Wolverhampton Canal, with many branches, the total length extending to 159 miles. In 1898 the traffic conveyed on this system amounted to 8,627,074 tons, of which 4,543,008 tons represented coal; the total revenue reached £208,036, and the expenditure, £88,843. The Leeds and Liverpool Canal, with its connected system, has a length of 141 miles; in 1898 the traffic conveyed on it reached 2,324,968 tons. The Grand Junction Canal, extending, with many branches, from Brentford to Aylesbury, Northampton, Leicester, and Market Harborough, besides joining other canal systems, has a length of 188 miles, and in 1898 served for the conveyance of 1,620,552 tons of goods.

See also the article United Kingdom, and the separate articles on Banking, Armies, Post Office, Local Government.

Books of Reference.—The following official publications are issued in London:—*Report on the Census of England and Wales,* 1891, 4 vols., 1893; *Preliminary Report on the Census of 1901*; *Annual*

Report and *Quarterly Returns of the Registrar-General; Annual Statistical Tables relating to Emigration and Immigration; Annual Report of Local Government Board; Judicial Statistics of England and Wales* (Annual); *Reports of Inspectors of Constabulary in England and Wales; Annual Report of the Board of Education; Return on Technical Education* (*Local Authorities*), 1900; *Reports from University Colleges. Agricultural Returns: Reports of Royal Commission on Agriculture, and Reports of Assistant Commissioners*, 24 vols., 1896; *Report of Royal Commission on Land in Wales and Monmouth*, 6 vols., 1896; *Returns as to Number and Size of Agricultural Holdings in Great Britain in 1895, 1896; Canals and Navigations, Returns made for 1898; Railway Returns* (Annual).

Other works relating to England and Wales are:—BOOTH. *Life and Labour of the People of London.* 9 vols. London, 1889–97. *The Aged Poor in England and Wales.* London, 1894.—LOCH. *The Annual Charities Register and Digest.* London.—MALTBIE. *English Local Government of To-day.* New York, 1897.—ODGERS. *Local Government in England and Wales.* London, 1899.—RHYS and JONES. *The Welsh People.* London, 1900.—PENDLETON. *Our Railways.* London, 1896.—STEPHEN. *History of the Criminal Law of England.* 3 vols. London, 1883.—WRIGHT and HOBHOUSE. *An Outline of Local Government and Local Taxation in England and Wales.* London, 1898.—THORNBURY and WALFORD. *Old and New London.* 6 vols.—E. WALFORD. *Greater London.* 2 vols. (I. P. A. R.)

Englewood, a city of Bergen county, New Jersey, U.S.A., near the Palisades of the Hudson river, and on a branch of the Erie Railway. It was organized in 1871, its area being taken from the town of Hackensack. Population (1880), 4076; (1890), 4785; (1900), 6253.

English Bazar or **Angrazabad,** a town of British India, headquarters of Malda district in Bengal, situated on the right bank of the river Mahananda. The population is about 13,500. Silk-weaving, as a centre for which it was originally chosen, is now a decaying industry. There are a high school, with 171 pupils in 1896–97; three printing-presses, one of which issues a fortnightly newspaper in the vernacular; a public library, and a Mahommedan Association.

English Bible.—In accordance with the report presented by the Joint Committee of the two Houses of the Convocation of Canterbury in May 1870, two companies were formed for the revision of the Authorized Version of the Old and New Testaments. These companies consisted of the following. 1. For the Old Testament:—(*a*) *Appointed by Convocation.*—The Bishops of St Davids, Llandaff, Ely, Lincoln, and Bath and Wells, Archdeacon Rose, Canon Selwyn, Dr Jebb, and Dr Kay. (*β*) *Invited.*—Alexander, Dr W. L.; Chenery, Professor; Cook, Canon; Davidson, Professor A. B.; Davies, Dr B.; Fairbairn, Professor; Field, Rev. F.; Ginsburg, Dr; Gotch, Dr; Harrison, Archdeacon; Leathes, Professor; M'Gill, Professor; Payne Smith, Canon; Perowne, Professor J. H.; Plumptre, Professor; Pusey, Canon; Wright, Dr (British Museum); Wright, W. A. (Cambridge). Of these, Canons Cook and Pusey declined to serve, and ten members died during the progress of the work. The secretary of the company was Mr W. Aldis Wright, Fellow of Trinity, Cambridge. 2. For the New Testament:—(*a*) *Appointed by Convocation.*—Bishops of Winchester, Gloucester and Bristol, and Salisbury, The Prolocutor (Dr Bickersteth), The Deans of Canterbury and Westminster, Canon Blakesley. (*β*) *Invited.*—Angus, Dr; Brown, Dr David; Dublin, Archbishop of; Eadie, Dr; Hort, Rev. F. J. A.; Humphrey, Rev. W. G.; Kennedy, Canon; Lee, Archdeacon; Lightfoot, Dr; Milligan, Professor; Moulton, Professor; Newman, Dr J. H.; Newth, Professor; Roberts, Dr A.; Smith, Rev. G. Vance; Scott, Dr; Scrivener, Rev. F. H. A.; St Andrews, Bishop of; Thompson, Dr; Tregelles, Dr; Vaughan, Dr; Westcott, Canon. Of these, Dr Thompson and Dr Newman declined to serve. Dean Alford, Dr Tregelles, Bishop Wilberforce, and Dr Eadie were removed by death. Only the first vacancy was filled up. Dean Merivale was co-opted, and on his resignation Professor, afterwards Archdeacon, Palmer. The Rev. J. Troutbeck, Minor Canon of Westminster, acted as Secretary. Negotiations were opened with the leading scholars of the Protestant denominations in America, with the result that similar companies were formed in the United States. The work of the English Revisers was regularly submitted to their consideration; their comments were carefully considered and largely adopted, and their divergences from the version ultimately agreed upon were printed in an Appendix to the published work. Thus the Revised Version was the achievement of English-speaking Christendom as a whole; only the Roman Catholic Church, of the great English-speaking denominations, refused to take part in the undertaking. The Church of England, which had put forth the version of 1611, fitly initiated the work, but for its performance most wisely invited the help of the sister Churches. The delegates of the Clarendon Press in Oxford, and the syndics of the Pitt Press in Cambridge, entered into a liberal arrangement with the Revisers, by which the necessary funds were provided for all their expenses. On the completion of its work the New Testament Company divided itself into three Committees, working at London, Westminster, and Cambridge, for the purpose of revising the Apocrypha.

The work of the Old Testament Company was different in some important respects from that which engaged the attention of the New Testament Company. The Received Hebrew text has undergone but little emendation, and the revisers had before them substantially the same Massoretic text which was in the hands of the translators of 1611. It was felt that there was no sufficient justification to make any attempt at an entire reconstruction of the text on the authority of the versions. The Old Testament revisers were therefore spared much of the labour of deciding between different readings, which formed one of the most important duties of the New Testament Company. But the advance in the study of Hebrew since the early part of the 17th century enabled them to give a more faithful translation of the received text. The value of their work is evident, especially in Job, Ecclesiastes, and the prophetical books.

It is the work of the New Testament Committee which has attracted most attention, whether for blame or praise. The critical resources at the disposal of scholars in 1611 were very meagre, and the few early manuscripts with which they were acquainted failed to receive the attention they deserved. The translators appear to have mainly relied on the later editions of Stephanus and Beza, and also to a certain extent the Complutensian Polyglott. All these were founded, for the most part, on a few manuscripts of late date. It is evident, therefore, that the Greek text of 1611 is largely Erasmian, and has no claim to any great critical value. The ancient versions were not examined, with the exception of the Vulgate, which the translators possessed in late and corrupt texts. The testimony of the fathers received no attention. Nearly all the more ancient documentary authorities have become known since 1611, and some of the most important of them have only been studied in quite recent times. Not one of the four most ancient and most important manuscripts was known to be in existence. Codex D, though it was known, was scarcely considered. Even Beza was unaware of the true value of the manuscript which bears his name, and scarcely any weight was assigned to it.

It was not until the middle of the 17th century that the preparation for an effective critical study of the New Testament began. The subject from the first excited the interest of English scholars, and received a considerable impulse in Great Britain by the gift of the Alexandrian manuscript (A) to Charles I. by Cyril Lucar, the Patriarch of Constantinople. At the beginning of the 18th century Mill collated a mass of documentary evidence; and though he failed to arrange the information which he had gained, he laid the foundation of work that has helped all subsequent textual critics. It became clear that the value of documents depended on antiquity rather than on their numerical superiority. It was Griesbach who first carried out this principle of textual criticism, and became the pioneer of that work of tracing the genealogical relations of the whole extant documentary evidence of the New Testament which has been developed with so much learning and skill by Lachmann, Tischendorf, and Tregelles. The results of these critical methods could not fail to make the incompleteness of the "Received Text," and of the "Authorized Version," which was based on it, obvious. It had long been the opinion of all competent scholars that a thorough revision was necessary. A proposal in favour of this course was made in Convocation in 1856, but it was not until fourteen years later that the Committee was appointed to undertake the work. The Revisers' first task was to reconstruct the Greek text, as the necessary foundation of their work. In this difficult duty they were no doubt influenced by Westcott and Hort's edition of the New Testament. These two scholars were members of the Committee which prepared the Revised Version, and on the question of various readings they appear to have exercised a predominating influence. The Revisers were privately supplied with instalments of Westcott and Hort's text as their work required them. But it is scarcely necessary to say that the Revised Version is not the work of one or two scholars. Different schools of criticism were represented on the Committee, and the most careful discussion took place before any decision was formed. Every precaution was taken to ensure that the version should represent the result of the best scholarship of the time, applied to the work before it with constant devotion and with the highest sense of responsibility. The changes in the Greek text of the Authorized Version when compared with the *textus receptus* are numerous, but the contrast between the English Versions of 1611 and 1881 are all the more striking because of the difference in the method of translation which was adopted. The Revisers aimed at the most scrupulous faithfulness. They adopted the plan—deliberately rejected by the translators of 1611—of always using the same English word for the same Greek word. "They endeavoured to enable the English reader to follow the correspondences of the original with the closest exactness, to catch the solemn repetition of words and phrases, to mark the subtleties of expression, to feel even the strangeness of unusual forms of speech."

The revision of the New Testament was completed in 407 meetings, distributed over more than ten years. It was formally presented to Convocation on May 17, 1881. The revision of the Old Testament occupied 792 days, and was finished on June 20, 1884. The revised Apocrypha did not make its appearance until 1895.

The text of the Revised Version is printed in paragraphs, the old division of books into chapters and verses being retained for convenience of reference. By this arrangement the capricious divisions of some books is avoided. Various editions of the New Version have been published, the most complete being the edition of the whole Bible with marginal references. These references had their origin in the work of two small sub-committees of the Revisers, but they received their present form at the hands of a specially appointed committee. The marginal references given in the original edition of the Authorized Version of 1611 have been retained as far as possible.

The work of the Revisers was received without enthusiasm. It was too thorough for the majority of religious people. Partisans found that havock had been played with their proof texts. Ecclesiastical conservatives were scandalized by the freedom with which the traditional text was treated. The advocates of change were discontented with the hesitating acceptance which their principles had obtained. The most vulnerable side of the Revision was that on which the mass of English readers thought itself capable of forming a judgment. The general effect of so many small alterations was to spoil the familiar sonorous style of the Authorized Version. The changes were freely denounced as equally petty and vexatious; they were, moreover, too often inconsistent with the avowed principles of the Revisers. The method of determining readings and renderings by vote was not favourable to the consistency and literary character of the Version. A whole literature of criticism and apology made its appearance, and the achievement of so many years of patient labour seemed destined to perish in a storm of resentments. On the whole, the Revised Version weathered the storm more successfully than might have been expected. Its considerable excellences were better realized by students than stated by apologists. The hue and cry of the critics largely died away, and was replaced by a calmer and juster appreciation.

Quite recently the work of the Revisers has been sharply criticized from the standpoint of specialists in New Testament Greek. Dr Rutherford has stated the case briefly and pointedly in the Preface to his translation of the Epistle to the Romans (London, 1900). He maintains that "the Greek of the New Testament may never be understood as classical Greek is understood," and accuses the Revisers of distorting the meaning "by translating in accordance with Attic idiom phrases that convey in later Greek a wholly different sense, the sense which the earlier translators in happy ignorance had recognized that the context demanded."

The use of the new Version has become general. Familiarity has mitigated the harshness of the Revisers' renderings; scholarship, on the whole, has confirmed their readings. The Version has been publicly read in parish churches both in London and in the country. In Canterbury Cathedral and Westminster Abbey it has definitely displaced the older Version. Bishops have acquiesced and congregations approved. It is no longer possible to maintain the plausible and damaging contention that the Revised Bible is ill-suited for public use. The Upper House of the Convocation of Canterbury, in May 1898, appointed a Committee to consider the expediency of "permitting or encouraging" the use of the Revised Version in the public services of the Church.

The Revisers have fully explained their principles and methods in the Preface to their Version. The American Committee of Revision issued an historical account of their work (New York, 1885). The case against the Revisers is ably stated in *The Revision Revised*, by Dean Burgon (London, 1883). The literary defects of the Version are elaborately exhibited by G. Washington Moon in two works: *The Revisers' English* (London, 1882); and *Ecclesiastical English* (London, 1886). The Version is successfully defended by J. B. Lightfoot, *On a Fresh Revision of the English New Testament* (London, 1871; 3rd edition, 1891); Westcott, *Some Lessons of the Revised Version* (London, 1897); Kennedy, *Ely Lectures on the Revised Version* (London, 1882). Reference may also be made to *Some Thoughts on the Textual Criticism of the New Testament*, by G. Salmon, D.D. (London, 1897); Bishop Ellicott's *Charge* (1901). The Greek Text of the New Testament adopted by the Revisers was edited for the Clarendon Press by Archdeacon Palmer (Oxford, 1881). Parallel editions of the Bible, showing both the Authorized and Revised Versions, a large type edition for public use, a reference edition, and finally (1900) a "Two Version" edition, have been issued by one or both the University Presses.

(H. H. H*.)

ENGLISH HISTORY, 1837-1901.

THE death of William IV., on the 20th June 1837, placed on the throne of England a young princess, who was destined to reign for a longer period than any of her predecessors. The new Queen, the only daughter of the duke of Kent, the fourth son of George III., had just attained her majority. Educated in comparative seclusion, her character and her person were unfamiliar to her future subjects, who were a little weary of the extravagances and eccentricities of her immediate predecessors. Her accession gave them a new interest in the House of Hanover. And their loyalty, which would in any case have been excited by the accession of a young and inexperienced girl to the throne of the greatest empire in the world, was stimulated by her conduct and appearance. She displayed from the first a dignity and good sense which won the affection of the multitude who merely saw her in public, and the confidence of the advisers who were admitted into her presence.

Queen Victoria's accession.

The ministry experienced immediate benefit from the change. The Whigs, who had governed England since 1830, under Lord Grey and Lord Melbourne, were suffering from the reaction which is the inevitable consequence of revolution. The country which, in half a dozen years, had seen a radical reform of Parliament, a no less radical reform of municipal corporations, the abolition of slavery, and the reconstruction of the poor laws, was longing for a period of political repose. The alliance, or understanding, between the Whigs and the Irish was increasing the distrust of the English people in the ministry, and Lord Melbourne's Government, in the first half of 1837, seemed doomed to perish. The accession of the Queen gave it a new lease of power. The election, indeed, which followed her accession did not materially alter the composition of the House of Commons. But the popularity of the Queen was extended to her Government. Taper's suggestion in *Coningsby* that the Conservatives should go to the country with the cry, "Our young Queen and our old institutions," expressed, in an epigram, a prevalent idea. But the institution which derived most immediate benefit from the new Sovereign was the old Whig ministry.

The difficulties of the ministry, nevertheless, were great. In the preceding years they had carried most of the reforms which were demanded in Great Britain; but they had failed to obtain the assent of the House of Lords to their Irish measures. They had desired (1) to follow up the reform of English corporations by a corresponding reform of Irish municipalities; (2) to convert the tithes, payable to the Irish church, into a rent charge, and to appropriate its surplus revenues to other purposes; (3) to deal with the chronic distress of the Irish people by extending to Ireland the principles of the English poor law. In the year which succeeded the accession of the Queen they accomplished two of these objects. They passed an Irish poor law and a measure commuting tithes in Ireland into a rent charge. The first of these measures was carried in opposition to the views of the Irish, who thought that it imposed an intolerable burden on Irish property. The second was only carried on the Government consenting to drop the appropriation clause, on which Lord Melbourne's Administration had virtually been founded.

Lord Melbourne's difficulties.

It was not, however, in domestic politics alone that the ministry was hampered. In the months which immediately followed the Queen's accession news reached England of disturbances or even insurrection in Canada. The rising was easily put down; but the condition of the colony was so grave that the ministry decided to suspend the constitution of Lower Canada for three years, and to send out Lord Durham with almost dictatorial powers. Lord Durham's conduct was, unfortunately, marked by indiscretions which led to his resignation; but before leaving the colony he drew up a report on its condition and on its future, which practically became a text-book for his successors, and has influenced the government of British colonies ever since. Nor was Canada the only great colony which was seething with discontent. In Jamaica the planters, who had sullenly accepted the abolition of slavery, were irritated by the passage of an Act of Parliament intended to remedy some grave abuses in the management of the prisons of the island. The colonial House of Assembly denounced this Act as a violation of its rights, and determined to desist from its legislative functions. The governor dissolved the assembly, but the new house, elected in its place, reaffirmed the decision of its predecessor; and the British ministry, in face of the crisis, asked Parliament in 1839 for authority to suspend the constitution of the island for five years. The Bill introduced for this purpose placed the Whig ministry in a position of some embarrassment. The advocates of popular government, they were inviting Parliament, for a second time, to suspend representative institutions in an important colony. Supported by only small and dwindling majorities, they saw that it was hopeless to carry the measure, and they decided on placing their resignations in the Queen's hands. The Queen naturally sent for Sir Robert Peel, who undertook to form a government. In the course of the negotiations, however, he stated that it would be necessary to make certain changes in the household, which contained some great ladies closely connected with the leaders of the Whig party. The Queen shrank from separating herself from ladies who had surrounded her since she came to the throne, and Sir Robert thereupon declined the task of forming a ministry. Technically he was justified in adopting this course, but people generally felt that there was some hardship in compelling a young Queen to separate herself from her companions and friends, and they consequently approved the decision of Lord Melbourne to support the Queen in her refusal, and to resume office. The Whigs returned to place, but they could not be said to return to power. They did not even venture to renew the original Jamaica Bill. They substituted for it a modified proposal which they were unable to carry. They were obviously indebted for office to the favour of the Queen, and not to the support of Parliament.

The bedchamber question.

Yet the session of 1839 was not without important results. After a long struggle, in which ministers narrowly escaped defeat in the Commons, and in the course of which they suffered severe rebuffs in the Lords, they succeeded in laying the foundation of the English system of national education. In the same session they were forced against their will to adopt a reform, which had been recommended by Mr Rowland Hill, and to confer on the nation the benefit of a uniform penny postage. No member of the Cabinet foresaw the consequences of this reform. The postmaster-general, in opposing it, declared that, if the revenue of his office was to be maintained, the correspondence of the country, on which postage was paid, must be increased from 42,000,000 to 480,000,000 letters a year, and he contended that there were neither people to write, nor machinery to deal with,

Penny postage.

so prodigious a mass of letters. He would have been astonished to hear that, before the end of the century, his office had to deal with more than 3,000,000,000 postal packets a year, and that the net profit which it paid into the exchequer was to be more than double what it received in 1839.

In 1840 the ministry was not much more successful than it had proved in 1839. After years of conflict it succeeded indeed in placing on the statute book a measure dealing with Irish municipalities. But its success was purchased by concessions to the Lords, which deprived the measure of much of its original merit. The closing years of the Whig Administration were largely occupied with the financial difficulties of the country. The first three years of the Queen's reign were memorable for a constantly deficient revenue. The deficit amounted to £1,400,000 in 1837; to £400,000 in 1838, and to £1,457,000 in 1839. Mr Baring, the chancellor of the exchequer, endeavoured to terminate this deficiency by a general increase of taxation, but this device proved a disastrous failure. The deficit rose to £1,842,000 in 1840. It was obvious that the old expedient of increasing taxation had failed, and that some new method had to be substituted for it. This new method Mr Baring endeavoured to discover in altering the differential duties on timber and sugar, and substituting a fixed duty of 8s. per qr. for the sliding duties hitherto payable on wheat. By these alterations he expected to secure a large increase of revenue, and at the same time to maintain a sufficient degree of protection for colonial produce. The Conservatives, who believed in protection, at once attacked the proposed alteration of the sugar duties. They were reinforced by many Liberals, who cared very little for protection, but a great deal about the abolition of slavery, and consequently objected to reducing the duties on foreign or slave-grown sugar. This combination of interests proved too strong for Mr Baring and his proposal was rejected. As ministers, however, did not resign on their defeat, Sir Robert Peel followed up his victory by moving a vote of want of confidence, and this motion was carried in an exceptionally full house by 312 votes to 311.

Fiscal policy.

Before abandoning the struggle, the Whigs decided on appealing from the House of Commons to the country. The general election which ensued largely increased the strength of the Conservative party. On the meeting of the new Parliament in August 1841, votes of want of confidence in the Government were proposed and carried in both houses; the Whigs were compelled to resign office, and the Queen again charged Sir Robert Peel with the task of forming a government. If the Queen had remained unmarried, it is possible that the friction which had arisen in 1839 might have recurred in 1841. In February 1840, however, Her Majesty had married her cousin, Prince Albert of Saxe-Coburg. She was, therefore, no longer dependent on the Whig ladies, to whose presence in her court she had attached so much importance in 1839. By the management of the Prince—who later in the reign was known as the Prince Consort—the great ladies of the household voluntarily tendered their resignations; and every obstacle to the formation of the new government was in this way removed.

Sir R. Peel forms a ministry.

Thus the Whigs retired from the offices which, except for a brief interval in 1834-35, they had held for eleven years. During the earlier years of their administration they had succeeded in carrying many memorable reforms: during the later years their weakness in the House of Commons had prevented their passing any considerable measures. But, if they had failed in this respect, Lord Melbourne had rendered conspicuous service to the Queen. Enjoying her full confidence, consulted by her on every occasion, he had always used his influence for the public good; and perhaps those who look back now with so much satisfaction at the Queen's conduct during a reign of unexampled length, imperfectly appreciate the debt which in this respect is owed to her first prime minister. The closing years of the Whig Government were marked by external complications. A controversy on the boundary of Canada and the United States was provoking increasing bitterness on both sides of the Atlantic. The intervention of Lord Palmerston in Syria, which resulted in a great military success at Acre, was embittering the relations between France and England, while the unfortunate expedition to Afghanistan, which the Whigs had approved, was already producing embarrassment, and was about to result in disaster. Serious, however, as were the complications which surrounded British policy in Europe, in the East, and in America, the country, in August 1841, paid more attention to what a great writer called the "condition of England" question. There had never been a period in British history when distress and crime had been so general. There had hardly ever been a period when food had been so dear, when wages had been so low, when poverty had been so widespread, and the condition of the lower orders so depraved and so hopeless, as in the early years of the Queen's reign. The condition of the people had prompted the formation of two great associations. The Chartists derived their name from the charter which set out their demands. The rejection of a monster petition which they presented to Parliament in 1839 led to a formidable riot in Birmingham, and to a projected march from South Wales on London, in which twenty persons were shot dead at Newport. Another organization, in one sense even more formidable than the Chartist, was agitating at the same time for the repeal of the corn laws, and was known as the Anti-Corn Law League. It had already secured the services of two men, Mr Cobden and Mr Bright, who, one by clear reasoning, the other by fervid eloquence, were destined to make a profound impression on all classes of the people.

The new Government had, therefore, to deal with a position of almost unexampled difficulty. The people were apparently sinking into deeper poverty and misery year after year. As an outward and visible sign of the inward distress, the state was no longer able to pay its way. It was estimated that the deficit, which had amounted to £1,842,000 in 1840, would reach £2,334,000 in 1841. It is the signal merit of Sir Robert Peel that he terminated this era of private distress and public deficits. He accomplished this task partly by economical administration—for no minister ever valued economy more—and partly by a reform of the financial system, effected in three great budgets. In the budget of 1842 Sir Robert Peel terminated the deficit by reviving the income tax. The proceeds of the tax, which was fixed at 7d. in the £, and was granted in the first instance for three years, were more than sufficient to secure this object. Sir Robert used the surplus to reform the whole customs tariff. The duties on raw materials, he proposed, should never exceed 5 per cent., the duties on partly manufactured articles 12 per cent., and the duties on manufactured articles 20 per cent. of their value. At the same time he reduced the duties on stage coaches, on foreign and colonial coffee, on foreign and colonial timber, and repealed the export duties on British manufactures. The success of this budget in stimulating consumption and in promoting trade induced Sir Robert Peel to follow it up in 1845 with an even more remarkable proposal. Instead of allowing the income tax to expire, he induced Parliament to continue it for a further period, and with the resources which were thus placed at

Budget reforms.

his disposal he purged the tariff of various small duties which produced little revenue, and had been imposed for purposes of protection. He swept away all the duties on British exports; he repealed the duties on glass, on cotton wool, and still further reduced the duties on foreign and colonial sugar. This budget was a much greater step towards free trade than the budget of 1842. The chief object in his third budget in 1846—the reduction of the duty on corn to 1s. a quarter—was necessitated by causes which will be immediately referred to. But it will be convenient at once to refer to its other features. Sir Robert Peel told the house that, in his previous budgets, he had given the manufacturers of the country free access to the raw materials which they used. He was entitled in return to call upon them to relinquish the protection which they enjoyed. He decided therefore to reduce the protective duties on cotton, woollen, silk, metal and other goods, as well as on raw materials still liable to heavy taxation, such as timber and tallow. As the policy of 1842 and 1845 had proved unquestionably successful in stimulating trade, he proposed to extend it to agriculture. He reduced the duties on the raw materials which the farmers used, such as seed and maize, and in return he called on them to give up the duties on cattle and meat, largely to reduce the duties on butter, cheese, and hops, and to diminish the duty on corn by gradual stages to 1s. a quarter. In making these changes Sir Robert Peel avowed that it was his object to make the country a cheap one to live in. There is no doubt that they were followed by a remarkable development of British trade. In the twenty-seven years from 1815 to 1842 the export trade of Great Britain diminished from £49,600,000 to £47,280,000; while in the twenty-seven years which succeeded 1842 it increased from £47,280,000 to nearly £190,000,000. These figures are a simple and enduring monument to the minister's memory. It is fair to add that the whole increase was not due to free trade. It was partly attributable to the remarkable development of communications which marked this period.

Two other financial measures of great importance were accomplished in Sir Robert Peel's ministry. In 1844 some £250,000,000 of the national debt still bore an interest of 3½ per cent. The improvement in the credit of the country enabled the Government to reduce the interest on the stock to 3¼ per cent. for the succeeding ten years, and to 3 per cent. afterwards. This conversion, which effected an immediate saving of £625,000, and an ultimate saving of £1,250,000 a year, was by far the most important measure which had hitherto been applied to the debt; and no operation on the same scale was attempted for more than forty years. In the same year the necessity of renewing the charter of the Bank of England afforded Sir Robert Peel an opportunity of reforming the currency. He separated the issue department from the banking department of the Bank, and decided that in future it should only be at liberty to issue notes against (1) the debt of £14,000,000 due to it from the Government, and (2) any bullion actually in its coffers. Few measures of the past century have been the subject of more controversy than this famous Act, and at one time its repeated suspension in periods of financial crises seemed to suggest the necessity of its amendment. But opinion on the whole has vindicated its wisdom, and it has survived all the attacks which have been made upon it.

The administration of Sir Robert Peel is also remarkable for its Irish policy. The Irish, under O'Connell, had constantly supported the Whig ministry of Lord Melbourne. But their alliance, or understanding, with the Whigs had not procured them all the results which they had expected from it. The two great Whig measures, dealing with the church and the municipalities, had only been passed after years of controversy, and in a shape which deprived them of many expected advantages. Hence arose a notion in Ireland that nothing was to be expected from a British Parliament, and hence began a movement for the repeal of the Union which had been accomplished in 1801. This agitation, which smouldered during the reign of the Whig ministry, was rapidly revived when Sir Robert Peel entered upon office. The Irish contributed large sums, which were known as repeal rent, to the cause, and they held monster meetings in various parts of Ireland to stimulate the demand for repeal. The ministry met this campaign by coercive legislation regulating the use of arms, by quartering large bodies of troops in Ireland, and by prohibiting a great meeting at Clontarf, the scene of Brian Boru's victory, in the immediate neighbourhood of Dublin. They further decided in 1843 to place O'Connell and some of the leading agitators on their trial for conspiracy and sedition. O'Connell was tried before a jury chosen from a defective panel, was convicted on an indictment which contained many counts, and the court passed sentence without distinguishing between these counts. These irregularities induced the House of Lords to reverse the judgment, and its reversal did much to prevent mischief. O'Connell's illness, which resulted in his death in 1847, tended also to establish peace. Sir Robert Peel wisely endeavoured to stifle agitation by making considerable concessions to Irish sentiment. He increased the grant which was made to the Roman Catholic College at Maynooth; he established three colleges in the north, south, and west of Ireland for the undenominational education of the middle classes; he appointed a commission —the Devon Commission, as it was called, from the name of the nobleman who presided over it—to investigate the conditions on which Irish land was held; and, after the report of the commission, he introduced, though he failed to carry, a measure for remedying some of the grievances of the Irish tenants. These wise concessions might possibly have had some effect in pacifying Ireland, if in the autumn of 1845 they had not been forgotten in the presence of a disaster which suddenly fell on that unhappy country. The potato, which was the sole food of at least half the people of an overcrowded island, failed, and a famine of unprecedented proportions was obviously imminent. Sir Robert Peel, whose original views on protection had been rapidly yielding to the arguments afforded by the success of his own budgets, concluded that it was impossible to provide for the necessities of Ireland without suspending the corn laws; and that, if they were once suspended, it would be equally impossible to restore them. He failed, however, to convince two prominent members of his cabinet—Lord Stanley and the duke of Buccleuch—that Protection must be finally abandoned, and considering it hopeless to persevere with a disunited cabinet he resigned office. On Sir Robert's resignation the Queen sent for Lord John Russell, who had led the Liberal party in the House of Commons with conspicuous ability for more than ten years, and charged him with the task of forming a new ministry. Differences, which it proved impossible to remove, between two prominent Whigs—Lord Palmerston and Lord Grey—made the task impracticable, and after an interval Sir Robert Peel consented to resume power. Sir Robert Peel was probably aware that his fall had been only postponed. In the four years and a half during which his ministry had lasted he had done much to estrange his party. They said, with some truth, that, whether his measures were right or wrong, they were opposed to the principles which he had been placed in power to support. The general election of 1841 had been mainly fought on the rival policies of Protection and Free Trade.

Ireland.

Free trade.

The country had decided for Protection, and Sir R. Peel had done more than all his predecessors to give it Free Trade. The Conservative party, moreover, was closely allied with the church, and Sir Robert had offended the church by giving an increased endowment to Maynooth, and by establishing undenominational colleges—"Godless colleges" as they were called—in Ireland. The Conservatives were, therefore, sullenly discontented with the conduct of their leader. They were lashed into positive fury by the proposal which he was now making to abolish the corn laws. Lord George Bentinck, who, in his youth, had been private secretary to Mr Canning, but who in his maturer years had devoted more time to the turf than to politics, placed himself at their head. He was assisted by a remarkable man—Mr Disraeli—who joined great abilities to great ambition, and who, embittered by Sir Robert Peel's neglect to appoint him to office, had already displayed his animosity to the minister. The policy on which Sir Robert Peel resolved facilitated attack. For the minister thought it necessary, while providing for famine by repealing the corn laws, to ensure the preservation of order by a new Coercion Bill. The Financial Bill and the Coercion Bill were both pressed forward, and each gave opportunities for discussion and, what was then new in Parliament, for obstruction. At last, on the very night on which the fiscal proposals of the ministers were accepted by the Lords, the Coercion Bill was defeated in the Commons by a combination of Whigs, Radicals, and Protectionists; and Sir R. Peel, worn out with a protracted struggle, placed his resignation in the Queen's hands.

Thus fell the great minister, who perhaps had conferred more benefits on his country than any of his predecessors. The external policy of his ministry had been almost as remarkable as its domestic programme. When he accepted office the country was on the eve of a great disaster in India; it was engaged in a serious dispute with the United States; and its relations with France were so strained that the two great countries of Western Europe seemed unlikely to be able to settle their differences without war. In the earlier years of his administration the disaster in Afghanistan was repaired in a successful campaign; and Lord Ellenborough, who was sent over to replace Lord Auckland as governor-general, increased the dominion and responsibilities of the East India Company by the unscrupulous but brilliant policy which led to the conquest of Scinde. The disputes with the United States were satisfactorily composed; and not only were the differences with France terminated, but a perfect understanding was formed between the two countries, under which M. Guizot, the prime minister of France, and Lord Aberdeen, the foreign minister of England, agreed to compromise all minor questions for the sake of securing the paramount object of peace. The good understanding was so complete that a disagreeable incident in the Sandwich Islands, in which the injudicious conduct of a French agent very nearly precipitated hostilities, was amicably settled; and the ministry had the satisfaction of knowing that, if their policy had produced prosperity at home, it had also maintained peace abroad.

Peel's Foreign policy.

On Sir R. Peel's resignation the Queen again sent for Lord John Russell. The difficulties which had prevented his forming a ministry in the previous year were satisfactorily arranged, and Lord Palmerston accepted the seals of the Foreign Office, while Lord Grey was sent to the Colonial Office. The history of the succeeding years was destined, however, to prove that Lord Grey had had solid reasons for objecting to Lord Palmerston's return to his old post; for, whatever judgment may ultimately be formed on Lord Palmerston's foreign policy, there can be little doubt that it did not tend to the maintenance of peace. The first occasion on which danger was threatened arose immediately after the installation of the new ministry on the question of the Spanish marriages. The queen of Spain, Isabella, was a little girl still in her teens; the heir to the throne was her younger sister, the infanta Fernanda. Diplomacy had long been occupied with the marriages of these children; and Lord Aberdeen had virtually accepted the principle, which the French Government had laid down, that a husband for the queen should be found among the descendants of Philip V., and that her sister's marriage to the duc de Montpensier—a son of Louis Philippe—should not be celebrated till the queen was married and had issue. While agreeing to this compromise, Lord Aberdeen declared that he regarded the Spanish marriages as a Spanish and not as a European question, and that, if it proved impossible to find a suitable consort for the queen among the descendants of Philip V., Spain must be free to choose a prince for her throne elsewhere. The available descendants of Philip V. were the two sons of Don Francis, the younger brother of Don Carlos, and of these the French Government was in favour of the elder, while the British Government preferred the younger, brother. Lord Palmerston strongly objected to the prince whom the French Government supported; and, almost immediately after acceding to office, he wrote a despatch in which he enumerated the various candidates for the queen of Spain's hand, including Prince Leopold of Saxe-Coburg, a near relation of the Prince Consort, among the number. Louis Philippe regarded this despatch as a departure from the principle on which he had agreed with Lord Aberdeen, and at once hurried on the simultaneous marriages of the queen with the French candidate, and of her sister with the duc de Montpensier. His action broke up the *entente cordiale* which had been established between M. Guizot and Lord Aberdeen.

The Spanish marriages.

The second occasion on which Lord Palmerston's vigorous diplomacy excited alarm arose out of the revolution which broke out almost universally in Europe in 1848. A rising in Hungary was suppressed by Austria with Russian assistance, and, after its suppression many leading Hungarians took refuge in Turkish territory. Austria and Russia addressed demands to the Porte for their surrender. Lord Palmerston determined to support the Porte in its refusal to give up these exiles, and actually sent the British fleet to the Dardanelles with this object. His success raised the credit of Great Britain and his own reputation. The presence of the British fleet, however, at the Dardanelles suggested to him the possibility of settling another long-standing controversy. For years British subjects settled in Greece had raised complaints against the Greek Government. In particular, Don Pacifico, a Jew, but a native of Gibraltar, complained that, at a riot, in which his house had been attacked, he had lost jewels, furniture, and papers which he alleged to be worth more than £30,000. As Lord Palmerston was unable by correspondence to induce the Greek Government to settle claims of this character, he determined to enforce them; and by his orders a large number of Greek vessels were seized and detained by the British fleet. The French Government tendered its good offices to compose the dispute, and an arrangement was actually arrived at between Lord Palmerston and the French minister in London. Unfortunately, before its terms reached Greece, the British minister at Athens had ordered the resumption of hostilities, and had compelled the Greek Government to submit to more humiliating conditions. News of this settlement excited the strongest feelings both in Paris and London. In Paris, Prince Louis Napoleon, who had acceded to the presidency of the French republic, decided on recalling his representative from the British

Don Pacifico.

court. In London the Lords passed a vote of censure on Lord Palmerston's proceedings; and the Commons only sustained the minister by adopting a resolution approving in general terms the principles on which the foreign policy of the country had been conducted.

In pursuing the vigorous policy which characterized his tenure of the Foreign Office, Lord Palmerston frequently omitted to consult his colleagues in the Cabinet, the prime minister, or the Queen. In the course of 1849 Her Majesty formally complained to Lord John Russell that important despatches were sent off without her knowledge; and an arrangement was made under which Lord Palmerston undertook to submit every despatch to the Queen through the prime minister. In 1850, after the Don Pacifico debate, the Queen repeated these commands in a much stronger memorandum. But Lord Palmerston, though all confidence between himself and the court was destroyed, continued in office. In the autumn of 1851 the Queen was much annoyed at hearing that he had received a deputation at the Foreign Office, which had waited on him to express sympathy with the Hungarian refugees, and to denounce the conduct of "the despots and tyrants" of Russia and Austria, and that he had, in his reply, expressed his gratification at the demonstration. If the Queen had had her way, Lord Palmerston would have been removed from the Foreign Office after this incident. A few days later the *coup d'état* in Paris led to another dispute. The Cabinet decided to do nothing that could wear the appearance of interference in the internal affairs of France; but Lord Palmerston, in conversation with the French minister in London, took upon himself to approve the bold and decisive step taken by the president. The ministry naturally refused to tolerate this conduct, and Lord Palmerston was summarily removed from his office.

Palmerston dismissed.

The removal of Lord Palmerston led almost directly to the fall of the Whig Government. Before relating, however, the exact occurrences which produced its defeat, it is necessary to retrace our steps and describe the policy which it had pursued in internal matters during the six years in which it had been in power. Throughout that period the Irish famine had been its chief anxiety and difficulty. Sir Robert Peel had attempted to deal with it (1) by purchasing large quantities of Indian corn, which he had retailed at low prices in Ireland, and (2) by enabling the grand juries to employ the people on public works, which were to be paid out of monies advanced by the state, one-half being ultimately repayable by the locality. These measures were not entirely successful. It was found, in practice, that the sale of Indian corn at low prices by the Government checked the efforts of private individuals to supply food; and that the offer of comparatively easy work to the poor at the cost of the public prevented their seeking harder private work either in Ireland or in Great Britain. The new Government, with this experience before it, decided on trusting to private enterprise to supply the necessary food, and on throwing the whole cost of the works, which the locality might undertake, on local funds. If the famine had been less severe, this policy might possibly have succeeded. Universal want, however, paralysed every one. The people, destitute of other means of livelihood, crowded to the relief works. In the beginning of 1847 nearly 750,000 persons—or nearly one person out of every ten in Ireland—were so employed. With such vast multitudes to relieve, it proved impracticable to exact the labour which was required as a test of destitution. The roads, which it was decided to make, were blocked by the labourers employed upon them, and by the stones, which the labourers were supposed to crush for their repair. In the presence of this difficulty the Government decided, early in 1847, gradually to discontinue the relief works, and to substitute for them relief committees charged with the task of feeding the people. At one time no less than 3,000,000 persons—more than one-third of the entire population of Ireland—were supported by these committees. At the same time it decided on adopting two measures of a more permanent character. The poor law of 1838 had made no provision for the relief of the poor outside the workhouse, and outdoor relief was sanctioned by an act of 1847. Irish landlords complained that their properties, ruined by the famine, and encumbered by the extravagances of their predecessors, could not bear the cost of this new poor law; and the ministry introduced and carried a measure enabling the embarrassed owners of life estates to sell their property and discharge their liabilities. It is the constant misfortune of Ireland that the measures intended for her relief aggravate her distress. The Encumbered Estates Act, though it substituted a solvent for an insolvent proprietary, placed the Irish tenants at the mercy of landlords of whom they had no previous knowledge, who were frequently absentees, who bought the land as a matter of business, and who dealt with it on business principles by raising the rent. The new poor law, by throwing the maintenance of the poor on the soil, encouraged landlords to extricate themselves from their responsibilities by evicting their tenants. Evictions were made on a scale which elicited from Sir Robert Peel an expression of the deepest abhorrence. The unfortunate persons driven from their holdings and forced to seek a refuge in the towns, in England, or—when they could afford it—in the United States, carried with them everywhere the seeds of disease, the constant handmaid of famine.

Irish famine.

Famine, mortality, and emigration left their mark on Ireland. In four years, from 1845 to 1849, its population decreased from 8,295,000 to 7,256,000, or by more than a million persons; and the decline which took place at that time went on to the end of the century. The population of Ireland in 1901 had decreased to 4,457,000 souls. This fact is the more remarkable, because Ireland is almost the only portion of the British Empire, or indeed of the civilized world, where such a circumstance has occurred. We must go to countries like the Asiatic provinces of Turkey, devastated by Ottoman rule, to find such a diminution in the numbers of the people as was seen in Ireland during the last half of the 19th century. It was probably inevitable that the distress of Ireland should have been followed by a renewal of Irish outrages. A terrible series of agrarian crimes was committed in the autumn of 1847; and the ministry felt compelled, in consequence, to strengthen its hands by a new measure of coercion, and by suspending the Habeas Corpus Act in Ireland. The latter measure at once brought to a crisis the so-called Rebellion of 1848, for his share in which Mr Smith O'Brien, an Irish member of Parliament, was convicted of high treason. The Government, however, did not venture to carry out the grim sentence which the law still applied to traitors, and introduced an Act enabling it to commute the death penalty to transportation. The "insurrection" had from the first proved abortive. With Mr Smith O'Brien's transportation it practically terminated.

Rebellion of 1848.

In the meanwhile the difficulties which the Government was experiencing from the Irish famine had been aggravated by a grave commercial crisis in England. In the autumn of 1847 a series of failures in the great commercial centres created a panic in the City of London, which forced consols down to 78, and induced the Government to take upon itself the responsibility of suspending the Bank Charter Act. That step, enabling the directors of the Bank of

England to issue notes unsecured by bullion, had the effect of gradually restoring confidence. But a grave commercial crisis of this character is often attended with other than financial consequences. The stringency of the money market increases the distress of the industrial classes by diminishing the demand for work; and, when labour suffers, political agitation flourishes. Early in 1848, moreover, revolutions on the Continent produced a natural craving for changes at home. Louis Philippe was driven out of Paris, the emperor of Austria was driven out of Vienna, the Austrian soldiery had to withdraw from Milan, and even in Berlin the crown had to make terms with the people. While thrones were falling or tottering in every country in Europe, it was inevitable that excitement and agitation should prevail in Great Britain. The Chartists, reviving the machinery which they had endeavoured to employ in 1839, decided on preparing a monster petition to Parliament, which was to be escorted to Westminster by a monster procession. Their preparations excited general alarm, and on the invitation of the Government no less than 170,000 special constables were sworn in to protect life and property against a rabble. By the judicious arrangements, however, which were made by the duke of Wellington, the peace of the metropolis was secured. The Chartists were induced to abandon the procession which had caused so much alarm, and the monster petition was carried in a cab to the House of Commons. There it was mercilessly picked to pieces by a select committee. It was found that, instead of containing nearly 6,000,000 signatures, as its originators had boasted, less than 2,000,000 names were attached to it. Some of the names, moreover, were obviously fictitious or even absurd. The exposure of these facts turned the whole thing into ridicule, and gave Parliament an excuse for postponing measures of organic reform which might otherwise have been brought forward.

Chartism

If the ministry thus abstained from pressing forward a large scheme of political reform, it succeeded in carrying two measures of the highest commercial and social importance. In 1849 it supplemented the free trade policy, which Sir Robert Peel had developed, by the repeal of the Navigation Acts. Briefly stated, these Acts, which had been originated during the Protectorate of Cromwell, and continued after the Restoration, reserved the whole coasting trade of the country for British vessels and British seamen, and much of the foreign trade for British vessels, commanded and chiefly manned by British subjects. The Acts, therefore, were in the strictest sense protective, but they were also designed to increase the strength of Great Britain at sea, by maintaining large numbers of British seamen. They had been defended by Adam Smith on the ground that defence was "of much more importance than opulence," and by the same reasoning they had been described by Mr John Stuart Mill as "though economically disadvantageous, politically expedient." The Acts, however, threw a grave burden on British trade and British shipowners. Their provisions by restricting competition naturally tended to raise freights; and by restricting employment made it difficult for shipowners to man their vessels. Accordingly the Government wisely determined on their repeal; and one of the last and greatest battles between Free Trade and Protection was fought over the question. The second reading of the Government Bill was carried in the House of Lords by a majority of only ten: it would not have been carried at all if the Government had not secured a much larger number of proxies than their opponents could obtain.

Navigation Acts.

If the repeal of the Navigation Acts constituted a measure of the highest commercial importance, the passage of the Ten Hours Bill in 1847 marked the first great advance in factory legislation. Something, indeed, had already been done to remedy the evils arising from the employment of women and very young children in factories and mines. In 1833 Lord Ashley, better known as Lord Shaftesbury, had carried the first important Factory Act. In 1842 he had succeeded, with the help of the striking report of a Royal Commission, in inducing Parliament to prohibit the employment of women and of boys under ten years of age in mines. And in 1843 Sir James Graham, who was Home Secretary in Sir Robert Peel's Administration, had been compelled by the pressure of public opinion to introduce a measure providing for the education of children employed in factories, and for limiting the hours of work of children and young persons. The educational clauses of this Bill were obviously framed in the interests of the Church of England, and raised a heated controversy which led to the abandonment of the measure; and in the following year Sir James Graham introduced a new Bill dealing with the labour question alone. Briefly stated, his proposal was that no child under nine years of age should be employed in a factory, and that no young person under eighteen should be employed for more than twelve hours a day. This measure gave rise to the famous controversy on the ten hours clause, which commenced in 1844 and was protracted till 1847. Lord Ashley and the factory reformers contended, on the one hand, that ten hours were long enough for any person to work; their opponents maintained, on the contrary, that the adoption of the clause would injure the working-classes by lowering the rate of wages, and ruin the manufacturers by exposing them to foreign competition. In 1847 the reform was at last adopted. It is a remarkable fact that it was carried against the views of the leading statesmen on both sides of the House. It was the triumph of common-sense over official arguments.

Ten Hours Bill.

During the first four years of Lord John Russell's Government, his administration had never enjoyed any very large measure of popular support, but it had been partly sustained by the advocacy of Sir Robert Peel. The differences which estranged Sir Robert from his old supporters were far greater than those which separated him from the Whigs, and the latter were therefore constantly able to rely on his assistance. In the summer of 1850, however, a lamentable accident—a fall from his horse—deprived the country of the services of its great statesman. His death naturally affected the position of parties. The small remnant of able men, indeed, who had been associated with him in his famous administration, still maintained an attitude of neutrality. But the bulk of the Conservative party rallied under the lead of Lord Stanley (afterwards Derby) in the House of Lords, and gradually submitted to, rather than accepted, the lead of Mr Disraeli in the House of Commons.

Death of Peel.

In the autumn which succeeded Sir Robert Peel's death, an event which had not been foreseen agitated the country and produced a crisis. During the years which had succeeded the Reform Bill a great religious movement had influenced politics both in England and Scotland. In England, a body of eminent men at Oxford—of whom Mr, afterwards Cardinal, Newman was the chief, but who numbered among their leaders Mr Hurrell Froude, the brother of the historian, and Mr Keble, the author of the *Christian Year*—endeavoured to prove that the doctrines of the Church of England were identical with those of the primitive Catholic Church, and that every Catholic doctrine might be held by those who were within its pale. This view was explained in

Oxford Movement.

a remarkable series of tracts, which gave their authors the name of Tractarians. The most famous of these, and the last of the series, Tract XC., was published three years after the Queen's accession to the throne. In Scotland, the Presbyterian Church — mainly under the guidance of Dr Chalmers, one of the most eloquent preachers of the century—was simultaneously engaged in a contest with the state on the subject of ecclesiastical patronage. Both movements had this in common, that they indicated a revival of religious energy, and aimed at vindicating the authority of the church and resisting the interference of the state in church matters. The Scottish movement led to the disruption of the Church of Scotland and the formation of the Free Church in 1843. The Tractarian movement was ultimately terminated by the secession of Newman and many of his associates from the Church of England, and their admission to the Church of Rome. These secessions raised a feeling of alarm throughout England. The people, thoroughly Protestant, were excited by the proofs—which they thought were afforded—that the real object of the Tractarians was to reconcile England with Rome; and practices which are now regarded as venial or even praiseworthy — such as the wearing of the surplice in the pulpit, and the institution of the weekly offertory—were denounced because they were instituted by the Tractarians, and were regarded as insidious devices to lead the country Romewards. The sympathies of the Whigs, and especially of the Whig prime minister, Lord John Russell, were with the people; and Lord John displayed his dislike to the Romanizing tendencies of the Tractarians by appointing Mr Hampden—whose views had been formally condemned by the Hebdomadal Board at Oxford—to the bishopric of Hereford. The High Church party endeavoured to oppose the appointment at every stage; but their attempts exposed them to a serious defeat. The courts held that, though the appointment of a bishop by the crown required confirmation in the archbishop's court, the confirmation was a purely ministerial act which could not be refused. The effort which the High Church party had made to resist Dr Hampden's appointment had thus resulted in showing conclusively that authority resided in the crown and not in the archbishop. It so happened that about the same time this view was confirmed by another judicial decision. The lord chancellor presented Mr Gorham to a living in Devonshire; and Dr Phillpotts, the bishop of Exeter, declined to institute him, on the ground that he held heretical views on the subject of baptism. The Court of Arches upheld the bishop's decision. The finding of the court, however, was reversed by the Privy Council, and its judgment dealt a new blow at the Tractarian party. For it again showed that authority—even in doctrine—resided in the crown and not in the church. Within a few months of this famous decision the Pope—perhaps encouraged by the activity and despondency of the High Church party—issued a brief "for re-establishing and extending the Catholic faith in England," and proceeded to divide England and Wales into twelve sees. One of them—Westminster—was made an archbishopric, and the new dignity was conferred on Mr Wiseman, who was almost immediately afterwards created cardinal. The publication of this brief caused much excitement throughout the country, which was fanned by a letter from the prime minister to the bishop of Durham, condemning the brief as "insolent and insidious" and "inconsistent with the Queen's supremacy, with the rights of our bishops and clergy, and with the spiritual independence of the nation." Somewhat unnecessarily the prime minister went on to condemn the clergymen of the Church of England who had subscribed the Thirty-nine Articles, "who have been the most forward in leading their own flocks, step by step, to the very edge of the precipice."

In accordance with the promise of Lord John Russell's letter, the ministry, at the opening of the session of 1851, introduced a measure forbidding the assumption of territorial titles by the priests and bishops of the Roman Catholic Church, declaring all gifts made to them and all acts done by them under these titles null and void, and forfeiting to the crown all property bequeathed to them. The Bill naturally encountered opposition from many Liberals, while it failed to excite any enthusiasm among Conservatives, who thought its remedies inadequate. In the middle of the debates upon it the Government was defeated on another question—a proposal to reduce the county franchise—and, feeling that it could no longer rely on the support of the House of Commons, tendered its resignation. But Lord Stanley, whom the Queen entrusted with the duty of forming a new administration, was compelled to decline the task, and Lord John resumed office. Mild as the original Ecclesiastical Titles Bill had been thought, the new edition of it, which was introduced after the restoration of the Whigs to power, was still milder. Though, after protracted debates, it was at last placed on the Statute Book, it satisfied nobody. Its provisions, as was soon found, could be easily evaded, and the Bill, which had caused so much excitement, and had nearly precipitated the fall of a ministry, remained a dead letter. The Government, in fact, was experiencing the truth that, if a defeated ministry may be occasionally restored to place, it cannot be restored to power. The dismissal of Lord Palmerston from the Foreign Office in 1851 further increased the embarrassments of the Government. In February 1852 it was defeated on a proposal to revive the militia, and resigned.

Ecclesiastical Titles Bill.

The circumstances which directly led to the defeat of the Whigs were, in one sense, a consequence of the revolutionary wave which had swept over Europe in 1848. The fall of Louis Philippe in that year created a panic in Great Britain. Men thought that the unsettled state of France made war probable, and they were alarmed at the defenceless condition of England. Lord Palmerston, speaking in 1845, had declared that "steam had bridged the Channel"; and the duke of Wellington had addressed a letter to Sir John Burgoyne, in which he had demonstrated that the country was not in a position to resist an invading force. The panic was so great that the ministry felt it necessary to make exceptional provisions for allaying it. Lord John Russell decided on asking Parliament to sanction increased armaments, and to raise the income tax to 1s. in the pound in order to pay for them. The occasion deserves to be recollected as the last on which a prime minister, who was not also chancellor of the exchequer, has himself proposed the budget of the year. But it was still more memorable because the remedy which Lord John proposed at once destroyed the panic which had suggested it. A certain increase of the income tax to a shilling seemed a much more serious calamity than the uncertain prospect of a possible invasion. The estimates were recast, the budget was withdrawn, and the nation was content to dispense with any addition to its military and naval strength. Events in France, in the meanwhile, moved with railway speed. Louis Napoleon became president of the French Republic: in 1851 he became emperor of the French. The new emperor, indeed, took pains to reassure a troubled Continent that "the empire was peace." The people insisted on believing—and, as the event proved, rightly—that the empire was war. Notwithstanding the success of the Great Exhibition of 1851, which was supposed to inaugurate a new reign of peace,

French scare.

the panic, which had been temporarily allayed in 1848, revived at the close of 1851, and the Government endeavoured to allay it by reconstituting the militia. There were two possible expedients. An Act of 1757 had placed a militia, composed of men selected in each parish by ballot, under the direct authority of the crown, liable to be called out for active service, and to be placed under military law. But the Act had been supplemented by a series of statutes passed between 1808 and 1812, which had provided a local militia, raised, like the regular militia, by ballot, but, unlike the latter, only liable for service for the suppression of riots, or in the event of imminent invasion. Lord John Russell's Government, forced to do something by the state of public opinion, but anxious—from the experience of 1848—to make that something moderate, decided on reviving the local militia. Lord Palmerston at once suggested that the regular and not the local militia should be revived; and, in a small house of only 265 members, he succeeded in carrying a resolution to that effect. He had, in this way, what he called his "tit for tat" with Lord John; and the Queen, accepting her minister's resignation, sent for Lord Derby—for Lord Stanley had now succeeded to the title—and charged him with the task of forming a ministry.

Lord Derby.

The Government which Lord Derby succeeded in forming was composed almost exclusively of the men who had rebelled against Sir Robert Peel in 1845. It was led in the House of Commons by the brilliant but somewhat unscrupulous statesman who had headed the revolt. With the exception of Lord Derby and one other man, its members had no experience of high office; and it had no chance of commanding a majority of the House of Commons in the existing Parliament. It owed its position to the divisions of its opponents. Profiting by their experience, it succeeded in framing and passing a measure reconstituting the regular militia, which obtained general approval. It is perhaps worth observing that it maintained the machinery of a ballot, but reserved it only in case experience should prove that it was necessary. Voluntary enlistment under the new Militia Bill was to be the rule: compulsory service was only to be resorted to if voluntary enlistment should fail. This success, to a certain extent, strengthened the position of the new ministry. It was obvious, however, that its stability would ultimately be determined by its financial policy. Composed of the men who had resisted the free trade measures of the previous decade, its fate depended on its attitude towards free trade. In forming his administration Lord Derby had found it necessary to declare that, though he was still in favour of a tax on corn, he should take no steps in this direction till the country had received an opportunity of expressing its opinion. His leader in the House of Commons went much farther, and declared that the time had gone by for recurring to protection. The view which Mr Disraeli thus propounded in defiance of his previous opinions was confirmed by the electors on the dissolution of Parliament. Though the new Government obtained some increased strength from the result of the polls, the country, it was evident, had no intention of abandoning the policy of free trade, which by this time, it was clear, had conferred substantial benefits on all classes. When the new Parliament met in the autumn of 1852 it was at once plain that the issue would be determined on the rival merits of the old and the new financial systems. Mr Disraeli courted the decision by at once bringing forward the budget, which custom, and perhaps convenience, would have justified him in postponing till the following spring. His proposal—in which he avowedly threw over his friends on the ground that "he had greater subjects to consider than the triumph of obsolete opinions"—was, in effect, an attempt to conciliate his old supporters by a policy of doles, and to find the means for doing so by the increased taxation of the middle classes. He offered to relieve the shipping interest by transferring some of the cost of lighting the coasts to the Consolidated Fund; the West India interest by sanctioning the refining of sugar in bond; and the landed classes by reducing the malt tax by one-half, and by repealing the old war duty on hops. He suggested that the cost of these measures should be defrayed by extending the income tax to Ireland, to industrial incomes of £100 and to permanent incomes of £50 a year, as well as by doubling the house tax, and extending it to all £10 householders. The weight, therefore, of these measures was either purposely or unintentionally thrown mainly on persons living in houses worth from £10 to £20 a year, or on persons in receipt of incomes from £50 to £150 a year. This defect in the budget was exposed in a great speech by Mr Gladstone, which did much to ensure the defeat of the scheme and the fall of the ministry.

Coalition, 1853.

On the resignation of Lord Derby, the Queen, anxious to terminate a period of weak governments, decided on endeavouring to combine in one cabinet the chiefs of the Whig party and the followers of Sir Robert Peel. With this view she sent both for Lord Aberdeen, who had held the Foreign Office under Sir Robert, and for Lord Lansdowne, who was the Nestor of the Whigs; and with Lord Lansdowne's concurrence charged Lord Aberdeen with the task of forming a government. In the new ministry Lord Aberdeen became first lord of the treasury, Mr Gladstone chancellor of the exchequer, Lord John Russell foreign minister—though he was almost immediately replaced in the Foreign Office by Lord Clarendon, and assumed himself the presidency of the Council. Lord Palmerston went to the Home Office. One other appointment must also be mentioned. The secretary of state for the colonies was also at that time secretary of state for war. No one in 1852, however, regarded that office as of material importance, and it was entrusted by Lord Aberdeen to an amiable and conscientious nobleman, the duke of Newcastle.

Budget of 1853.

The first session of the Aberdeen Administration will be chiefly recollected for the remarkable budget which Mr Gladstone brought forward. It constituted a worthy supplement to the measures of 1842, 1845, and 1846. Mr Gladstone swept away the duty on one great necessary of life—soap; he repealed the duties on 123 other articles; he reduced the duties on 133 others, among them on tea; and he found means for paying for these reforms and for the gradual reduction and ultimate abolition of the income tax, which had become very unpopular, by (1) extending the tax to incomes of £100 a year; (2) an increase of the spirit duties; and (3) applying the death duties to real property, and to property passing by settlement. There can be little doubt that this great proposal was one of the most striking which had ever been brought forward in the House of Commons; there can also, unhappily, be no doubt that its promises and intentions were frustrated by events which proved too strong for its author. For Mr Gladstone, in framing his budget, had contemplated a continuance of peace, and the country was, unhappily, already drifting into war.

The holy places.

For some years an obscure quarrel had been conducted at Constantinople about the custody of the holy places at Jerusalem. France, relying on a treaty concluded in the first half of the 18th century, claimed the guardianship of these places for the Latin Church. But the rights which the Latin Church had thus obtained had practically fallen into disuse, while the Greek branch of the Christian Church had occupied and repaired the shrines which the Latins had neglected. In the years which preceded 1853, however, France had shown more activity in asserting her claims; and the new emperor of the French, anxious to conciliate the church which had supported his elevation to the throne, had a keen interest in upholding them. If, for reasons of policy, the emperor had grounds for his action, he had personal motives for thwarting the Tsar of Russia; for the latter potentate had been foolish enough, in recognizing the second empire, to address its sovereign as "Mon Cher Ami," instead of, in the customary language of sovereigns, as "Monsieur Mon Frère." Thus at the close of 1852, and in the beginning of 1853, Russia and France were both addressing opposite and irreconcilable demands to the Porte, and France was already talking of sending her fleet to the Dardanelles, while Russia was placing a corps d'armée on active service and despatching Prince Mentschikoff on a special mission to Constantinople. So far the quarrel which had occurred at the Porte was obviously one in which Great Britain had no concern. The Aberdeen ministry, however, thought it desirable that it should be represented in the crisis by a strong man at Constantinople; and it selected Lord Stratford de Redcliffe for the post, which he had filled in former years with marked ability. Whatever merits Lord Stratford possessed—and he stands out in modern diplomacy as the one strong man whom England has produced —there was no doubt that he had this disqualification: the Emperor Nicholas had refused some years before to receive him as ambassador at St Petersburg, and Lord Stratford had resented, and never forgiven, the discourtesy of this refusal. Lord Stratford soon discovered that Prince Mentschikoff was the bearer of larger demands, and that he was requiring the Porte to agree to a treaty acknowledging the right of Russia to protect the Greek Church throughout the Turkish dominions. By Lord Stratford's advice the Porte—while making the requisite concession respecting the holy places—refused to grant the new demand; and Prince Mentschikoff thereupon withdrew from Constantinople.

The rejection of Prince Mentschikoff's ultimatum was followed by momentous consequences. Russia—or rather her Tsar—resolved on the occupation of the principalities; the British ministry—though the quarrel did not directly concern Great Britain—sent a fleet to the Dardanelles and placed it under Lord Stratford's orders. Diplomacy, however, made a fresh attempt to terminate the dispute, and in July 1853 a note was agreed upon by the four neutral Powers, France, Great Britain, Austria, and Prussia, which it was decided to present to Constantinople and St Petersburg. This note, the adoption of which would have insured peace, was accepted at St Petersburg; at Constantinople it was, unfortunately, rejected, mainly on Lord Stratford's advice, and in opposition to his instructions from home. Instead, however, of insisting on the adoption of the note to which it had agreed, Lord Aberdeen's ministry recommended the Tsar to accept some amendments to it suggested by Lord Stratford, which it was disposed to regard as unimportant. It then discovered, however, that the Tsar attached a different meaning to the original note than it had itself applied to it, and in conjunction with France it thereupon ceased to recommend the Vienna Note—as it was called—for acceptance. This decision separated the two western Powers from Austria and Prussia, who were disposed to think that Russia had done all that could have been required of her in accepting the note which the four Powers had agreed upon.

It was obvious that the control of the situation was passing from the hands of the Cabinet at home into those of Lord Stratford at Constantinople. The ambassador, in fact, had the great advantage that he knew his own mind; the Cabinet laboured under the fatal disadvantage that it had, collectively, no mind. Its chief, Lord Aberdeen, was dominated by a desire to preserve peace; but he had not the requisite force to control the stronger men who were nominally serving under him. Lord John Russell was a little sore at his own treatment by his party. He thought that he had a claim to the first place in the ministry, and he did not, in consequence, give the full support to Lord Aberdeen which the latter had a right to expect from him. Lord Palmerston, on the other hand, had no personal grudge to nurture, but he was convinced that the first duty of England was to support Turkey and to resist Russia. He represented in the Cabinet the views which Lord Stratford was enforcing at Constantinople, and step by step Lord Stratford, thus supported, drove the country nearer and nearer to war.

In October the Porte, encouraged by the presence of the British fleet in the Bosphorus, took the bold step of summoning the Russians to evacuate the principalities. Following up this demand the Turkish troops attacked the Russian army, and inflicted on it one or two sharp defeats. The Russians retaliated by loosing their squadron from Sebastopol, and on the 30th of November it attacked and destroyed the Turkish fleet at Sinope. The massacre of Sinope—as it was rather inaccurately called in Great Britain, for it is difficult to deny that it was a legitimate act of a belligerent Power — created an almost irresistible demand for war among the British people. Yielding to popular opinion, the British ministry assented to a suggestion of the French emperor that the fleets of the Allied Powers should enter the Black Sea and "invite" every Russian vessel to return to Sebastopol. The decision was taken at an unfortunate hour. Diplomatists, pursuing their labours at Vienna, had succeeded in drawing up a fresh note which they thought might prove acceptable both at St Petersburg and at Constantinople. Presented almost at the moment at which the Tsar learned that the French and British fleets had entered the Black Sea, the Russian Government, instead of considering it, withdrew its ministers from London and Paris; the French and British ambassadors were thereupon withdrawn from St Petersburg. An ultimatum was soon afterwards addressed to Russia requiring her to evacuate the principalities, and war began. In deciding on war the British Government relied on the capacity of its fleet, which was entrusted to the command of Sir Charles Napier, to strike a great blow in the Baltic. The fleet was despatched with extraordinary rejoicings, and amidst loud and confident expressions of its certain triumph. As a matter of fact it did very little. In the south of Europe, however, the Turkish armies on the Danube, strengthened by the advice of British officers, were more successful. The Russians were forced to retire, and the principalities were evacuated. A prudent Administration might possibly have succeeded in stopping the war at this point. But the temper of the country was by this time excited, and it was loudly demanding something more than a preliminary success. It was resolved to invade the Crimea and attack the great arsenal, Sebastopol, whence the Russian fleet had sailed to Sinope, and in September 1854 the Allied armies landed in the Crimea. On the 20th the Russian army, strongly posted on the banks of the Alma, was completely defeated, and it is almost certain that, if the victory had been at once followed up, Sebastopol would have fallen. The commanders of the Allied armies, however, hesitated to throw themselves

Crimean war.

against the forts erected to the north of the town, and decided on the hazardous task of marching round Sebastopol and attacking it from the south. The movement was successfully carried out, but the Allies again hesitated to attempt an immediate assault. The Russians, who were advised by Colonel Todleben, the only military man who attained a great reputation in the war, thus gained time to strengthen their position by earthworks; and the Allies found themselves forced, with scanty preparations, to undertake a regular siege against an enemy whose force was numerically superior to their own. In the early days of the siege, indeed, the Allied armies were twice in great peril. A formidable attack on the 20th October on the British position at Balaclava led to a series of encounters which displayed the bravery of British troops but did not enhance the reputation of British commanders. A still more formidable sortie on the 5th of November was with difficulty repulsed at Inkerman. And the Russians soon afterwards found, in the climate of the country, a powerful ally. The Allied armies, imperfectly organized, and badly equipped for such a campaign, suffered severely from the hardships of a Crimean winter. The whole expedition seemed likely to melt away from want and disease.

The terrible condition of the army, vividly described in the letters which the war correspondents of the newspapers sent home, aroused strong feelings of indignation in Great Britain. When Parliament met Mr Roebuck gave notice that he would move for a committee of inquiry. Lord John Russell—who had already vainly urged in the Cabinet that the duke of Newcastle should be superseded, and the conduct of the war entrusted to a stronger minister—resigned office. His resignation was followed by the defeat of the Government, and Lord Aberdeen, thus driven from power, was succeeded by Lord Palmerston. In selecting him for the post, the Queen undoubtedly placed her seal on the wish of the country to carry out the war to the bitter end. But it so happened that the formation of a new ministry was accompanied by a fresh effort to make terms of peace. Before the change of administration a conference had been decided on, and Lord Palmerston entrusted its management to Lord John Russell. While the latter was on his way to Vienna an event occurred which seemed at first to facilitate his task. The Tsar, worn out with disappointment, suddenly died, and was succeeded by his son Alexander. Unfortunately the conference failed, and the war went on for another year. In September 1855 the Allied troops succeeded in obtaining possession of the southern side of Sebastopol, and the emperor of the French, satisfied with this partial success, or alarmed at the expense of the war, decided on withdrawing from the struggle. The attitude of Napoleon made the conclusion of peace only a question of time. In the beginning of 1856 a congress to discuss the terms was assembled at Paris; in February hostilities were suspended; and in April a treaty was concluded. The peace set back the boundaries of Russia from the Danube to the Pruth; it secured the free navigation of the first of these rivers; it opened the Black Sea to the commercial navies of the world, closing it to vessels of war and forbidding the establishment of arsenals upon its shores. The last condition, to which Great Britain attached most importance, endured for about fourteen years. Peace without this provision could undoubtedly have been secured at Vienna, and the prolongation of the war from 1855 to 1856 only resulted in securing this arrangement for a little more than one decade.

Palmerston's Ministry.

The Crimean war left other legacies behind it. The British Government had for some time regarded with anxiety the gradual encroachments of Russia in Central Asia. Russian diplomacy was exerting an increasing influence in Persia, and the latter had always coveted the city of Herat, which was popularly regarded as the gate of India. In 1856 the Persian Government, believing that England had her hands fully occupied in the Crimea, seized Herat, and, in consequence, a fresh war—in which a British army under Sir James Outram rapidly secured a victory—broke out. The campaign, entered upon when Parliament was not in session, was unpopular in the country. A grave constitutional question, which was ultimately settled by legislation, was raised as to the right of the Government to undertake military operations beyond the boundaries of India without the consent of Parliament. But the incidents of the Persian war were soon forgotten in the presence of a still graver crisis; for in the following year, 1857, the country suddenly found itself involved in war with China, and face to face with one of the greatest dangers which it has ever encountered—the mutiny of the Sepoy army in India. The Chinese war arose from the seizure by the Chinese authorities of a small vessel, the *Arrow*, commanded by a British subject, and at one time holding a license (which, however, had expired at the time of the seizure) from the British superintendent at Hongkong, and the detention of her crew on the charge of piracy. Sir John Bowring, who represented Great Britain in China, failing to secure the reparation and apology which he demanded, directed the British admiral to bombard Canton. Lord Palmerston's Cabinet decided to approve and support Sir John Bowring's vigorous action. Mr Cobden, however, brought forward a motion in the House of Commons condemning these high-handed proceedings. He succeeded in securing the co-operation of his own friends, of Lord John Russell, and of other independent Liberals, as well as of the Conservative party, and in inflicting a signal defeat on the Government. Lord Palmerston at once appealed from the House to the country. The constituencies, imperfectly acquainted with the technical issues involved in the dispute, rallied to the minister, who was upholding British interests. Lord Palmerston obtained a decisive victory, and returned to power apparently in irresistible strength. Lord Elgin had already been sent to China with a considerable force to support the demand for redress. On his way thither he learned that the British in India were reduced to the last extremities by the mutiny of the native army in Bengal, and, on the application of Lord Canning, the governor-general, he decided on diverting the troops, intended to bring the Chinese to reason, to the more pressing duty of saving India for the British crown.

Wars with Persia and China.

During the years which had followed the accession of the Queen, the territories and responsibilities of the East India Company had been considerably enlarged by the annexation of Scinde by Lord Ellenborough, the conquest of the Punjab after two desperate military campaigns under Lord Dalhousie, the conquest of Pegu, and the annexation of Oudh. These great additions to the empire had naturally imposed an increased strain on the Indian troops, while the British garrison, instead of being augmented, had been depleted to meet the necessities of the Russian war. Several circumstances, moreover, tended to propagate disaffection in the Indian army. Indian troops operating outside the Company's dominions were granted increased allowances, but these were automatically reduced when conquest brought the provinces in which they were serving within the British pale. The Sepoys again had an ineradicable dislike to serve beyond the sea, and the invasion of Pegu necessitated their transport by water to the seat of war. Finally, the invention of a new rifle led to the introduction of a cartridge which, though it was

Indian Mutiny.

officially denied at the moment, was in fact lubricated with a mixture of cow's fat and lard. The Sepoys thought that their caste would be destroyed if they touched the fat of the sacred cow or unclean pig; they were even persuaded that the British Government wished to destroy their caste in order to facilitate their conversion to Christianity. Isolated mutinies in Bengal were succeeded by much more serious events at Cawnpore in Oudh, and at Meerut in the North-West Provinces. From Meerut the mutineers, after some acts of outrage and murder, moved on Delhi, the capital of the old Mogul empire, which became the headquarters of the mutiny. In Oudh the native regiments placed themselves under a Mahratta chief, Nana Sahib, by whose orders the British in Cawnpore, including the women and children, were foully murdered. In the summer of 1857 these events seemed to imperil British rule in India. In the autumn the courage of the troops and the arrival of reinforcements gradually restored the British cause. Delhi, after a memorable siege, was at last taken by a brilliant assault. Lucknow, where a small British garrison was besieged in the Residency, was twice relieved, once temporarily by Sir James Outram and General Havelock, and afterwards permanently by Sir Colin Campbell, who had been sent out from England to take the chief command. Subsequent military operations broke up the remnants of the revolt, and in the beginning of 1858 the authority of the Queen was restored throughout India. The mutiny, however, had impressed its lesson on the British people, and, as the first consequence, it was decided to transfer the government from the old East India Company to the crown. Lord Palmerston's administration was defeated on another issue before it succeeded in carrying the measure which it introduced for the purpose, though Lord Derby's second ministry, which succeeded it, was compelled to frame its proposals on somewhat similar lines. The home government of India was entrusted to a secretary of state, with a council to assist him; and though the numbers of the council have been reduced, the form of government which was then established has endured.

Orsini.

The cause which led to the second fall of Lord Palmerston was in one sense unexpected. Some Italian refugees living in London, of whom Orsini was the chief, formed a design to assassinate the emperor of the French. On the evening of 14th January 1858, while the emperor, accompanied by the empress, was driving to the opera, these men threw some bombs under his carriage. The brutal attempt happily failed. Neither the emperor nor the empress was injured by the explosion, but the carriage in which they were driving was wrecked, and a large number of persons who happened to be in the street at the time were either killed or wounded. This horrible outrage naturally created indignation in France, and it unfortunately became plain that the conspiracy had been hatched in England and that the bombs had been manufactured in Birmingham. On these facts becoming known, Count Walewski, the chief of the French Foreign Office, who was united by ties of blood to the emperor, called on the British Government to provide against the danger to which France was exposed. "Ought the right of asylum to protect such a state of things?" he asked. "Is hospitality due to assassins? Ought the British Legislature to continue to favour their designs and their plans? And can it continue to shelter persons who by these flagrant acts place themselves beyond the pale of common rights?" Lord Clarendon, the head of the British Foreign Office, told the French ambassador, who read him this despatch, that "no consideration on earth would induce the British Parliament to pass a measure for the extradition of political refugees," but he added that it was a question whether the law was as complete and as stringent as it should be, and he stated that the Government had already referred the whole subject to the law officers of the crown for their consideration. Having made these remarks, however, he judged it wise to refrain from giving any formal reply to Count Walewski's despatch, and contented himself with privately communicating to the British ambassador in Paris the difficulties of the British Government. After receiving the opinion of the law officers the Cabinet decided to introduce a Bill into Parliament increasing in England the punishment for a conspiracy to commit a felony either within or without the United Kingdom. The first reading of this Bill was passed by a considerable majority. But, before the Bill came on for a second reading, the language which was being used in France created strong resentment in England. The regiments of the French army sent addresses to the emperor congratulating him on his escape and violently denouncing the British people. Some of these addresses, which were published in the *Moniteur*, spoke of London as "an assassins' den," and invited the emperor to give his troops the order to destroy it. Such language did not make it easier to alter the law in the manner desired by the Government. The House of Commons, reflecting the spirit of the country, blamed Lord Clarendon for neglecting to answer Count Walewski's despatch, and blamed Lord Palmerston for introducing a Bill at French dictation. The feeling was so strong that, when the Conspiracy Bill came on for a second reading, an amendment hostile to the Government was carried, and Lord Palmerston at once resigned.

Lord Derby's second ministry.

For a second time Lord Derby undertook the difficult task of carrying on the work of government without the support of a majority of the House of Commons. If the Liberal party had been united his attempt would have failed immediately. In 1858, however, the Liberal party had no cohesion. The wave of popularity which had carried Lord Palmerston to victory in 1857 had lost its strength. The Radicals, who were slowly recovering the influence they had lost during the Crimean war, regarded even a Conservative government as preferable to his return to power, while many Liberals desired to entrust the fortunes of their party to the guidance of their former chief, Lord John Russell. It was obvious to most men that the dissensions thus visible in the Liberal ranks could be more easily healed in the cold shade of the Opposition benches than in the warmer sunlight of office. And therefore, though no one had much confidence in Lord Derby, or in the stability of his second Administration, every one was disposed to acquiesce in its temporary occupation of office.

Jews in Parliament.

Ministries which exist by sufferance are necessarily compelled to adapt their measures to the wishes of those who permit them to continue in power. The second ministry of Lord Derby experienced the truth of this rule. For some years a controversy had been conducted in the Legislature in reference to the admission of the Jews to Parliament. This dispute had been raised in 1847 into a question of practical moment by the election of Baron Rothschild as representative of the City of London, and its importance had been emphasized in 1851 by the return of another Jew, Alderman Salomons, for another constituency. The Liberal party generally in the House of Commons was in favour of such a modification of the oaths as would enable the Jews so elected to take their seats. The bulk of the Conservative party, on the contrary, and the House of Lords, were strenuously opposed to the change. Early in 1858 the House of Commons, by an increased majority, passed a Bill amending the oaths imposed by law on members of both Houses, and directing the omission of the words "on the true faith of a Christian" from the oath of abjuration when it was taken by a Jew. If the Conservatives had remained in Opposition there can be little doubt that this Bill would have shared the fate of its predecessors and have been rejected by the Lords. The lord chancellor, indeed, in speaking upon the clause relieving the Jews, expressed a hope that the peers would not hesitate to pronounce that our "Lord is king, be the people never so impatient." But some Conservative peers realized the inconvenience of maintaining a conflict between the two Houses when the Conservatives were in power; and Lord Lucan, who had commanded the cavalry in the Crimea, suggested as a compromise that either House should be authorized by resolution to determine the form of oath to be administered to its members. This solution was reluctantly accepted by Lord Derby, and Baron Rothschild was thus enabled to take the seat from which he had been so long excluded. Eight years afterwards Parliament was induced to take a fresh step in advance. It imposed a new oath from which the words which disqualified the Jews were omitted. The door of the House of Lords was thus thrown open, and Baron Rothschild, raised to the peerage, was enabled to take his seat in the upper chamber.

This question was not the only one on which a Conservative Government, without a majority at its back, was compelled to make concessions. For some years past a growing disposition had been displayed among the more earnest Liberals to extend the provisions of the Reform Act of 1832. Lord John Russell's ministry had been defeated in 1851 on a proposal of Mr Locke King to place £10 householders in counties on the same footing as regards the franchise as £10 householders in towns, and Lord John himself in 1854 had actually introduced a new Reform Bill. After the general election of 1857 the demand for reform increased, and, in accepting office in 1858, Lord Derby thought it necessary to declare that, though he had maintained in Opposition that the settlement of 1832, with all its anomalies, afforded adequate representation to all classes, the promises of previous governments and the expectations of the people imposed on him the duty of bringing forward legislation on the subject. The scheme which Lord Derby's Government adopted was peculiar. Its chief proposal was the extension of the county franchise to £10 householders. But it also proposed that persons possessing a 40s. freehold in a borough should in future have a vote in the borough in which their property was situated, and not in the county. The Bill also conferred the franchise on holders of a certain amount of stock, on depositors in savings banks, on graduates of universities, and on other persons qualified by position or education. The defect of the Bill was that it did nothing to meet the only real need of reform—the enfranchisement of a certain proportion of the working classes. On the contrary, in this respect it perpetuated the settlement of 1832. The £10 householder was still to furnish the bulk of the electorate, and the ordinary working man could not afford to pay £10 a year for his house. While the larger proposals of the Bill were thus open to grave objection, its subsidiary features provoked ridicule. The suggestions that votes should be conferred on graduates and stockholders were laughed at as "Fancy Franchises." The Bill, moreover, was not brought forward with the authority of a united Cabinet. Two members of the Government—Mr Spencer Walpole and Mr Henley—declined to be responsible for its provisions, and placed their resignations in Lord Derby's hands. In Mr Walpole's judgment the Bill was objectionable because it afforded no reasonable basis for a stable settlement. There was nothing in a £10 franchise which was capable of permanent defence, and if it was at once applied to counties as well as boroughs it would sooner or later be certain to be extended. He himself advocated with some force that it would be wiser and more popular to fix the county franchise at £20 and the borough franchise at £6 rateable value; and he contended that such a settlement could be defended on the old principle that taxation and representation should go together, for £20 was the minimum rent at which the house tax commenced, and a rateable value of £6 was the point at which the householder could not compound to pay his rates through his landlord. Weakened by the defection of two of its more important members, the Government had little chance of obtaining the acceptance of its scheme. An amendment of Lord John Russell, condemning its main provisions, was adopted in an unusually full house by a substantial majority, and the Cabinet had no alternative but to resign or dissolve. It chose the latter course. The general election, which almost immediately took place, increased to some extent the strength of the Conservative party. For the first time since their secession from Sir Robert Peel the Conservatives commanded more than three hundred votes in the House of Commons, but this increased strength was not sufficient to ensure them a majority. When the new Parliament assembled, Lord Hartington, the eldest son of the duke of Devonshire, was put forward to propose a direct vote of want of confidence in the Administration. It was carried by 323 votes to 310, and the second Derby Administration came to an end.

Reform Bill, 1859.

It was plain that the House of Commons had withdrawn its support from Lord Derby, but it was not clear that any other leading politician would be able to form a government. The jealousies between Lord John Russell and Lord Palmerston still existed; the more extreme men, who were identified with the policy of Mr Cobden and Mr Bright, had little confidence in either of these statesmen; and it was still uncertain whether the able group who had been the friends of Sir Robert Peel would finally gravitate to the Conservative or to the Liberal camp. The Queen, on the advice of Lord Derby, endeavoured to solve the first of these difficulties by sending for Lord Granville, who led the Liberal party in the Lords, and authorizing him to form a government which should combine, as far as possible, all the more prominent Liberals. The attempt, however, failed, and the Queen thereupon fell back upon Lord Palmerston. Lord John Russell agreed to accept office as foreign minister; Mr Gladstone consented to take the chancellorship of the exchequer. Mr Cobden was offered, but declined, the presidency of the Board of Trade; and the post which he refused was conferred on a prominent free trader, who had associated himself with Mr Cobden's fortunes, Mr Milner Gibson. Thus Lord Palmerston had succeeded in combining in one ministry the various representatives of political progress. He had secured the support of the Peelites, who had left him after the fall of Lord Aberdeen in 1855, and of the free traders, who had done so much to defeat him in 1857 and 1858. His new Administration was accordingly based on a broader bottom, and contained greater elements of strength than his former Cabinet. And the country was requiring more stable government. The three first ministries of the Queen had endured from the spring of 1835 to the spring of 1852, or for very nearly seventeen years; but the next seven years had seen the formation and dissolution of no less than four Cabinets. It was felt that these frequent changes were unfortunate for the country, and every one was glad to welcome the advent of a Government which seemed to promise greater permanence. That promise was fulfilled. The Administration which Lord Palmerston succeeded in forming in 1859 endured till his death in 1865, and with slight modifications, under its second chief Lord John (afterwards Earl) Russell, till the summer of 1866. It had thus a longer life than any Cabinet which had governed

Palmerston's second ministry.

England since the first Reform Act. But it owed its lasting character to the benevolence of its opponents rather than to the enthusiasm of its supporters. The Conservatives learned to regard the veteran statesman, who had combined all sections of Liberals under his banner, as the most powerful champion of Conservative principles; a virtual truce of parties was established during his continuance in office; and, for the most part of his ministry, a tacit understanding existed that the minister, on his side, should pursue a Conservative policy, and that the Conservatives, on theirs, should abstain from any real attempt to oust him from power. Lord John Russell, indeed, was too earnest in his desire for reform to abstain from one serious effort to accomplish it. Early in 1860 he proposed, with the sanction of the Cabinet, a measure providing for the extension of the county franchise to £10 householders, of the borough franchise to £6 householders, and for a moderate redistribution of seats. But the country, being in enjoyment of considerable prosperity, paid only a languid attention to the scheme; its indifference was reflected in the House; the Conservatives were encouraged in their opposition by the lack of interest which the new Bill excited, and the almost unconcealed dislike of the prime minister to its provisions. The Bill, thus steadily opposed and half-heartedly supported, made only slow progress; and at last it was withdrawn by its author. He did not again attempt during Lord Palmerston's life to reintroduce the subject. Absorbed in the work of the Foreign Office, which at this time was abnormally active, he refrained from pressing home the arguments for internal reform.

Mr Gladstone's budgets.

In one important department, however, the ministry departed from the Conservative policy it pursued in other matters. Mr Gladstone signalized his return to the exchequer by introducing a series of budgets which excited keen opposition at the time, but in the result largely added to the prosperity of the country. The first of these great budgets, in 1860, was partly inspired by the necessity of adapting the fiscal system to meet the requirements of a commercial treaty which, mainly through Mr Cobden's exertions, had been concluded with the emperor of the French. The treaty bound France to reduce her duties on English coal and iron, and on many manufactured articles; while, in return, Great Britain undertook to sweep away the duties on all manufactured goods, and largely to reduce those on French wines. But Mr Gladstone was not content with these great alterations, which involved a loss of nearly £1,200,000 a year to the exchequer; he voluntarily undertook to sacrifice another million on what he called a supplemental measure of customs reform. He proposed to repeal the duties on paper, by which means he hoped to increase the opportunities of providing cheap literature for the people. The budget of 1860 produced a protracted controversy. The French treaty excited more criticism than enthusiasm on both sides of the Channel. In France the manufacturers complained that they would be unable to stand against the competition of English goods. In England many people thought that Great Britain was wasting her resources and risking her supremacy by giving the French increased facilities for taking her iron, coal, and machinery, and that no adequate advantage could result from the greater consumption of cheap claret. But the criticism which the French treaty aroused was drowned in the clamour which was created by the proposed repeal of the paper duties. The manufacture of paper was declared to be a struggling industry, which would be destroyed by the withdrawal of protection. The dissemination of cheap literature, and the multiplication of cheap newspapers, could not compensate the nation for the ruin of an important trade. If money could be spared, moreover, for the remission of taxation, the paper duties were much less oppressive than those on some other articles. The tax on tea, for example, which had been raised during the late war to no less than 1s. 5d. a ℔, was much more injurious; and it would be far wiser—so it was contended—to reduce the duty on tea than to abandon the duties on paper. Notwithstanding the opposition which the Paper Duties Bill undoubtedly excited, the proposal was carried in the Commons; it was, however, thrown out in the Lords, and its rejection led to a crisis which seemed at one time to threaten the good relations between the two houses of Parliament. It was argued that if the Lords had the right to reject a measure remitting existing duties, they had in effect the right of imposing taxation, since there was no material difference between the adoption of a new tax and the continuance of an old one which the Commons had determined to repeal. Lord Palmerston, however, with some tact postponed the controversy for the time by obtaining the appointment of a committee to search for precedents; and, after the report of the committee, he moved a series of resolutions affirming the right of the Commons to grant aids and supplies as their exclusive privilege, stating that the occasional rejection of financial measures by the Lords had always been regarded with peculiar jealousy, but declaring that the Commons had the remedy in their own hands by so framing Bills of Supply as to secure their acceptance. In accordance with this suggestion the Commons in the following year again resolved to repeal the paper duties; but, instead of embodying their decision in a separate Bill, they included it in the same measure which dealt with all the financial arrangements of the year, and thus threw on the Lords the responsibility of either accepting the proposal, or of paralysing the whole machinery of administration by depriving the crown of the supplies which were required for the public services. The Lords were not prepared to risk this result, and they accordingly accepted a reform which they could no longer resist, and the Bill became law. In order to enable him to accomplish these great changes, Mr Gladstone temporarily raised the income tax, which he found at 9d. in the pound, to 10d. But the result of his reforms was so marked that he was speedily able to reduce it. The revenue increased by leaps and bounds, and the income tax was gradually reduced till it stood at 4d. in the closing years of the Administration. During the same period the duty on tea was reduced from 1s. 5d. to 6d. in the ℔; and the national debt was diminished from rather more than £800,000,000 to rather less than £780,000,000, the charge for the debt declining, mainly through the falling in of the Long Annuities, by some £2,600,000 a year. With the possible exception of Sir Robert Peel's term of office, no previous period of British history had been memorable for a series of more remarkable financial reforms. Their success redeemed the character of the Administration. The Liberals, who complained that their leaders were pursuing a Conservative policy, could at least console themselves by the reflection that the chancellor of the exchequer was introducing satisfactory Budgets. The language, moreover, which Mr Gladstone was holding on other subjects encouraged the more advanced Liberals to expect that he would ultimately place himself at the head of the party of progress. This expectation was the more remarkable because Mr Gladstone was the representative in the Cabinet of the old Conservative party which Sir Robert Peel had led to victory. As lately as 1858 he had reluctantly refused to serve under Lord Derby; he was still a member of the Carlton Club; he sat for the university of Oxford; and on many questions he displayed a constant sympathy with Conservative traditions. Yet, on all the chief domestic questions which came before Parliament in Lord Palmerston's second Administration, Mr

Paper duties repealed.

Gladstone almost invariably took a more Liberal view than his chief. It was understood, indeed, that the relations between the two men were not always harmonious; that Lord Palmerston disapproved the resolute conduct of Mr Gladstone, and that Mr Gladstone deplored the Conservative tendencies of Lord Palmerston. It was believed that Mr Gladstone on more than one occasion desired to escape from a position which he disliked by resigning office, and that the resignation was only averted through a consciousness that the ministry could not afford to lose its most eloquent member.

While on domestic matters other than those affecting finance the Liberal ministry was pursuing a Conservative policy, its members were actively engaged on, and the attention of the public was keenly directed to, affairs abroad. For the period was one of foreign unrest, and the wars which were then waged have left an enduring mark on the map of the world, and have affected the position of the Anglo-Saxon race for all time. In the far East, the operations which it had been decided to undertake in China were necessarily postponed on account of the diversion of the forces, intended to exact redress at Peking, to the suppression of mutiny in India. It was only late in 1858 that Lord Elgin and Baron Gros, the French plenipotentiary (for France joined England in securing simultaneous redress for grievances of her own), were enabled to obtain suitable reparation. It was arranged that the treaty, which was then provisionally concluded at Tientsin, should be ratified at Peking in the following year; and in June 1859 Mr Bruce, Lord Elgin's brother, who had been appointed plenipotentiary, attempted to proceed up the Peiho with the object of securing its ratification. The Allied squadron, however, was stopped by the forts at the mouth of the Peiho, which fired on the vessels; a landing party, which was disembarked to storm the forts, met with a disastrous check, and the squadron had to retire with an acknowledged loss of three gunboats and 400 men. This reverse necessitated fresh operations, and in 1860 Lord Elgin and Baron Gros were directed to return to China, and, at the head of an adequate force, were instructed to exact an apology for the attack on the Allied fleets, the ratification and execution of the treaty of Tientsin, and the payment of an indemnity for the expenses of the war. The weakness of the Chinese empire was not appreciated at that time; the unfortunate incident on the Peiho in the previous summer had created an exaggerated impression of the strength of the Chinese arms, and some natural anxiety was felt for the success of the expedition. But the Allied armies met with no serious resistance. The Chinese, indeed, endeavoured to delay their progress by negotiation rather than by force; and they succeeded in treacherously arresting some distinguished persons who had been sent into the Chinese lines to negotiate. But by the middle of October the Chinese army was decisively defeated; Peking was occupied; those British and French prisoners who had not succumbed to the hardships of their confinement were liberated; Lord Elgin determined on teaching the rulers of China a lesson by the destruction of the Summer Palace; and the Chinese Government was compelled to submit to the terms of the Allies, and to ratify the treaty of Tientsin. There is no doubt that these operations helped to open the Chinese markets to British trade; but incidentally, by regulating the emigration of Chinese coolies, they had the unforeseen effect of exposing the industrial markets of the world to the serious competition of cheap "yellow" labour. A distinguished foreign statesman observed that Lord Palmerston had made a mistake. He thought that he had opened China to Europe; instead, he had let out the Chinese. It was perhaps a happier result of the war that it tended to the continuance of the Anglo-French alliance. French and British troops had again co-operated in a joint enterprise, and had shared the dangers and successes of a campaign.

China war, 1859-60.

War was not confined to China. In the beginning of 1859 diplomatists were alarmed at the language addressed by the emperor of the French to the Austrian ambassador at Paris, which seemed to breathe the menace of a rupture. Notwithstanding the exertions which Great Britain made to avert hostilities, the provocation of Count Cavour induced Austria to declare war against Piedmont, and Napoleon thereupon moved to the support of his ally, promising to free Italy from the Alps to the Adriatic. As a matter of fact, the attitude of northern Germany, which was massing troops on the Rhine, and the defenceless condition of France, which was drained of soldiers for the Italian campaign, induced the emperor to halt before he had carried out his purpose, and terms of peace were hastily concerted at Villafranca, and were afterwards confirmed at Zurich, by which Lombardy was given to Piedmont, while Austria was left in possession of Venice and the Quadrilateral, and Central Italy was restored to its former rulers. The refusal of the Italians to take back the Austrian grand dukes made the execution of these arrangements impracticable. Napoleon, indeed, used his influence to carry them into effect; but Lord John Russell, who was now in charge of the British Foreign Office, and who had Lord Palmerston and Mr Gladstone on his side in the Cabinet, gave a vigorous support to the claim of the Italians that their country should be allowed to regulate her own affairs. The French emperor had ultimately to yield to the determination of the inhabitants of Central Italy, when it was backed by the arguments of the British Foreign Office, and Tuscany, Modena, Parma, as well as a portion of the States of the Church, were united to Piedmont. There was no doubt that through the whole of the negotiations the Italians were largely indebted to the labours of Lord John Russell. They recognized that they owed more to the moral support of England than to the armed assistance of France. The French emperor, moreover, took a step which lost him the sympathy of many Italians. Before the war he had arranged with Count Cavour that France should receive, as the price of her aid, the duchy of Savoy and the county of Nice. After Villafranca, the emperor, frankly recognizing that he had only half kept his promise, consented to waive his claim to these provinces. But, when he found himself unable to resist the annexation of Central Italy to Piedmont, he reverted to the old arrangement. The formation of a strong Piedmontese kingdom, with the spoliation of the papal dominion, was unpopular in France; and he thought—perhaps naturally—that he must have something to show his people in return for sacrifices which had cost him the lives of 50,000 French soldiers, and concessions which the whole Catholic party in France resented. Count Cavour consented to pay the price which Napoleon thus exacted, and the frontier of France was accordingly extended to the Alps. But it is very doubtful whether Napoleon did not lose more than he gained by this addition to his territory. It certainly cost him the active friendship of Great Britain. The Anglo-French alliance had been already strained by the language of the French colonels in 1858 and the Franco-Austrian war of 1859; it never fully recovered from the shock which it received by the evidence, which the annexation of Savoy and Nice gave, of the ambition of the French emperor. The British people gave way to what Mr Cobden called the last of the three panics. Lord Palmerston proposed and carried the provision of a large sum of money for the fortification of the coasts; and the volunteer movement, which had its origin in 1859, received a remarkable stimulus in 1860. In this year the course of events in

Unification of Italy.

Italy emphasized the differences between the policy of Great Britain and that of France. Garibaldi, with a thousand followers, made his famous descent on the coast of Sicily. After making himself master of that island, he crossed over to the mainland, drove the king of Naples out of his capital, and forced him to take refuge in Gaeta. In France these events were regarded with dismay. The emperor wished to stop Garibaldi's passage across the Strait, and stationed his fleet at Gaeta to protect the king of Naples. Lord John Russell, on the contrary, welcomed Garibaldi's success with enthusiasm. He declined to intervene in the affairs of Italy by confining the great liberator to Sicily; he protested against the presence of the French fleet at Gaeta; and when other foreign nations denounced the conduct of Piedmont, he defended it by quoting Vattel and citing the example of William III. When, finally, Italian troops entered the dominions of the pope, France withdrew her ambassador from the court of Turin, and England under Lord John Russell's advice at once recognized the new kingdom of Italy.

In these great events—for the union of Italy was the greatest fact which had been accomplished in Europe since the fall of the first Napoleon—the British ministry had undoubtedly acquired credit. It was everywhere felt that the new kingdom owed much to the moral support which had been steadily and consistently given to it by Great Britain. Soon afterwards, however, in the autumn of 1863, the death of the king of Denmark led to a new revolution in the north of Europe, in which Lord Palmerston's Government displayed less resolution and lost much of the prestige which it had acquired by its Italian policy. The duchies of Schleswig and Holstein had been for centuries united to the kingdom of Denmark by the golden link of the crown; in other respects they had been organically kept distinct, while one of them—Holstein—was a member of the German confederation.

Schleswig-Holstein question.

The succession to the crown of Denmark, however, was different from that in the duchies. In Denmark the crown could descend, as it descends in Great Britain, through females. In the duchies the descent was confined to the male line; and, as Frederick VII., who ascended the Danish throne in 1848, had no direct issue, the next heir to the crown of Denmark under this rule was Prince Christian of Glucksburg, afterwards king; the next heir to the duchies being the duke of Augustenburg. In 1850 an arrangement had been made to prevent the separation of the duchies from the kingdom. As a result of a conference held in London, the duke of Augustenburg was induced to renounce his claim on the receipt of a large sum of money. Most of the Great Powers of Europe were parties to this plan. But the German confederation was not represented at the conference, and was not therefore committed to its conclusions. During the reign of Frederick VII. the Danish Government endeavoured to cement the alliance between the duchies and the kingdom, and specially to separate the interests of Schleswig, which was largely Danish in its sympathies, from those of Holstein, which was almost exclusively German. With this object, in the last year of his life, Frederick VII. granted Holstein autonomous institutions, and bound Schleswig more closely to the Danish monarchy. The new King Christian IX. confirmed this arrangement. The German Diet at Frankfort at once protested against it. Following up words with acts it decided on occupying Holstein, and it delegated the duty of carrying out its order to Hanover and Saxony. While federal execution was taking place, the duke of Augustenburg—regardless of the arrangements to which he had consented—delegated his rights in the duchies to his son, who formally claimed the succession. So far the situation, which was serious enough, had been largely dependent on the action of Germany. In the closing days of 1863 it passed mainly into the control of the two chief German Powers. In Prussia Bismarck had lately become prime minister, and was animated by ambitious projects for his country's aggrandizement. Austria, afraid of losing her influence in Germany, followed the lead of Prussia, and the two powers required Denmark to cancel the arrangements which Frederick VII. had made, and which Christian IX. had confirmed, threatening in case of refusal to follow up the occupation of Holstein by that of Schleswig. As the Danes gave only a provisional assent to the demand, Prussian and Austrian troops entered Schleswig. These events created much excitement in England. The great majority of the British people, who imperfectly understood the merits of the case, were unanimous in their desire to support Denmark by arms. Their wish had been accentuated by the circumstance that the marriage in the previous spring of the prince of Wales to the daughter of the new king of Denmark had given them an almost personal interest in the struggle. Lord Palmerston had publicly expressed the views of the people by declaring that, if Denmark were attacked, her assailants would not have to deal with Denmark alone. The language of the public press and of Englishmen visiting Denmark confirmed the impression which the words of the prime minister had produced; and there is unfortunately no doubt that Denmark was encouraged to resist her powerful opponents by the belief, which she was thus almost authorized in entertaining, that she could reckon in the hour of her danger on the active assistance of the United Kingdom. If Lord Palmerston had been supported by his Cabinet, or if he had been a younger man, he might possibly, in 1864, have made good the words which he had rashly uttered in 1863. But the Queen, who, it is fair to add, understood the movement which was tending to German unity much better than most of her advisers, was averse from war. A large section of the Cabinet shared the Queen's hesitation, and Lord Palmerston—with the weight of nearly eighty summers upon him—was not strong enough to enforce his will against both his sovereign and his colleagues. He made some attempt to ascertain whether the emperor of the French would support him if he went to war. But he found that the emperor had not much fancy for a struggle which would have restored Holstein to Denmark; and that, if he went to war at all, his chief object would be the liberation of Venice and the rectification of his own frontiers. Even Lord Palmerston shrank from entering on a campaign which would have involved all Europe in conflagration, and would have unsettled the boundaries of most Continental nations; and the British Government endeavoured thenceforward to stop hostilities by referring the question immediately in dispute to a conference in London. The labours of the conference proved abortive. Its members were unable to agree upon any methods of settlement, and the war went on. Denmark, naturally unable to grapple with her powerful antagonists, was forced to yield, and the two duchies, which were the subject of the dispute, were taken from her.

The full consequences of this struggle were not visible at the time. It was impossible to foresee that it was the first step which was to carry Prussia forward, under her ambitious minister, to a position of acknowledged supremacy on the Continent. But the results to Great Britain were plain enough. She had been mighty in words and weak in deeds. It was no doubt open to her to contend, as perhaps most wise people consider, that the cause of Denmark was not of sufficient importance to justify her in going to war. But it was not open to her to encourage a weak Power to resist, and then desert her in the hour of her necessity. Lord

Palmerston should not have used the language which he employed in 1863, if he had not decided that his brave words would be followed by brave action. His conduct lowered the prestige of Great Britain at least as much as his Italian policy had raised it. Continental statesmen thenceforward assumed that Great Britain, however much she might protest, would not resort to arms, and the influence of England suffered, as it was bound to suffer, in consequence.

Meanwhile, in this period of warfare, another struggle was being fought out on a still greater scale in North America. The election of Mr Abraham Lincoln to the presidency of the United States emphasized the fact that the majority of the inhabitants of the Northern States were opposed to the continuance of slavery; and, in the beginning of 1861, several of the Southern States formally seceded from the union. A steamer sent by the Federal Government with reinforcements to Fort Sumter was fired upon, and both parties made preparations for the civil war which was apparently inevitable. On the one side the Confederate States—as the seceding states were called—were animated by a resolution to protect their property. On the other side the "conscience" of the North was excited by a passionate desire to wipe out the blot of slavery. Thus both parties were affected by some of the most powerful considerations which can influence mankind, while the North were further actuated by the natural incentive to preserve the union, which was threatened with disruption. The progress of the great struggle was watched with painful attention in England. The most important manufacturing interest in England was paralysed by the loss of the raw cotton, which was obtained almost exclusively from the United States, and tens of thousands of workpeople were thrown out of employment. The distress which resulted naturally created a strong feeling in favour of intervention, which might terminate the war and open the Southern ports to British commerce; and the initial successes which the Confederates secured seemed to afford some justification for such a proceeding. In the course of 1862 indeed, when the Confederate armies had secured many victories, Mr Gladstone, speaking at Newcastle, used the famous expression that President Jefferson Davis had "made a nation"; and Lord Palmerston's language in the House of Commons—while opposing a motion for the recognition of the South—induced the impression that his thoughts were tending in the same direction as Mr Gladstone's. The Emperor Napoleon, in July of the same year, confidentially asked the British minister whether the moment had not come for recognizing the South; and in the following September Lord Palmerston was himself disposed in concert with France to offer to mediate on the basis of separation. Soon afterwards, however, the growing exhaustion of the South improved the prospects of the Northern States: an increasing number of persons in Great Britain objected to interfere in the interests of slavery; and the combatants were allowed to fight out their quarrel without the interference of Europe.

American Civil War.

At the beginning of the war, Lord John Russell (who was made a peer as Earl Russell in 1861) acknowledged the Southern States as belligerents. His decision caused some ill-feeling at Washington; but it was inevitable. For the North had proclaimed a blockade of the Southern ports; and it would have been both inconvenient and unfair if Lord Russell had decided to recognize the blockade and had refused to acknowledge the belligerent rights of the Southern States. Lord Russell's decision, however, seemed to indicate some latent sympathy for the Southern cause; and the irritation which was felt in the North was increased by the news that the Southern States were accrediting two gentlemen to represent them at Paris and at London. These emissaries, Messrs Mason and Slidell, succeeded in running the blockade and in reaching Cuba, where they embarked on the *Trent*, a British mail steamer sailing for England. On her passage home the *Trent* was stopped by the Federal steamer *San Jacinto;* she was boarded, and Messrs Mason and Slidell were arrested. There was no doubt that the captain of the *San Jacinto* had acted irregularly. While he had the right to stop the *Trent*, examine the mails, and, if he found despatches for the enemy among them, carry the vessel into an American port for adjudication, he had no authority to board the vessel and arrest two of her passengers. "The British Government," to use its own language, "could not allow such an affront to the national honour to pass without due reparation." They decided on sending what practically amounted to an ultimatum to the Federal Government, calling upon it to liberate the prisoners and to make a suitable apology. The presentation of this ultimatum, which was accompanied by the despatch of troops to Canada, was very nearly provoking war with the United States. If, indeed, the ultimatum had been presented in the form in which it was originally framed, war might have ensued. But at the Prince Consort's suggestion its language was considerably modified, and the responsibility for the outrage was thrown on the officer who committed it, and not on the Government of the Republic. It ought not to be forgotten that this important modification was the last service rendered to his adopted country by the Prince Consort before his fatal illness. He died before the answer to the despatch was received; and his death deprived the Queen of an adviser who had stood by her side since the earlier days of her reign, and who, by his prudence and conduct, had done much to raise the tone of the court and the influence of the Crown. Happily for the future of the world, the Government of the United States felt itself able to accept the despatch which had been thus addressed to it, and to give the reparation which was demanded; and the danger of war between the two great branches of the Anglo-Saxon race was averted. But, in the following summer, a new event excited fresh animosities, and aroused a controversy which endured for the best part of ten years.

The "Trent" incident.

The Confederates, naturally anxious to harass the commerce of their enemies, endeavoured from the commencement of hostilities to purchase armed cruisers from builders of neutral nations. In June 1862 the American minister in London drew Lord Russell's attention to the fact that a vessel, lately launched at Messrs Laird's yard at Birkenhead, was obviously intended to be employed as a Confederate cruiser. The solicitor to the Commissioners of Customs, however, considered that no facts had been revealed to authorize the detention of the vessel, and this opinion was reported in the beginning of July to the American minister, Mr Adams. He thereupon supplied the Government with additional facts, and at the same time furnished them with the opinion of an eminent English lawyer, Mr Collier (afterwards Lord Monkswell), to the effect that "it would be difficult to make out a stronger case of infringement of the Foreign Enlistment Act, which if not enforced on this occasion is little better than a dead letter." These facts and this opinion were at once sent to the Law Officers. They reached the Queen's advocate on Saturday, the 26th July; but, by an unfortunate mischance, the Queen's advocate had just been wholly incapacitated by a distressing illness; and the papers, in consequence, did not reach the Attorney- and Solicitor-

The "Alabama"

General till the evening of the following Monday, when they at once advised the Government to detain the vessel. Lord Russell thereupon sent orders to Liverpool for her detention. In the meanwhile the vessel—probably aware of the necessity for haste—had put to sea, and had commenced the career which made her famous as the *Alabama*. Ministers might even then have taken steps to stop the vessel by directing her detention in any British port to which she resorted for supplies. The Cabinet, however, shrank from this course. The *Alabama* was allowed to prey on Federal commerce, and undoubtedly inflicted a vast amount of injury on the trade of the United States. In the autumn of 1862 Mr Adams demanded redress for the injuries which had thus been sustained, and this demand was repeated for many years in stronger and stronger language. At last, in 1871, long after Lord Palmerston's death and Lord Russell's retirement, a joint commission was appointed to examine into the many cases of dispute which had arisen between the United States and Great Britain. The commissioners agreed upon three rules by which they thought neutrals should in future be bound, and recommended that they should be given a retrospective effect. They decided also that the claims which had arisen out of the depredations of the *Alabama* should be referred to arbitration. In the course of 1872 the arbitrators met at Geneva. Their finding was adverse to Great Britain, which was condemned to pay a large sum of money—more than £3,000,000—as compensation. A period of exceptional prosperity, which largely increased the revenue, enabled a chancellor of the exchequer to boast that the country had drunk itself out of the *Alabama* difficulty.

Lord Russell's second ministry.

In October 1865 Lord Palmerston's rule, which had been characterized by six years of political inaction at home and by constant disturbance abroad, was terminated by his death. The ministry, which had suffered many losses from death during its duration, was temporarily reconstructed under Lord Russell; and the new minister at once decided to put an end to the period of internal stagnation, which had lasted so long, by the introduction of a new Reform Bill. Accordingly, in March 1866 Mr Gladstone, who now led the House of Commons, introduced a measure which proposed to extend the county franchise to £14 and the borough franchise to £7 householders. The Bill did not create much enthusiasm among Liberals, and it was naturally opposed by the Conservatives, who were reinforced by a large section of moderate Liberals, nicknamed, in consequence of a phrase in one of Mr Bright's speeches, Adullamites. After many debates, in which the Commons showed little disposition to give the ministry any effective support, an amendment was carried by Lord Dunkellin, the eldest son of Lord Clanricarde, basing the borough franchise on rating instead of rental. The Cabinet, recognizing from the division that the control of the House had passed out of its hands, resigned office, and the Queen was compelled to entrust Lord Derby with the task of forming a new administration.

Lord Derby's third ministry.

For the third time in his career Lord Derby undertook the formidable task of conducting the government of the country with only a minority of the House of Commons to support him. The moment at which he made this third attempt was one of unusual anxiety. Abroad, the almost simultaneous outbreak of war between Prussia and Austria was destined to affect the whole aspect of Continental politics. At home, a terrible murrain had fallen on the cattle, inflicting ruin on the agricultural interest; a grave commercial crisis was creating alarm in the City of London, and, in its consequences, injuring the interests of labour; while the working classes, at last roused from their long indifference, and angry at the rejection of Lord Russell's Bill, were assembling in their tens of thousands to demand reform. The Cabinet determined to prohibit a meeting which the Reform League decided to hold in Hyde Park on the 23rd July, and closed the gates of the park on the people. But the mob, converging on the park in thousands, surged round the railings, which a little inquiry might have shown were too weak to resist any real pressure. Either accidentally or intentionally, the railings were overturned in one place, and the people, perceiving their opportunity, at once threw them down round the whole circuit of the park. Few acts in Queen Victoria's reign were attended with greater consequences. For the riot in Hyde Park led almost directly to a new Reform Act, and to the transfer of power from the middle classes to the masses of the people.

Reform, 1867.

Yet, though the new Government found it necessary to introduce a Reform Bill, a wide difference of opinion existed in the Cabinet as to the form which the measure should take. Several of its members were in favour of assimilating the borough franchise to that in force in municipal elections, and practically conferring a vote on every householder who had three years' residence in the constituency. General Peel, however—Sir Robert Peel's brother—who held the seals of the War Office, objected to this extension; and the Cabinet ultimately decided on evading the difficulty by bringing forward a series of resolutions on which a scheme of reform might ultimately be based. Their success in 1858, in dealing with the government of India in this way, commended the decision to the acceptance of the Cabinet. But it was soon apparent that the House of Commons required a definite scheme, and that it would not seriously consider a set of abstract resolutions which committed no one to any distinct plan. Hence on the 23rd February 1867 the Cabinet decided on withdrawing its resolutions and reverting to its original Bill. On the following day Lord Cranborne—better known afterwards as Lord Salisbury—discovered that the Bill had more democratic tendencies than he had originally supposed, and refused to be a party to it. On Monday, the 25th, the Cabinet again met to consider the new difficulty which had thus arisen; and it decided (as was said afterwards by Sir John Pakington) in ten minutes to substitute for the scheme a mild measure extending the borough franchise to houses rated at £6 a year, and conferring the county franchise on £20 householders. The Bill, it was soon obvious, would be acceptable to no one; and the Government again fell back on its original proposal. Three members of the Cabinet, however, Lord Cranborne, Lord Carnarvon, and General Peel, refused to be parties to the measure, and resigned office, the Government being necessarily weakened by these defections. In the large scheme which the Cabinet had now adopted, the borough franchise was conferred on all householders rated to the relief of the poor, who had for two years occupied the houses which gave them the qualification; the county franchise was given to the occupiers of all houses rated at £15 a year or upwards. But it was proposed that these extensions should be accompanied by an educational franchise, and a franchise conferred on persons who had paid twenty shillings in assessed taxes or income tax; the taxpayers who had gained a vote in this way being given a second vote in respect of the property which they occupied. In the course of the discussion on the Bill in the House of Commons, the securities on which its authors had relied to enable them to stem the tide of democracy were, chiefly through Mr Gladstone's exertions, swept away. The dual vote was abandoned, direct payment of rates was surrendered, the county franchise was extended to £12 householders, and the redistribution of seats was largely increased. The Bill, in the shape in which it had been introduced, had been surrounded with safeguards to property. With their loss it involved a great radical change, which placed the working classes of the country in the position of predominance which the middle classes had occupied since 1832.

The passage of the bill necessitated a dissolution of Parliament; but it had to be postponed to enable Parliament to supplement the English Reform Act of 1867 with measures applicable to Scotland and Ireland, and to give time for settling the boundaries of the new constituencies which had been created. This delay gave the Conservatives another year of office. But the first place in the Cabinet passed in 1868 from Lord Derby to his lieutenant, Mr Disraeli. The change added interest to political life. Thenceforward, for the next thirteen years, the chief places in the two great parties in the state were filled by the two men, Mr. Gladstone and Mr Disraeli, who were unquestionably the ablest representatives of their respective followers. But the situation was also remarkable because power thus definitely passed from men who, without exception, had been born in the 18th century, and had all held Cabinet offices before 1832, to men who had been born in the 19th century, and had only risen to Cabinet rank in the 'forties and the 'fifties. It was also interesting to reflect that Mr Gladstone had begun life as a Conservative, and had only gradually moved to the ranks of the Liberal party; while Mr. Disraeli had fought his first election under the auspices of Mr O'Connell and Mr Hume, had won his spurs by his attacks on Sir Robert Peel, and had been only reluctantly adopted by the Conservatives as their leader in the House of Commons.

Disraeli Prime Minister.

The struggle commenced in 1868 on an Irish question. During the previous years considerable attention had been paid to a secret conspiracy in Ireland and among the Irish in America. The Fenians, as they were called, actually attempted insurrection in Ireland, and an invasion of Canada from the United States. At the beginning of 1866 Lord Russell's Government thought itself compelled to suspend the Habeas Corpus Act in Ireland; and in 1867 Lord Derby's Government was confronted in the spring by a plot to seize Chester Castle, and in the autumn by an attack on a prison van at Manchester containing Fenian prisoners, and by an atrocious attempt to blow up Clerkenwell Prison. Conservative politicians deduced from these circumstances the necessity of applying firm government to Ireland. Liberal statesmen, on the contrary, desired to extirpate rebellion by remedying the grievances of which Ireland still complained. Chief among these was the fact that the Established Church in Ireland was the church of only a minority of the Irish people. In March 1868 Mr Maguire, an Irish Roman Catholic, asked the House of Commons to resolve itself into a committee to take into immediate consideration the affairs of Ireland. Mr Gladstone, in the course of the debate, declared that in his opinion the time had come when the Irish Church, as a political institution, should cease; and he followed up his declaration by a series of resolutions, which were accepted by considerable majorities, pledging the House to its disestablishment. Mr Disraeli, recognizing the full significance of this decision, announced that, as soon as the necessary preparations could be made, the Government would appeal from the House to the country. Parliament was dissolved at the end of July, but the general election did not take place till the end of the following November. The future of the Irish Church naturally formed one of the chief subjects which occupied the attention of the electors, but the issue was largely determined by wider considerations. The country, after the long political truce which had been maintained by Lord Palmerston, was again ranged in two hostile camps, animated by opposing views. It was virtually asked to decide in 1868 whether it would put its trust in Liberal or Conservative, in Mr Gladstone or Mr Disraeli. By an overwhelming majority it threw its lot in favour of Mr Gladstone; and Mr Disraeli, without even venturing to meet Parliament, took the unusual course of at once placing his resignation in the Queen's hands.

Irish Church.

The Conservative Government, which thus fell, will be chiefly recollected for its remarkable concession to democratic principles by the passage of the Reform Act of 1867; but it deserves perhaps a word of praise for its conduct of a distant and unusual war. The emperor of Abyssinia had, for some time, detained some Englishmen prisoners in his country; and the Government, unable to obtain redress in other ways, decided on sending an army to release them. The expedition, entrusted to Sir Robert Napier, afterwards Lord Napier of Magdala, was fitted out at great expense, and was rewarded with complete success. The prisoners were released, and the Abyssinian monarch committed suicide. Mr Disraeli—whose oriental imagination was excited by the triumph—incurred some ridicule by his bombastic declaration that "the standard of St George was hoisted upon the mountains of Rasselas." But the ministry could at least claim that the war had been waged to rescue Englishmen from captivity, that it had been conducted with skill, and that it had accomplished its results. The events of the Abyssinian war, however, were forgotten in the great political revolution which had swept the Conservatives from office and placed Mr Gladstone in power. His Government was destined to endure for more than five years. During that period it experienced the alternate prosperity and decline which nearly forty years before had been the lot of the Whigs after the passage of the first Reform Act. During its first two sessions it accomplished greater changes in legislation than had been attempted by any ministry since that of Lord Grey. In its three last sessions it was destined to sink into gradual disrepute; and it was ultimately swept away by a wave of popular reaction, as remarkable as that which had borne it into power.

Abyssinian war.

It was generally understood that Mr Gladstone intended to deal with three great Irish grievances—"the three branches of the upas tree"—the religious, agricultural, and educational grievances. The session of 1869 was devoted to the first of these subjects. Mr Gladstone introduced a Bill disconnecting the Irish Church from the state, establishing a synod for its government, and—after leaving it in possession of its churches and its parsonages, and making ample provision for the life-interests of its existing clergy—devoting the bulk of its property to the relief of distress in Ireland. The Bill was carried by large majorities through the House of Commons; and the feeling of the country was so strong that the Lords did not venture on its rejection. They satisfied themselves with engrafting on it a series of amendments which, on the whole, secured rather more liberal terms of compensation for existing interests. Some of these amendments were adopted by Mr. Gladstone; a compromise was effected in respect of the others; and the Bill, which had practically occupied the whole session, and had perhaps involved higher constructive skill than any measure passed in the previous half-century, became law. Having dealt with the Irish Church in 1869, Mr Gladstone turned to the more complicated question of Irish land. So far back as the 'forties Sir R. Peel had appointed a commission, known from its chairman as the Devon Commission, which had recommended that the Irish tenant,

Gladstone's first ministry.

Irish land.

in the event of disturbance, should receive some compensation for certain specified improvements which he had made in his holding. Parliament neglected to give effect to these recommendations; in a country where agriculture was the chief or almost only occupation, the tenant remained at his landlord's mercy. In 1870 Mr. Gladstone proposed to give the tenant a pecuniary interest in improvements, suitable to the holding, which he had made either before or after the passing of the Act. He proposed also that, in cases of eviction, the smaller tenantry should receive compensation for disturbance. The larger tenantry, who were supposed to be able to look after their own interests, were entirely debarred, and tenants enjoying leases were excluded from claiming compensation except for tillages, buildings, and reclamation of lands. A special court, it was further provided, should be instituted to carry out the provisions of the Bill. Large and radical as the measure was, reversing many of the accepted principles of legislation by giving the tenant a *quasi*-partnership with the landlord in his holding, no serious opposition was made to it in either House of Parliament. Its details, indeed, were abundantly criticized, but its principles were hardly disputed, and it became law without any substantial alteration of its original provisions. In two sessions two branches of the upas tree had been summarily cut off. But Parliament in 1870 was not solely occupied with the wrongs of Irish tenantry. In the same year Mr Forster, as vice-president of the Council, succeeded in carrying the great measure which for the first time made education compulsory. In devising his scheme, Mr Forster endeavoured to utilize, as far as possible, the educational machinery which had been voluntarily provided by various religious organizations. He gave the institutions which had been thus established the full benefit of the assistance which the Government was prepared to afford to board schools, on their adopting a conscience clause under which the religious susceptibilities of the parents of children were protected. This provision led to many debates, and produced the first symptoms of disruption in the Liberal party. The Nonconformists contended that no such aid should be given to any school which was not conducted on undenominational principles. Supported by the bulk of the Conservative party, Mr Forster was enabled to defeat the Dissenters. But the victory which he secured was, in one sense, dearly purchased. The first breach in the Liberal ranks had been made; and the Government, after 1870, never again commanded the same united support which had enabled it to pursue its victorious career in the first two sessions of its existence.

Elementary education.

Towards the close of the session of 1870 other events, for which the Government had no direct responsibility, introduced new difficulties. War unexpectedly broke out between France and Prussia. The French empire fell; the German armies marched on Paris; and the Russian Government, at Count Bismarck's instigation, took advantage of the collapse of France to repudiate the clause in the treaty of 1856 which neutralized the Black Sea. Lord Granville, who had succeeded Lord Clarendon at the Foreign Office, protested against this proceeding. But it was everywhere felt that his mere protest was not likely to affect the result; and the Government at last consented to accept a suggestion made by Count Bismarck, and to take part in a conference to discuss the Russian proposal. Though this device enabled them to say that they had not yielded to the Russian demand, it was obvious that they entered the conference with the foregone conclusion of conceding the Russian claim. The attitude which the Government thus chose to adopt was perhaps inevitable in the circumstances, but it confirmed the impression, which the abandonment of the cause of Denmark had produced in 1864, that Great Britain was not prepared to maintain its principles by going to war. The weakness of the British Foreign Office was emphasized by its consenting, almost at the same moment, to allow the claims of the United States, for the depredations of the *Alabama*, to be settled under a rule only agreed upon in 1871. Most Englishmen now appreciate the wisdom of a concession which has gained for them the friendship of the United States. But in 1871 the country resented the manner in which Lord Granville had acted. Whatever credit the Government might have derived from its domestic measures, it was discredited, or it was thought to be, by its foreign policy. In these circumstances legislation in 1871 was not marked with the success which had attended the Government in previous sessions. The Government succeeded in terminating a long controversy by abolishing ecclesiastical tests at universities. But the Lords ventured to reject a measure for the introduction of the ballot at elections, and refused to proceed with a Bill for the abolition of purchase in the Army. The result of these decisions was indeed remarkable. In the one case, the Lords in 1872 found it necessary to give way, and to pass the Ballot Bill, which they had rejected in 1871. In the other, Mr Gladstone decided on abolishing, by the direct authority of the Crown, the system which the Lords had refused to do away with by legislation. But his high-handed proceeding, though it forced the Lords to reconsider their decision, strained the allegiance of many of his supporters, and still further impaired the popularity of his Administration. Most men felt that it would have been permissible for him at the commencement of the session, to have used the Queen's authority to terminate the purchase system; but they considered that, as he had not taken this course, it was not open to him to reverse the decision of the Legislature by resorting to the prerogative. Two appointments, one to a judicial office, the other to an ecclesiastical preferment, in which Mr Gladstone, about the same time, showed more disposition to obey the letter than the spirit of the law, confirmed the impression which the abolition of purchase had made. Great reforming ministers would do well to recollect that the success of even liberal measures may be dearly purchased by the resort to what are regarded as unconstitutional expedients.

Black Sea neutrality.

Army purchase.

In the following years the embarrassments of the Government were further increased. In 1872 Mr Bruce, the home secretary, succeeded in passing a measure of licensing reform. But the abstainers condemned the Bill as inadequate; the publicans denounced it as oppressive; and the whole strength of the licensed victuallers was thenceforward arrayed against the ministry. In 1873 Mr Gladstone attempted to complete his great Irish measures by conferring on Ireland the advantage of a university which would be equally acceptable to Protestants and Roman Catholics. But his proposal again failed to satisfy those in whose interests it was proposed. The second reading of the Bill was rejected by a small majority, and Mr Gladstone resigned; but, as Mr Disraeli could not form a government, he resumed office. The power of the great minister was, however, spent; his ministry was hopelessly discredited. History, in fact, was repeating itself. The ministry was suffering, as Lord Grey's Government had suffered nearly forty years before, from the effect of its own successes. It had accomplished more than any of its supporters had expected, but in doing so it had harassed many interests and excited much opposition. Mr Gladstone endeavoured to meet the storm by a rearrangement of his crew. Mr Bruce, who had offended the licensed victuallers, was removed from the Home

1872-1874.

Office, and made a peer and president of the Council. Mr Lowe, who had incurred unpopularity by his fiscal measures, and especially by an abortive suggestion for the taxation of matches, was transferred from the Exchequer to the Home Office, and Mr Gladstone himself assumed the duties of chancellor of the exchequer. He thereby created a difficulty for himself which he had not foreseen: Up to 1867, a minister leaving one office and accepting another vacated his seat; after 1867 a transfer from one post to another did not necessitate a fresh election. But Mr Gladstone in 1873 had taken a course which had not been contemplated in 1867. He had not been transferred from one office to another. He had accepted a new in addition to his old office. It was, to say the least, uncertain whether his action in this respect had or had not vacated his seat. It would be unfair to suggest that the inconvenient difficulty with which he was thus confronted determined his policy, though he was probably insensibly influenced by it. However this may be, on the eve of the session of 1874 he suddenly decided to dissolve Parliament and to appeal to the country. He announced his decision in an address to his constituents, in which, among other financial reforms, he promised to repeal the income tax. The course which Mr Gladstone took, and the bait which he held out to the electors, were generally condemned. The country, wearied of the ministry and of its measures, almost everywhere supported the Conservative candidates. Mr Disraeli found himself restored to power at the head of an overwhelming majority, and the great minister who, five years before, had achieved so marked a triumph temporarily withdrew from the leadership of the party with whose aid he had accomplished such important results. His ministry had been essentially one of peace, yet its closing days were memorable for one little war in which a great soldier increased a reputation already high. Sir Garnet Wolseley triumphed over the difficulties which the climate of the west coast of Africa imposes on Europeans, and brought a troublesome contest with the Ashantees to a successful conclusion.

Disraeli's second ministry.

The history of Mr Disraeli's second Administration affords an exact reverse to that of Mr Gladstone's first Cabinet. In legislation the ministry attempted little and accomplished less. They did something to meet the wishes of the publicans, whose discontent had contributed largely to Mr Gladstone's defeat, by amending some of the provisions of Mr Bruce's licensing Bill; they supported and succeeded in passing a measure, brought in by the Primate, to restrain some of the irregularities which the Ritualists were introducing into public worship; and they were compelled by the violent insistence of Mr Plimsoll to pass an Act to protect the lives of merchant seamen. Mr Disraeli's Government, however, will be chiefly remembered for its foreign policy. Years before he had propounded in *Tancred* the theory that England should aim at eastern empire. Circumstances in his second term of office enabled him to translate his theory into practice. In 1875 the country was suddenly startled at hearing that it had acquired a new position and assumed new responsibilities in Egypt by the purchase of the shares which the Khedive of Egypt held in the Suez Canal. In the following spring a new surprise was afforded by the introduction of a measure authorizing the Queen to assume the title of Empress of India. But these significant actions were almost forgotten in the presence of a new crisis; for in 1876 misgovernment in Turkey had produced its natural results, and the European provinces of the Porte were in a state of armed insurrection. In the presence of a grave danger, Count Andrassy, the Austrian minister, drew up a note which was afterwards known by his name, declaring that the Porte had failed to carry into effect the promises of reform which she had made, and that some combined action on the part of Europe was necessary to compel her to do so. The note was accepted by the three Continental empires, but Great Britain refused in the first instance to assent to it, and only ultimately consented at the desire of the Porte, whose statesmen seem to have imagined that the nominal co-operation of England would have the effect of restraining the action of other Powers. Turkey accepted the note and renewed the promises of reform which she had so often made, and which meant so little. The three northern Powers thereupon agreed upon what was known as the Berlin Memorandum, in which they demanded an armistice, and proposed to watch over the completion of the reforms which the Porte had promised. The British Government refused to be a party to this memorandum, which in consequence became abortive. The insurrection increased in intensity. The Sultan Abdul Aziz, thought unequal to the crisis, was hastily deposed; he was either murdered or led to commit suicide; and insurrection in Bulgaria was stamped out by massacre. The story of the "Bulgarian atrocities" was published in Great Britain in the summer of 1876. Mr Disraeli characteristically dismissed it as "coffee-house babble," but official investigation proved the substantial accuracy of the reports which had reached England. The people regarded these events with horror. Mr Gladstone, emerging from his retirement, denounced the conduct of the Turks. In a phrase which became famous he declared that the only remedy for the European provinces of the Porte was to turn out the Ottoman Government "bag and baggage." All England was at once arrayed into two camps. One party was led by Mr Disraeli, who was supposed to represent the traditional policy of England of maintaining the rule of the Turk at all hazards; the other, inspired by the example of Mr Gladstone, was resolved at all costs to terminate oppression, but was at the same time distrusted as indirectly assisting the ambitious views by which the Eastern policy of Russia had always been animated. The crisis soon became intense. In June 1876 Servia and Montenegro declared war against Turkey. In a few months Servia was hopelessly beaten. Through the insistence of Russia an armistice was agreed upon; and Lord Beaconsfield—for Mr Disraeli had now been raised to the peerage—endeavoured to utilize the breathing space by organizing a conference of the Great Powers at Constantinople, which was attended on behalf of Great Britain by Lord Salisbury. The Constantinople Conference proved abortive, and in the beginning of 1877 Russia declared war. For some time, however, her success was hardly equal to her expectations. The Turks, entrenched at Plevna, delayed the Russian advance; and it was only towards the close of 1877 that Plevna at last fell and Turkish resistance collapsed. With its downfall the war party in England, which was led by the prime minister, increased in violence. From the refrain of a song, sung night after night at a London music hall, its members became known as Jingoes. The Government ordered the British fleet to pass the Dardanelles and go up to Constantinople; and though the order was subsequently withdrawn, it asked for and obtained a grant of £6,000,000 for naval and military purposes. When news came that the Russian armies had reached Adrianople, that they had concluded some arrangement with the Turks, and that they were pressing forward towards Constantinople, the fleet was again directed to pass the Dardanelles. Soon afterwards the Government decided to call out the reserves and to bring a contingent of Indian troops to the Mediterranean. Lord Derby, who was at the Foreign Office, thereupon retired from the ministry, and was succeeded by

Bulgarian "atrocities."

Lord Salisbury. Lord Derby's resignation was everywhere regarded as a proof that Great Britain was on the verge of war. Happily war did not occur. At Prince Bismarck's suggestion Russia consented to refer the treaty which she had concluded at San Stefano to a congress of the Great Powers; and the congress, at which Great Britain was represented by Lord Beaconsfield and Lord Salisbury, succeeded in substituting for the treaty of San Stefano the treaty of Berlin. The one great advantage derived from it was the tacit acknowledgment by Russia that Europe could alone alter arrangements which Europe had made. In every other sense it is doubtful whether the provisions of the treaty of Berlin were more favourable than those of the treaty of San Stefano. On Lord Beaconsfield's return, however, he claimed for Lord Salisbury and himself that they had brought back "peace with honour," and the country accepted with wild delight the phrase, without taking much trouble to analyse its justice.

Berlin treaty.

If Lord Beaconsfield had dissolved Parliament immediately after his return from Berlin, it is possible that the wave of popularity which had been raised by his success would have borne him forward to a fresh victory in the constituencies. His omission to do so gave the country time to meditate on the consequences of his policy. One result soon became perceptible. Differences with Russia produced their inevitable consequences in fresh complications on the Indian frontier. The Russian Government, confronted with a quarrel with Great Britain in eastern Europe, endeavoured to create difficulties in Afghanistan. A Russian envoy was sent to Kabul, where Shere Ali, who had been placed on the throne after the war of 1841, was still reigning; and the British Government, alarmed at this new embarrassment, decided on sending a mission to the Afghan capital. The mission was stopped on the frontier by an agent of Shere Ali, who declined to allow it to proceed. The British Government refused to put up with an affront of this kind, and their envoy, supported by an army, continued his advance. Afghanistan was again invaded. Kabul and Kandahar were occupied; and Shere Ali was forced to fly, and soon afterwards died. His successor, Yakoob Khan, came to the British camp and signed, in May 1879, the treaty of Gandamuk. Under the terms of this treaty the Indian Government undertook to pay the new Ameer a subsidy of £60,000 a year; and Yakoob Khan consented to receive a British mission at Kabul, and to cede some territory in the Himalayas which the military advisers of Lord Beaconsfield considered necessary to make the frontier more "scientific." This apparent success was soon followed by disastrous news. The deplorable events of 1841 were re-enacted in 1879. The new envoy reached Kabul, but was soon afterwards murdered. A British army was again sent into Afghanistan, and Kabul was again occupied. Yakoob Khan, who had been made Ameer in 1879, was deposed, and Abdurrahman Khan was selected as his successor. The British did not assert their superiority without much fighting and some serious reverses. Their victory was at last assured by the excellent strategy of Sir Donald Stewart and Sir Frederick (afterwards Lord) Roberts. But before the final victory was gained Lord Beaconsfield had fallen. His policy had brought Great Britain to the verge of disaster in Afghanistan: the credit of reasserting the superiority of British arms was deferred till his successors had taken office.

Afghan wars.

It was not only in Afghanistan that the new imperial policy which Lord Beaconsfield had done so much to encourage was straining the resources of the empire. In South Africa a still more serious difficulty was already commencing. At the time at which Lord Beaconsfield's administration began, British territory in South Africa was practically confined to Cape Colony and Natal. Years before, in 1852, the British Government, at that time a little weary of the responsibilities of colonial rule, had recognized the independence of the two Dutch republics, the Transvaal and the Orange Free State. Powerful native tribes occupied the territory to the north of Natal and the east of the Transvaal. War broke out between the Transvaal Republic and one of the most powerful of these native chieftains, Secoceni; and the Transvaal was worsted in the struggle. Alarmed at the possible consequences of this defeat, and conscious of their inability to carry on the struggle, a party in the Transvaal openly recommended the annexation of the country to British territory. Sir Theophilus Shepstone, who was sent to inquire into the proposal, mistook the opinion of a party for the verdict of the republic, and declared the Transvaal a part of the British empire. His policy entailed far more serious consequences than the mission to Afghanistan. The first was a war with the Zulus, the most powerful and warlike of the native African tribes, who under their ruler, Cetewayo, had organised a formidable army. A dispute had been going on for some time about the possession of a strip of territory which some British arbitrators had awarded to the Zulu king. Sir Bartle Frere, who had won distinction in India, and was sent out by Lord Beaconsfield's Government to the Cape, kept back the award; and, though he ultimately communicated it to Cetewayo, thought it desirable to demand the disbandment of the Zulu army. In the war which ensued, the British troops who invaded Zulu territory met with a severe reverse; and, though the disaster was ultimately retrieved by Lord Chelmsford and Sir Garnet Wolseley, the war involved heavy expenditure and brought little credit to the British army, while one unfortunate incident, the death of Prince Napoleon, who had obtained leave to serve with the British troops, and was surprised by the Zulus while reconnoitring, created a deep and unfortunate impression. Imperialism, which had been excited by Lord Beaconsfield's policy in 1878, and by the prospect of a war with a great European Power, fell into discredit when it degenerated into a fresh expedition into Afghanistan, and an inglorious war with a savage African tribe. A period of distress at home increased the discontent which Lord Beaconsfield's external policy was exciting; and, when Parliament was at last dissolved in 1880, it seemed no longer certain that the country would endorse the policy of the minister who only a short time before had acquired such popularity. Mr Gladstone, emerging from his retirement, practically placed himself again at the head of the Liberal party. In a series of speeches in Midlothian, where he offered himself for election, he denounced the whole policy which Lord Beaconsfield had pursued. His impassioned eloquence did much more than influence his own election. His speeches decided the contest throughout the kingdom. The Liberals secured an even more surprising success than that which had rewarded the Conservatives six years before. For the first time in the Queen's reign, a solid Liberal majority, independent of all extraneous Irish support, was returned, and Mr Gladstone resumed in triumph his old position as prime minister.

Zulu war.

The new minister had been swept into power on a wave of popular favour, but he inherited difficulties from his predecessors in almost every quarter of the world; and his own language had perhaps tended to increase them. He was committed to a reversal of Lord Beaconsfield's policy; and, in politics, it is never easy, and perhaps rarely wise, suddenly and violently to change a system. In one quarter of

Gladstone's second ministry.

the world the new minister achieved much success. The war in Afghanistan, which had begun with disaster, was creditably concluded. A better understanding was gradually established with Russia; and, before the ministry went out, steps had been taken which led to the delimitation of the Russian and Afghan frontier. In South Africa, however, a very different result ensued. Mr Gladstone, before he accepted office, had denounced the policy of annexing the Transvaal; his language was so strong that he was charged with encouraging the Boers to maintain their independence by force; his example had naturally been imitated by some of his followers at the general election; and, when he resumed power, he found himself in the difficult dilemma of either maintaining an arrangement which he had declared to be unwise, or of yielding to a demand which the Boers were already threatening to support in arms. The events of the first year of his administration added to his difficulty. Before its close the Boers seized Heidelberg and established a republic; they destroyed a detachment of British troops at Bronker's Spruit; they treacherously murdered a British officer; and they surrounded and attacked the British garrisons in the Transvaal. Troops were of course sent from England to maintain the British cause; and Sir George Colley, who enjoyed a high reputation and had experience in South African warfare, was made governor of Natal, and entrusted with the military command. The events which immediately followed will not be easily forgotten. Wholly miscalculating the strength of the Boers, Sir George Colley, at the end of January 1881, attacked them at Laing's Nek, in the north of Natal, and was repulsed with heavy loss. Some ten days afterwards he fought another action on the Ingogo, and was again forced to retire. On the 26th February, with some 600 men, he occupied a high hill, known as Majuba, which, he thought, dominated the Boer position. The following day the Boers attacked the hill, overwhelmed its defenders, and Sir George Colley was himself killed in the disastrous contest on the summit. News of these occurrences was received with dismay in England. It was, no doubt, possible to say a good deal for Mr Gladstone's indignant denunciation of his predecessor's policy in annexing the Transvaal; it would have been equally possible to advance many reasons for reversing the measures of Lord Beaconsfield's Cabinet, and for conceding independence to the Transvaal in 1880. But the great majority of persons considered that, whatever arguments might have been urged for concession in 1880, when British troops had suffered no reverses, nothing could be said for concession in 1881, when their arms had been tarnished by a humiliating disaster. Great countries can afford to be generous in the hour of victory; but they cannot yield, without loss of credit, in the hour of defeat. Unfortunately this reasoning was not suited to Mr Gladstone's temperament. The justice or injustice of the British cause seemed to him a much more important matter than the vindication of military honour; and he could not bring himself to acknowledge that Majuba had altered the situation, and that the terms which he had made up his mind to concede before the battle could not be safely granted till military reputation was restored. The independence of the Transvaal was accordingly recognized, though it was provided that the Republic should remain under the suzerainty of the Queen. Even this great concession did not satisfy the ambition of the Boers, who were naturally elated by their victories. Three years later some Transvaal deputies, with their president, Kruger, came to London and saw Lord Derby, the Secretary of State for the Colonies. Lord Derby consented to a new convention, from which any verbal reference to suzerainty was excluded; and the South African Republic was made independent, subject only to the condition that it should conclude no treaties with Foreign Powers without the approval of the Crown. (For the details and disputes concerning the terms of this Convention the reader is referred to the articles TRANSVAAL and SUZERAINTY.)

Boer war, 1881.

Mr Gladstone's Government declined in popularity from the date of the earliest of these concessions. Mr Gladstone, in fact, had succeeded in doing what Lord Beaconsfield had failed to accomplish. Annoyance at his foreign policy had rekindled the imperialism which the embarrassments created by Lord Beaconsfield had done so much to damp down. And, if things were going badly with the new Government abroad, matters were not progressing smoothly at home. At the general election of 1880, the borough of Northampton, which of late years has shown an unwavering preference for Liberals of an advanced type, returned as its members Mr Henry Labouchere and Mr Bradlaugh. Mr Bradlaugh, who had attained some notoriety for an aggressive atheism, claimed the right to make an affirmation of allegiance instead of taking the customary oath, which he declared was, in his eyes, a meaningless form. The Speaker, instead of deciding the question, submitted it to the judgment of the House, and it was ultimately referred to a select committee, which reported against Mr Bradlaugh's claim. Mr Bradlaugh, on hearing the decision of the committee, presented himself at the bar and offered to take the oath. It was objected that, as he had publicly declared that the words of the oath had no clear meaning for him, he could not be permitted to take it; and after some wrangling the matter was referred to a fresh committee, which supported the view that Mr Bradlaugh could not be allowed to be sworn, but recommended that he should be permitted to make the affirmation at his own risk. The House refused to accept the recommendation of this committee when a Bill was introduced to give effect to it. This decision naturally enlarged the question before it. For, while hitherto the debate had turned on the technical points whether an affirmation could be substituted for an oath, or whether a person who had declared that an oath had no meaning for him could properly be sworn, the end at which Mr Bradlaugh's opponents were thenceforward aiming was the imposition of a new religious test—the belief in a God—on members of the House of Commons. The controversy which thus began continued through the Parliament of 1880, and led to many violent scenes, which lowered the dignity of the House. It was quietly terminated, in the Parliament of 1886, by the firm action of a new Speaker. Mr Peel, who had been elected to the chair, decided that neither the Speaker nor any other member had the right to intervene to prevent a member from taking the oath if he was willing to take it. Parliament subsequently, by a new Act, permitted affirmations to be used, and thenceforward religion, or the absence of religion, was no disqualification for a seat in the House of Commons. The atheist, like the Roman Catholic and the Jew, could sit and vote.

Bradlaugh.

The Bradlaugh question was not the only difficulty with which the new Government was confronted. Ireland was again attracting the attention of politicians. The Fenian movement had practically expired; some annual motions for the introduction of Home Rule, made with all the decorum of parliamentary usage, had been regularly defeated. But the Irish were placing themselves under new leaders and adopting new methods. During the Conservative Government of 1874, the Irish members had endeavoured to arrest attention by organized obstruction. Their efforts had increased the difficulties of Government and taxed the endurance of Parliament. These tactics were destined to be raised to a fine art by Mr Parnell,

Parnell

who succeeded to the head of the Irish party about the time of the formation of Mr Gladstone's Government. It was Mr Parnell's determination to make legislation impracticable and Parliament unendurable till Irish grievances were redressed. It was his evident belief that by pursuing such tactics he could force the House of Commons to concede the legislation which he desired. The Irish members were not satisfied with the legislation which Parliament had passed in 1869-1870. The Land Act of 1870 had given the tenant no security in the case of eviction for non-payment of rent; and the tenant whose rent was too high or had been raised was at the mercy of his landlord. It so happened that some bad harvests had temporarily increased the difficulties of the tenantry, and there was no doubt that large numbers of evictions were taking place in Ireland. In these circumstances, the Irish contended that the relief which the Act of 1870 had afforded should be extended, and that, till such legislation could be devised, a temporary measure should be passed giving the tenant compensation for disturbance. Mr Gladstone admitted the force of this reasoning, and a Bill was introduced to give effect to it. Passed by the Commons, it was thrown out towards the end of the session by the Lords; and the Government acquiesced—perhaps could do nothing but acquiesce—in this decision. In Ireland, however, the rejection of the measure was attended with disastrous results. Outrages increased, obnoxious landlords and agents were "boycotted"—the name of the first gentleman exposed to this treatment adding a new word to the language; and Mr Forster, who had accepted the office of chief secretary, thought it necessary, in the presence of outrage and intimidation, to adopt stringent measures for enforcing order. A measure was passed on his initiation, in 1881, authorizing him to arrest and detain suspected persons; and many well-known Irishmen, including Mr Parnell himself and other members of Parliament, were thrown into prison. It was an odd commentary on Parliamentary government that a Liberal ministry should be in power, and that Irish members should be in prison; and early in 1882 Mr Gladstone determined to liberate the prisoners on terms. The new policy—represented by what was known as the Kilmainham Treaty—led to the resignation of the viceroy, Lord Cowper, and of Mr Forster, and the appointment of Lord Spencer and Lord Frederick Cavendish as their successors. On the 6th May 1882 Lord Spencer made his entry into Dublin, and on the evening of the same day Lord Frederick, unwisely allowed to walk home alone with Mr Burke, the under-secretary to the Irish Government, was murdered with his companion in Phoenix Park. This gross outrage led to fresh measures of coercion. The disclosure, soon afterwards, of a conspiracy to resort to dynamite still further alienated the sympathies of the Liberal party from the Irish nation. Mr Gladstone might fairly plead that he had done much, that he had risked much, for Ireland, and that Ireland was making him a poor return for his services.

Egypt.

In the meanwhile another difficulty was further embarrassing a harassed Government. The necessities of the Khedive of Egypt had been only temporarily relieved by the sale to Lord Beaconsfield's Government of the Suez Canal shares. Egyptian finance, in the interests of the bondholders, had been placed under the dual control of England and France. The new arrangement naturally produced some native resentment, and Arabi Pacha placed himself at the head of a movement which was intended to rid Egypt of foreign interference. His preparations eventually led to the bombardment of Alexandria by the British fleet, and still later to the invasion of Egypt by a British army under Sir Garnet, afterwards Lord Wolseley, and to the battle of Tel-el-Kebir, after which Arabi was defeated and taken prisoner. The bombardment of Alexandria led to the immediate resignation of Mr Bright, whose presence in the Cabinet had been of importance to the Government; the occupation of Egypt broke up the dual control, and made Great Britain responsible for Egyptian administration. The effects of British rule were, in one sense, remarkable. The introduction of good government increased the prosperity of the people, and restored confidence in Egyptian finance. At the same time it provoked the animosity of the French, who were naturally jealous of the increase of British influence on the Nile, and it also threw new responsibilities on the British nation. For, south of Egypt, lay the great territory of the Sudan, which to some extent commands the Nile, and which with Sir Samuel Baker's assistance had been conquered by the Khedive. In 1881 a fanatic sheikh —known as the Mahdi—had headed an insurrection against the Khedive's authority; and towards the close of 1883 an Egyptian army under an Englishman, Colonel Hicks, was almost annihilated by the insurgent soldiery. The insurrection increased the responsibilities which intervention had imposed on England, and an expedition was sent to Suakin to guard the littoral of the Red Sea; while, at the beginning of 1884, General Gordon—whose services in China had gained him a high reputation, and who had previous experience in the Sudan—was sent to Khartum to report on the condition of affairs. These decisions led to momentous results. The British expedition to Suakin was engaged in a series of battles with Osman Digna, the Mahdi's lieutenant; while General Gordon, after alternate reverses and successes, was isolated at Khartum. Anxious as Mr Gladstone's ministry was to restrict the sphere of its responsibilities, it was compelled to send an expedition to relieve General Gordon; and at the close of 1884 Lord Wolseley, who was appointed to the command, decided on moving up the Nile to his relief. The expedition proved much more difficult than Lord Wolseley had anticipated. And, before it reached its goal, Khartum was forced to surrender, and General Gordon and his few faithful followers were murdered. General Gordon's death inflicted a fatal blow on the Liberal Government. It was thought that the General, whose singular devotion to duty made him a popular hero, had been allowed to assume an impossible task; had been feebly supported; and that the measures for his relief had been unduly postponed and at last only reluctantly undertaken. The ministry ultimately experienced defeat on a side issue. The budget, which Mr Childers brought forward as chancellor of the exchequer, was attacked by the Conservative party; and an amendment proposed by Sir Michael Hicks-Beach, condemning an increase in the duties on spirits and beer, was adopted by a small majority. Mr Gladstone resigned office, and Lord Salisbury, who, after Lord Beaconsfield's death, had succeeded to the lead of the Conservative party, was instructed to form a new Administration.

Gordon.

Reform Act, 1884.

It was obvious that the new Government, as its first duty, would be compelled to dissolve the Parliament that had been elected when Mr Gladstone was enjoying the popularity which he had lost so rapidly in office. But it so happened that it was no longer possible to appeal to the old constituencies. For, in 1884, Mr Gladstone had introduced a new Reform Bill; and, though its passage had been arrested by the Lords, unofficial communications between the leaders of both parties had resulted in a compromise which had led to the adoption of a large and comprehensive Reform Act. By this measure, household franchise was extended to the counties. But counties and boroughs were broken up into a number of small constituencies, for the most part returning only one member each; while the necessity of increasing the relative weight of Great Britain, and the reluctance to inflict disfranchisement on Ireland, led to an increase in the numbers of the House of Commons from 658 to 670 members. This radical reconstruction of the electorate necessarily made the result of the elections doubtful. As a matter of fact, the new Parliament comprised 334 Liberals, 250 Conservatives, and 86 Irish Nationalists. It was plain beyond the possibility of doubt that the future depended on the course which the Irish Nationalists might adopt. If they threw in their lot with Mr Gladstone, Lord Salisbury's Government was evidently doomed. If, on the contrary, they joined the Conservatives, they could make a Liberal Administration impracticable.

Home Rule.

In the autumn of 1885 it was doubtful what course the Irish Nationalists would take. It was generally understood that Lord Carnarvon, who had been made Viceroy of Ireland, had been in communication with Mr Parnell; that Lord Salisbury was aware of the interviews which had taken place; and it was whispered that Lord Carnarvon was in favour of granting some sort of administrative autonomy to Ireland. Whatever opinion Lord Carnarvon may have formed—and his precise view is uncertain—a greater man than he had suddenly arrived at a similar conclusion. In his election speeches Mr Gladstone had insisted on the necessity of the country returning a Liberal majority which could act independently of the Irish vote; and the result of the general election had left the Irish the virtual arbiters of the political situation. In these circumstances Mr Gladstone arrived at a momentous decision. He recognized that the system under which Ireland had been governed in the past had failed to win the allegiance of her people; and he decided that it was wise and safe to entrust her with a large measure of self-government. It was perhaps characteristic of Mr Gladstone, though it was unquestionably unfortunate, that, in determining on this radical change of policy, he consulted few, if any, of his previous colleagues. On the meeting of the new Parliament Lord Salisbury's Government was defeated on an amendment to the address, demanding facilities for agricultural labourers to obtain small holdings for gardens and pasture—the policy, in short, which was described as "Three acres and a cow." Lord Salisbury resigned, and Mr Gladstone resumed power. The attitude, however, which Mr Gladstone was understood to be taking on the subject of Home Rule threw many difficulties in his way. Lord Hartington, and others of his former colleagues, declined to join his Administration; Mr Chamberlain, who, in the first instance, accepted office, retired almost immediately from the ministry; and Mr Bright, whose eloquence and services gave him a unique position in the House, threw in his lot in opposition to Home Rule. A split in the Liberal party thus began, which was destined to endure; and Mr Gladstone found his difficulties increased by the defection of the men on whom he had hitherto largely relied. He persevered, however, in the task which he had set himself, and introduced a measure endowing Ireland with a parliament, and excluding the Irish members from Westminster. He was defeated, and appealed from the House which had refused to support him to the country. For the first time in the Queen's reign, two general elections occurred within twelve months. The country showed no more disposition than the House of Commons to approve the course which the minister was taking. A large majority of the members of the new Parliament were pledged to resist Home Rule. Mr Gladstone, bowing at once to the verdict of the people, resigned office, and Lord Salisbury returned to power.

The new Cabinet, which was formed to resist Home Rule, did not succeed in combining all the opponents to this measure. The secessionists from the Liberal party—the Liberal Unionists, as they were called—held aloof from it; and Lord Salisbury was forced to form his Cabinet out of his immediate followers. The most picturesque appointment was that of Lord Randolph Churchill, who was made chancellor of the exchequer, and leader of the House of Commons. But before many months were over, Lord Randolph—unable to secure acceptance of a policy of financial retrenchment—resigned office, and Lord Salisbury was forced to reconstruct his ministry. Though he again failed to obtain the co-operation of the Liberal Unionists, one of the more prominent of them—Mr Goschen—accepted the seals of the Exchequer. Mr W. H. Smith moved from the War Office to the Treasury, and became leader of the House of Commons; while Lord Salisbury himself returned to the Foreign Office, which the dramatically sudden death of Lord Iddesleigh, better known as Sir Stafford Northcote, vacated. These arrangements lasted till 1891, when, on Mr Smith's death, the Treasury and the lead of the Commons were entrusted to Lord Salisbury's nephew, Mr Arthur Balfour, who had made a great reputation as chief secretary for Ireland (*q.v.*).

Unionism.

The ministry of 1886, which endured till 1892, gave to London a county council; introduced representative government into every English county; and made elementary education free throughout England. The alliance with the Liberal Unionists was, in fact, compelling the Conservative Government to promote measures which were not wholly consistent with the stricter Conservative traditions or wishes. In other respects, the legislative achievements of the Government were not great; and the time of Parliament was largely occupied in devising rules for the conduct of its business, which the obstructive attitude of the Irish members made necessary, and in discussing the charges brought against the Nationalist party by the *Times*, of complicity in the Phoenix Park murders. Under the new rules, the sittings of the House on ordinary days were made to commence at 3 P.M., and opposed business was automatically interrupted at midnight, while for the first time a power was given to the majority in a House of a certain size to conclude debate by what was known as the closure. Notwithstanding these new rules obstructive tactics continued to prevail; and, in the course of the Parliament, many members were suspended for disorderly conduct. The hostility of the Irish members was perhaps increased by some natural indignation at the charges brought against Mr Parnell. The *Times*, in April 1887, printed the facsimile of a letter purporting to be signed by Mr Parnell, in which he declared that he had no other course open to him but to denounce the Phoenix Park murders, but that, while he regretted "the accident" of Lord Frederick Cavendish's death, he could not "refuse to admit that Burke got no more than his deserts." The publication of this letter, and later of other similar documents, naturally created a great sensation; and the Government ultimately appointed a special commission of three judges to inquire into the charges and allegations that were made. In the course of the inquiry it was proved that the letters had emanated from a man named Pigott, who had at one time been associated with the Irish Nationalist movement, but who for some time past had earned a precarious living by writing begging and threatening letters. Pigott, subjected to severe cross-examination by Sir Charles Russell (afterwards Lord Russell of Killowen), broke down, fled from justice, and committed suicide. His flight practically settled the question; and an inquiry, which many people had thought at its inception would brand Mr Parnell as a criminal, raised him to an influence which he had never enjoyed before. But in the same year, which witnessed his triumph, his fall was doomed. He was made co-respondent in a divorce suit brought by Captain O'Shea—another Irishman—for the dissolution of his marriage; and the disclosures made at the trial induced Mr Gladstone, who was supported by the Nonconformists generally throughout the United Kingdom, to request Mr Parnell to withdraw from the leadership of the Irish party. Mr Parnell refused to comply with this request, and the Irish party was shattered into fragments by his decision. Mr Parnell himself did not long survive the disruption of the party which he had done so much to create. The exertions which he made to retrieve his waning influence proved too much for his strength, and in the autumn of 1891 he died suddenly at Brighton. Mr Parnell's death radically altered the political situation. At the general elections of 1885 and 1886 the existence of a strong, united Irish party had exercised a dominating influence. As the Parliament of 1886 was drawing to a close, the dissensions among the Irish members, and the loss of their great leader, were visibly sapping the strength of the Nationalists. At the general election of 1892, Home Rule was still the prominent subject before the electors. But the English Liberals were already a little weary of allies who were quarrelling among themselves, and whose disputes were introducing a new factor into politics. The political struggle virtually turned not on measures but on men. Mr Gladstone's great age, and the marvellous powers which he displayed at a time when most men seek the repose of retirement, were the chief causes which affected the results. His influence enabled him to secure a small Liberal majority. But it was noticed that the majority depended on Scottish, Irish, and Welsh votes, and that England—the "predominant partner," as it was subsequently called by Lord Rosebery—returned a majority of members pledged to resist any attempt to dissolve the union between the three kingdoms.

Nationalist split.

On the meeting of the new Parliament Lord Salisbury's Government was defeated on a vote of want of confidence, and for a fourth time Mr Gladstone became prime minister. In the session of 1893 he again introduced a Home Rule Bill. But the measure of 1893 differed in many respects from that of 1886. In particular, the Irish were no longer to be excluded from the Imperial Parliament at Westminster. The bill which was thus brought forward was actually passed by the Commons. It was, however, rejected by the Lords. The dissensions among the Irish themselves, the hostility which English constituencies were displaying to the proposal, emboldened the Peers to arrive at this decision. Some doubt was felt as to the course which Mr Gladstone would take in this crisis. Many persons thought that he should at once have appealed to the country, and have endeavoured to obtain a distinct mandate from the constituencies to introduce a new Home Rule Bill. Other persons imagined that he should have followed the precedent which had been set by Lord Grey in 1831, and, after a short prorogation, have re-introduced his measure in a new session. As a matter of fact, Mr Gladstone adopted neither of these courses. The Government decided not to take up the gauntlet thrown down by the Peers, but to proceed with the rest of their political programme. With this object an autumn and winter session was held, during which the Parish Councils Act, introduced by Mr Fowler, was passed, after several important amendments which had been introduced into it in the House of Lords had been reluctantly accepted by Mr Gladstone. On the other hand an Employers' Liability Bill, introduced by Mr Asquith, the Home Secretary, was ultimately dropped by Mr Gladstone after passing all stages in the House of Commons, rather than that an amendment of the Peers, allowing "contracting out," should be accepted.

Home Rule Bill, 1893.

Before, however, the session had quite run out (3rd March 1894), Mr Gladstone, who had now completed his eighty-fourth year, laid down a load which his increasing years made it impossible for him to sustain (see the article GLADSTONE). He was succeeded by Lord Rosebery, whose abilities and attainments had raised him to a high place in the Liberal counsels. Lord Rosebery did not succeed in popularizing the Home Rule proposal which Mr Gladstone had failed to carry. He declared, indeed, that success was not attainable till England was converted to its expediency. He hinted that success would not even then be assured until something was done to reform the constitution of the House of Lords. But if, on the one hand, he refused to introduce a new Home Rule Bill, he hesitated, on the other, to court defeat by any attempt to reform the Lords. His Government, in these circumstances, while it failed to conciliate its opponents, excited no enthusiasm among its supporters. It was generally understood, moreover, that a large section of the Liberal party resented Lord Rosebery's appointment to the first place in the ministry, and thought that the lead should have been conferred on Sir W. Harcourt. It was an open secret that these differences in the party were reflected in the Cabinet, and that the relations between Lord Rosebery and Sir W. Harcourt were too strained to ensure either the harmonious working or the stability of the Administration. In these circumstances the fall of the ministry was only a question of time. It occurred—as often happens in Parliament—on a minor issue which no one had foreseen. Attention was drawn in the House of Commons to the insufficient supply of cordite provided by the War Office, and the House—notwithstanding the assurance of the War minister (Sir Henry Campbell-Bannerman) that the supply was adequate — placed the Government in a minority. Lord Rosebery resigned office, and Lord Salisbury for the third time became prime minister, the duke of Devonshire, Mr Chamberlain, and other Liberal Unionists joining the Government. The Parliament of 1892 was dissolved, and a new Parliament, in which the Unionists obtained an overwhelming majority, was returned.

Lord Rosebery.

The Government of 1892, which was successively led by Mr Gladstone and Lord Rosebery, will, on the whole, be recollected for its failures. Yet it passed two measures which have exercised and are exercising a wide influence. The Parish Councils Act introduced electoral institutions into the government of every parish, and in 1894 Sir W. Harcourt, as Chancellor of the Exchequer, availed himself of the opportunity, which a large addition to the navy invited, to reconstruct the death duties. He swept away in doing so many of the advantages which the owner of real estate and the life tenant of settled property had previously enjoyed, and drove home a principle which Mr Goschen had tentatively introduced a few years before by increasing the rate of the duty with the amount of the estate. Rich men, out of their superfluities, were thenceforward to pay more than poor men out of their necessities.

It is difficult to recapitulate the history of the Unionist Government of 1895, which (with minor changes) was still in office in 1901. History may hereafter conclude that the most significant circumstance of the period is to be found in the demonstration of loyalty and affection to which the sixtieth anniversary of Queen Victoria's accession led in 1897. Ten years before, her jubilee had been the occasion of enthusiastic rejoicings, and the Queen's progress through London to a service of thanksgiving at Westminster had impressed the imagination of her subjects and proved the affection of her people. But the rejoicings of 1887 were forgotten amid the more striking demonstrations ten years later. It was seen then that the Queen, by her conduct and character, had gained a popularity which has had no parallel in history, and had won a place in the hearts of her subjects which perhaps no other monarch had ever previously enjoyed. There was no doubt that, if the opinion of the English-speaking races throughout the world could have been tested by a plebiscite, an overwhelming majority would have declared that the fittest person for the rule of the British empire was the gracious and kindly lady who for sixty years, in sorrow and in joy, had so worthily discharged the duties of her high position. This remarkable demonstration was not confined to the British empire alone. In every portion of the globe the sixtieth anniversary of the Queen's reign excited interest; in every country the Queen's name was mentioned with affection and respect; while the people of the United States vied with the subjects of the British empire in praise of the Queen's character and in expressions of regard for her person. Only a year or two before, an obscure dispute on the boundary of British Venezuela had brought the United States and Great Britain within sight of a quarrel. The jubilee showed conclusively that, whatever politicians might say, the ties of blood and kinship, which united the two peoples, were too close to be severed by either for some trifling cause; that the wisest heads in both nations were aware of the advantages which must arise from the closer union of the Anglo-Saxon races; and that the true interests of both countries lay in their mutual friendship. A war in which the United States was subsequently engaged with Spain cemented this feeling. The Government and the people of the United States recognized the advantage which they derived from the goodwill of Great Britain in the hour of their necessity, and the two nations drew together as no other two nations had perhaps ever been drawn together in the history of the world.

The two jubilees.

If the jubilee was a proof of the closer union of the many sections of the British empire, and of their warm attachment to their Sovereign, it also gave expression to the "Imperialism" which was becoming a dominant factor in British politics. Few people realized the mighty change which in this respect had been effected in thought and feeling. Forty years before, the most prominent English statesmen had regarded with anxiety the huge responsibilities of a world-wide empire. In 1897 the whole tendency of thought and opinion was to enlarge the burden of which the preceding generation had been weary. The extension of British influence, the protection of British interests, were almost universally advocated; and the few statesmen who repeated in the 'nineties the sentiments which would have been generally accepted in the 'sixties, were regarded as "Little Englanders." It is perhaps needless in this page to refer to the effect which these new ideas had on Oriental politics, whether in China or Turkey. But a few words must be added on the consequences which they produced in Africa. Both in the north and in the south of this great and imperfectly explored continent, memories still clung which were ungrateful to Imperialism. In the north, the murder of Gordon was still unavenged; and the vast territory known as the Sudan had escaped from the control of Egypt. In the south, war with the Transvaal had been concluded by a British defeat; and the Dutch were elated, the English irritated, at the recollection of Majuba. In 1898 Lord Salisbury's Government decided on extending the Anglo-Egyptian rule over the Sudan, and a great expedition was sent from Egypt under the command of Sir Herbert (afterwards Lord) Kitchener to Khartum. Few military expeditions have been more elaborately organized, or have achieved a more brilliant success. The Sudanese forces were decisively beaten, with great slaughter, in the immediate neighbourhood of Omdurman; and Khartum became thenceforward the capital of the new province, which was placed under Lord Kitchener's rule. Soon after this decisive success, a French exploring expedition under Major Marchand reached the Upper Nile and hoisted the French flag at Fashoda. It was obvious that the French could not be allowed to remain at a spot which the Khedive of Egypt claimed as Egyptian territory; and after some negotiation, and some irritation, the French were withdrawn. In South Africa still more important events were in the meanwhile progressing. Ever since the independence of the South African Republic had been virtually conceded by the Convention of 1884, unhappy differences had prevailed between the Dutch and British residents in the Transvaal. The discovery of gold at Johannesburg and elsewhere had led to a large immigration of British and other colonists. Johannesburg had grown into a great and prosperous city. The foreign population of the Transvaal, which was chiefly English, became actually more numerous than the Boers themselves, and they complained that they were deprived of all political rights, that they were subjected to unfair taxation, and that they were hampered in their industry and unjustly treated by the Dutch courts and Dutch officials. Failing to obtain redress, at the end of 1895 certain persons among them contemplated a revolution. Dr Jameson, who was administering the adjacent territory of Rhodesia, accompanied by some British officers, actually attempted an invasion of the Transvaal. His force, utterly inadequate for the purpose, was stopped by the Boers, and he and his fellow-officers were taken prisoners. There was no doubt that this raid on the territory of a friendly state was totally unjustifiable. Unfortunately, Dr Jameson's original plans had been framed with the knowledge of Mr Rhodes, the Prime Minister at the Cape, and many persons thought that they ought to have been suspected by the Colonial Office in London. England at any rate would have had no valid ground of complaint if the leaders of a buccaneering force had been summarily dealt with by the Transvaal authorities. The president of the republic, Mr Kruger, however, handed over his prisoners to the British authorities, and Parliament instituted an inquiry by a select committee into the circumstances of the raid. The inquiry was terminated somewhat abruptly. The committee acquitted the Colonial Office of any knowledge of the plot; but a good many suspicions remained unanswered. The chief actors in the raid were tried under the Foreign Enlistment Act, found guilty, and subsequently released after short terms of imprisonment. Mr Rhodes himself was not removed from the privy council, as his more extreme accusers demanded; but he had to abandon his career in Cape politics for a time, and confine his energies to the development of Rhodesia.

Omdurman, Fashoda.

Jameson Raid.

In consequence of these proceedings, the Transvaal authorities at once set to work to accumulate armaments, and they succeeded in procuring vast quantities of artillery and military stores. The British Government would undoubtedly have been entitled to insist that these armaments should cease. It was obvious that they could only be directed against Great Britain; and no nation is bound to allow another people to prepare great armaments to be employed against itself. The criminal folly of the raid prevented the British Government from making this demand. It could not say that the Transvaal Government had no cause for alarm when British officers had attempted an invasion of its territory and had been treated rather as heroes than as criminals at home. Ignorant of the strength of Great Britain, and elated by the recollection of their previous successes, the Boers themselves believed that a new struggle might give them predominance in South Africa. The knowledge that a large portion of the population of Cape Colony was of Dutch extraction, and that public men at the Cape sympathized with them in their aspirations, increased their confidence. In the meantime, while the Boers were silently and steadily continuing their military preparations, the British settlers at Johannesburg—the Uitlanders, as they were called—were demanding consideration for their grievances. In the spring of 1899, Sir Alfred Milner, governor of the Cape, met President Kruger at Bloemfontein, the capital of the Orange Free State, and endeavoured to accomplish that result by negotiation. He thought, at the time, that if the Uitlanders were given the franchise and a fair proportion of influence in the legislature, other difficulties might be left to settle themselves. The negotiations thus commenced unfortunately failed. The discussion, which had originally turned on the franchise, was enlarged by the introduction of the question of suzerainty or supremacy; and at last, in the beginning of October, when the rains of an African spring were causing the grass to grow on which the Boer armies were largely dependent for forage, the Boers declared war and invaded Natal. The British Government had not been altogether happy in its conduct of the preceding negotiations. It was certainly unhappy in its preparations for the struggle. It made the great mistake of underrating the strength of its enemy; it suffered its agents to commit the strategical blunder of locking up the few troops it had in an untenable position in the north of Natal. It was not surprising, in such circumstances, that the earlier months of the war should have been memorable for a series of exasperating reverses. These reverses, however, were redeemed by the valour of the British troops, the spirit of the British nation, and the enthusiasm which induced the great autonomous colonies of the empire to send men to support the cause of the mother country. The gradual arrival of reinforcements, and the appointment of a soldier of genius—Lord Roberts—to the supreme command, changed the military situation; and, before the summer of 1900 was concluded, the places which had been besieged by the Boers—Kimberley, Ladysmith, and Mafeking—had been successively relieved; the capitals of the Orange Free State and of the Transvaal had been occupied; and the two republics, which had rashly declared war against the British empire, had been formally annexed to the dominions of the Queen.

Boer War, 1899.

The defeat and dispersal of the Boer armies, and the apparent collapse of Boer resistance, induced a hope that the war was over; and the Government seized the opportunity to terminate the parliament, which had already endured for more than five years. The election was conducted with unusual bitterness; but the constituencies practically affirmed the policy of the Government by maintaining, almost unimpaired, the large majority which the Unionists had secured in 1895. Unfortunately, the expectations which had been formed at the time of the dissolution were disappointed. The same circumstances which had emboldened the Boers to declare war in the autumn of 1899, induced them to renew a guerilla warfare in the autumn of 1900—the approach of an African summer supplying the Boers with the grass on which they were dependent for feeding their hardy horses. Guerilla bands suddenly appeared in different parts of the Orange River Colony and of the Transvaal. They interrupted the communications of the British armies; they won isolated victories over British detachments; they even attempted the invasion of the Cape Colony. Thus the year which concluded the century closed in disappointment and gloom. The serious losses which the war entailed, the heavy expenses which it involved, and the large force which it absorbed, filled thoughtful men with anxiety.

The close of 1900.

No one felt more sincerely for the sufferings of her soldiers, and no one regretted more truly the useless prolongation of the struggle, than the venerable lady who occupied the throne. She had herself lost a grandson (Prince Christian Victor) in South Africa; and sorrow and anxiety perhaps told even on a constitution so unusually strong as hers. At any rate, towards the close of 1900 it was reported, in well-informed circles, that Her Majesty was not enjoying her usual health. About the middle of January 1901 it was known that she was seriously ill; on the 22nd she died. The death of the Queen thus occurred immediately after the close of the century over so long a period of which her reign had extended. That reign witnessed the greatest industrial triumphs which the world had ever seen; the expansion of the Anglo-Saxon race and the development of Anglo-Saxon rule in every quarter of the globe. Commencing in a period of great internal suffering, it ended at a time of unusual prosperity; and of all the remarkable facts in the reign, there is, perhaps, nothing more noteworthy than these: during the first five years of it poverty and crime in England attained their maxima; while, during the last five years of it, the pressure of poverty and the burden of crime were reduced to the lowest proportions which had ever been known. The vast expansion of the empire, and the marked improvement in the condition of the people, were due to causes with which the Queen herself had no direct concern. But in other respects the Queen rendered services to the country of the highest importance. In the first place, her own example exerted a beneficial influence on all who surrounded her. The atmosphere of the court, which had been injuriously affected during the reigns of her immediate predecessors, was purified by her influence and her conduct. The tone of society was insensibly raised by her example, and it is not too much to say that she left her country better than she found it. The Queen's public conduct, moreover, was as much above criticism as her private life. It would, perhaps, be an exaggeration to say that she invented constitutional government; but she practically determined by her example the right course for constitutional sovereigns to pursue. Though, throughout her reign, she exercised a great and increasing influence on the counsels of her ministers, she never identified herself with any minister or any party. Each of the ten men who successively filled the first place in her counsels, was able to rely on the same loyal and unwavering support, and each of them was ready to acknowledge the debt that was due to her judgment and her experience.

The death of the Queen.

The reign of the Queen may, perhaps, be divided into three periods. During nearly the whole of the first period, from 1837 to 1862, she had her consort by her side, and was largely influenced by his advice. The Prince's stiff and reserved manners, however, diverted attention from his many admirable qualities; and the court hardly enjoyed the full measure of popularity which it deserved at the time and which it acquired later on. During the second period, from the death of the Prince Consort to the earlier 'eighties, the sorrow which had fallen on the Queen induced her to withdraw from the more prominent duties of her position; the people grew accustomed to the absence of their sovereign, and forgot or were unaware of the many great services which she was rendering to them. Even during these years of mourning, however, the Queen's sympathy with suffering made a profound impression on the nation; and if in some respects she lost ground as a ruler, she gained the affection of her subjects by her many excellent qualities as a woman. But it was not till her jubilee of 1887 that the people generally became thoroughly acquainted with the great qualities of their sovereign. The Queen herself saw with surprise the admiration and love which her presence everywhere excited. Thenceforward she emerged more and more from her retirement, and made exertions, which were the more remarkable from the growing infirmities of her age, to display her gratitude for her people's appreciation. She acquired in these years a popularity which no British sovereign, and perhaps no sovereign in the world, has ever enjoyed; and, partly through her connexion with the ruling houses of Europe, and partly in consequence of the authority bestowed by age and experience, she exercised an influence abroad almost as great and beneficial as that which she exerted at home.

The long period over which her reign extended was, in one sense, the most remarkable in the history of the world. So far as the English-speaking races were concerned, it witnessed a material and moral progress which has no parallel in their annals. During her reign the people of Great Britain doubled their number; but the accumulated wealth of the country increased at least threefold, and its trade sixfold. All classes shared the prevalent prosperity. Notwithstanding the increase of population, the roll of paupers at the end of the reign, compared with the same roll at the beginning, stood as 2 stands to 3; the criminals as 1 to 2. The expansion abroad was still more remarkable. There were not 200,000 white persons in Australasia when the Queen came to the throne; there were nearly 5,000,000 when she died. The great Australian colonies were almost created in her reign; two of them—Victoria and Queensland—owe their name to her; they all received those autonomous institutions, under which their prosperity has been built up, during its continuance. Expansion and progress were not confined to Australasia. The opening months of the Queen's reign were marked by rebellion in Canada. The close of it saw Canada one of the most loyal portions of the Empire. In Africa, the advance of the red line which marks the bounds of British dominion has been even more rapid; while in India the Punjab, Scindh, Oudh, and Burma are some of the acquisitions which were added to the British Empire while the Queen was on the throne. When she died one square mile in four of the land in the world was under the British flag, and at least one person out of every five persons alive was a subject of the Queen.

Material progress was largely facilitated by industry and invention. The first railways had been made, the first steamship had been built, before the Queen came to the throne. But, so far as railways are concerned, none of the great trunk lines had been constructed in 1837; the whole capital authorized to be spent on railway construction did not exceed £55,000,000; and, five years after the reign had begun, there were only 18,000,000 passengers. The paid-up capital of British railways now exceeds £1,100,000,000; the passengers, not including season ticket-holders, also number 1,100,000,000; and the sum which is annually spent in working the lines considerably exceeds the whole capital authorized to be spent on their construction in 1837. The progress of the commercial marine was still more noteworthy. In 1837 the entire commercial navy comprised 2,800,000 tons, of which less than 100,000 tons were moved by steam. At the end of the reign the tonnage of British merchant vessels had reached 13,700,000 tons, of which more than 11,000,000 tons were moved by steam. At the beginning of the reign it was supposed to be impossible to build a steamer which could either cross the Atlantic or face the monsoon in the Red Sea. The development of steam navigation since then has made Australia much more accessible than America was in 1837, and has brought New York, for all practical purposes, nearer to London than Aberdeen was at the commencement of the reign. Electricity has had a greater effect on communication than steam on locomotion; and electricity, as a practical invention, had its origin in the reign. The first experimental telegraph line was only erected in the year in which Queen Victoria came to the throne. Submarine telegraphy, which has done so much to knit the Empire together, was not perfected for many years afterwards; and long ocean cables were almost entirely constructed in the last half of the reign.

These are some of the more striking changes which have taken place in the period with which this article is concerned. Concentrated as they have been in the years which have been covered by a single reign, they impart additional importance and interest to the age of Queen Victoria. On personal grounds her memory will be consecrated in history as that of the best of sovereigns; on imperial grounds her reign will be recollected for the extension of the British Empire, the expansion of the British race, and the material and moral progress of the British people. (s. w.)

[See also the articles British Empire, and Victoria, Queen.]

English Law (History of).—In English jurisprudence "legal memory" is said to extend as far as, but no farther than the coronation of Richard I. (Sept. 3, 1189). This is a technical doctrine concerning prescriptive rights, but is capable of expressing an important truth. For the last seven centuries, little more or less, the English law, which is now over-shadowing a large share of the earth, has had not only an extremely continuous, but a matchlessly well-attested history, and, moreover, has been the subject matter of rational exposition. Already in 1194 the daily doings of a tribunal which was controlling and moulding the whole system were being punctually recorded in letters yet legible, and from that time onwards it is rather the enormous bulk than any dearth of available materials that prevents us from tracing the transformation of every old doctrine and the emergence and expansion of every new idea. If we are content to look no farther than the text-books—the books written by lawyers for lawyers—we may read our way backwards to Blackstone (d. 1780), Hale (d. 1676), Coke (d. 1634), Fitzherbert (d. 1538), Littleton (d. 1481), Bracton (d. 1268), Glanvill (d. 1190), until we are in the reign of Henry of Anjou, and yet shall perceive that we are always reading of one and the same body of law, though the little body has become great, and the ideas that were few and indefinite have become many and explicit.

Beyond these seven lucid centuries lies a darker period. Nearly six centuries will still divide us from the dooms of Æthelbirht (*circ.* 600), and nearly seven from the Lex Salica (*circ.* 500). We may regard the Norman conquest of England as marking the confluence of two streams of law. The one we may call French or Frankish. If we follow it upwards we pass through the capitularies of Carlovingian emperors and Merovingian kings until we see Chlodwig and his triumphant Franks invading Gaul, submitting their Sicambrian necks to the yoke of the imperial religion, and putting their traditional usages into written Latin. The other rivulet we may call Anglo-Saxon. Pursuing it through the code of Cnut (d. 1035) and the ordinances of Alfred (*circ.* 900) and his successors, we see Ine publishing laws in the newly-converted Wessex (*circ.* 690), and, almost a century earlier, Æthelbirht doing the same in the newly-converted Kent (*circ.* 600). This he did, says Beda, in accordance with Roman precedents. Perhaps from the Roman missionaries he had heard tidings of what the Roman emperor had lately been doing far off in New Rome. We may at any rate notice with interest that in order of time Justinian's law-books fall between the *Lex Salica* and the earliest Kentish dooms; also that the great Pope who sent Augustine to England is one of the very few men who between Justinian's day and the 11th century lived in the Occident and yet can be proved to have used the Digest. In the Occident the time for the Germanic "folk-laws" (*Leges Barbarorum*) had come, and a Canon law, ambitious of independence, was being constructed, when in the Orient the lord of church and state was "enucleating" all that was to live of the classical jurisprudence of pagan Rome. It was but a brief interval between Gothic and Lombardic domination that enabled him to give law to Italy: Gaul and Britain were beyond his reach.

The Anglo-Saxon laws that have come down to us (and we have no reason to fear the loss of much beyond some dooms of the Mercian Offa) are best studied as members of a large Teutonic family. Those that proceed from the Kent and Wessex of the 7th century are closely related to the Continental folk-laws. Their next of kin seem to be the *Lex Saxonum* and the laws of the Lombards. Then, though the 8th and 9th centuries are unproductive, we have from Alfred (*circ.* 900) and his successors a series of edicts which strongly resemble the Frankish capitularies —so strongly that we should see a clear case of imitation, were it not that in Frankland the age of legislation had come to its disastrous end long before Alfred was king. This, it may be noted, gives to English legal history a singular continuity from Alfred's day to our own. The king of the English was expected to publish laws at a time when hardly any one else was attempting any such feat, and the English dooms of Cnut the Dane are probably the most comprehensive statutes that were issued in the Europe of the 11th century. No genuine laws of the sainted Edward have descended to us, and during his reign England seems but too likely to follow the bad example of Frankland, and become a loose congeries of lordships. From this fate it was saved by the Norman duke, who, like Cnut before him, subdued a land in which kings were still expected to publish laws.

Germanic Law.

In the study of early Germanic law—a study which now for some fifty years has been scientifically prosecuted in Germany—the Anglo-Saxon dooms have received their due share of attention. A high degree of racial purity may be claimed on their behalf. Celtic elements have been sought for in them, but have never been detected. At certain points, notably in the regulation of the blood-feud and the construction of a tariff of atonements, the law of one rude folk will always be somewhat like the law of another; but the existing remains of old Welsh and old Irish law stand far remoter from the dooms of Æthelbirht and Ine than stand the edicts of Rothari and Liutprand, kings of the Lombards. Indeed, it is very dubious whether distinctively Celtic customs play any considerable part in the evolution of that system of rules of Anglian, Scandinavian, and Frankish origin which becomes the law of Scotland. Within England itself, though for a while there was fighting enough between the various Germanic folks, the tribal differences were not so deep as to prevent the formation of a common language and a common law. Even the strong Scandinavian strain seems to have rapidly blended with the Anglian. It amplified the language and the law, but did not permanently divide the country. If, for example, we can to-day distinguish between *law* and *right*, we are debtors to the Danes; but very soon *law* is not distinctive of eastern or *right* of western England. In the first half of the 12th century a would-be expounder of the law of England had still to say that the country was divided between the Wessex law, the Mercian law, and the Danes' law, but he had also to point out that the law of the king's own court stood apart from and above all partial systems. The local customs were those of shires and hundreds, and shaded off into each other. We may speak of more Danish and less Danish counties; it was a matter of degree; for rivers were narrow and hills were low. England was meant by nature to be the land of one law.

Then as to Roman law. In England and elsewhere Germanic law developed in an atmosphere that was charged with traditions of the old world, and many of these traditions had become implicit in the Christian religion. It might be argued that all that we call progress is due to the influence exercised by Roman civilization; that, were it not for this, Germanic law would never have been set in writing; and that theoretically unchangeable custom would never have been supplemented or superseded by express legislation. All this and much more of the same sort might be said; but the survival in Britain, or the re-introduction into England, of anything that we should dare to call Roman jurisprudence would be a different matter. Eyes, carefully trained, have minutely scrutinized the Anglo-Saxon legal texts without finding the least trace of a Roman rule outside the ecclesiastical sphere. Even within that sphere modern research is showing that the church-property-law of the Middle Ages, the law of the ecclesiastical "benefice," is permeated by Germanic ideas. This is true of Gaul and Italy, and yet truer of an England in which Christianity was for a while extinguished. Moreover, the laws that were written in England were, from the first, written in the English tongue; and this gives them an unique value in the eyes of students of Germanic folk-law, for even the very ancient and barbarous *Lex Salica* is a Latin document, though many old Frankish words are enshrined in it. Also we notice—and this is of grave importance—that in England there are no vestiges of any "Romani" who are being suffered to live under their own law by their Teutonic rulers. On the Continent we may see Gundobad, the Burgundian, publishing one law-book for the Burgundians and another for the Romani who own his sway. A book of laws, excerpted chiefly from the Theodosian code, was issued by Alaric the Visigoth for his Roman subjects before the days of Justinian, and this book (the so-called *Breviarium Alarici* or *Lex Romana Visigothorum*) became for a long while the chief representative of Roman law in Gaul. The Frankish king in his expansive realm ruled over many men whose law was to be found not in the *Lex Salica* or *Lex Ribuaria*, but in what was called the *Lex Romana.* "A system of personal law" prevailed: the *homo Romanus* handed on his Roman law to his children, while Frankish or Lombardic, Swabian or Saxon law would run in the blood of the *homo barbarus.* Of all this we hear nothing in England. Then on the mainland of Europe Roman and barbarian law could not remain in juxtaposition without affecting each other. On the one hand we see distinctively Roman rules making their way into the law of the victorious tribes, and on the other hand we see a decay and debasement of jurisprudence which ends in the formation of what modern historians have called a Roman "vulgar law" (*Vulgarrecht*). For a short age which centres round the year 800 it seemed possible that Frankish kings, who were becoming Roman emperors, would be able to rule by their capitularies nearly the whole of the Christian Occident. The dream vanished before fratricidal wars, heathen invaders, centrifugal feudalism, and a centripetal church which found its law in the newly-concocted forgeries of the Pseudo-Isidore (*circ.* 850). The "personal laws" began to transmute themselves into local customs, and the Roman vulgar-law began to look like the local custom of those districts where the Romani were the preponderating element in the population. Meanwhile, the Norse pirates subdued a large tract of what was to be northern France —a land where Romani were few. Their restless and boundless vigour these Normans retained; but they showed a wonderful power of appropriating whatever of alien civilization came in their way. In their language, religion, and law, they had become French many years before they subdued England. It is a plausible opinion that among them there lived some sound traditions of the Frankish monarchy's best days, and that Norman dukes, rather than German emperors or kings of the French, are the truest spiritual heirs of Charles the Great.

In our own day German historians are apt to speak of English law as a "daughter" of French or Frankish law. This tendency derived its main impulse from Brunner's proof that the germ of trial by jury, which cannot be found in the Anglo-Saxon laws, can be found in the prerogative procedure of the Frankish kings. We must here remember that during a long age English lawyers wrote in French and even thought in French, and that to this day most of the technical terms of the law, more especially of the private law, are of French origin. Also, it must be allowed, that when the law has taken shape in the 13th century it is very like one of the *coutumes* of northern France. Even when linguistic difficulties have been surmounted, the Saxon Mirror of Eike von Repgow will seem far less familiar to an Englishman than the so-called Establishments of St. Louis. This was the outcome of a slow process which fills more than a century (1066–1189), and was in a great measure due to the reforming energy of Henry II., the French prince who, in addition to England, ruled a good half of France. William the Conqueror seems to have intended to govern Englishmen by English law. After the tyranny of Rufus Henry I. promised a restoration of king Edward's law: that is, the law of the Confessor's time (*Lagam Eadwardi regis vobis reddo*). Various attempts were then made, mostly, so it would seem, by men of French birth, to state in a modern and practicable form the *laga Eadwardi* which was thus restored. The result of their labours is an intricate group of legal tracts which has been recently explored by Dr. Liebermann. The best of these has long been known as the *Leges Henrici Primi*, and aspires to be a comprehensive law-book. Its author, though he had some foreign sources at his command, such as the *Lex Ribuaria* and an epitome of the Breviary of Alaric, took the main part of his matter from the code of Cnut and the older English dooms. Neither the Conqueror nor either of his sons had issued many ordinances: the invading Normans had little, if any, written law to bring with them, and had invaded a country where kings had been lawgivers. Moreover, there was much in the English system that the Conqueror was keenly interested in retaining—especially an elaborate method of taxing the land and its holders. The greatest product of Norman government, the grandest feat of government that the world had seen for a long time past, the compilation of *Domesday Book*, was a conservative effort, an attempt to fix upon every landholder, French or English, the amount of geld that was due from his predecessor in title. Himself the rebellious vassal of the French king, the duke of the Normans, who had become king of the English, knew much of disruptive feudalism, and had no mind to see England that other France which it had threatened to become in the days of his pious but incompetent cousin. The sheriffs, though called *vicecomites*, were to be the king's officers; the shire-moots might be called county courts, but were not to be the courts of counts. Much that was sound and royal in English public law was to be preserved if William could preserve it.

The Norman Age.

The gulf that divides the so-called *Leges Henrici* (*circ.* 1115) from the text-book ascribed to Ranulf Glanvill (*circ.* 1188), seems at first sight very wide. The one represents a not easily imaginable chaos and clash of old rules and new; it represents also a stage in the development of feudalism which in other countries is represented chiefly by a significant silence. The other is an orderly, rational book, which through all the subsequent centuries will be readily understood by English lawyers. Making no attempt to tell us what goes on in the local courts, its author, who may be Henry II.'s chief justiciar, Ranulf Glanvill, or may be Glanvill's nephew, Hubert Walter, fixes our attention on a novel element which is beginning to subdue all else to its powerful operation. He speaks to us of the justice that is done by the king's own court. Henry II. had opened the doors of his French-speaking court to the mass of his subjects. Judges chosen for their ability were to sit there, term after term; judges were to travel in circuits through the land, and in many cases the procedure by way of "an inquest of the country," which the Norman kings had used for the ascertainment of their fiscal rights, was to be at the disposal of ordinary litigants. All this had been done in a piecemeal, experimental fashion by ordinances that were known as "assizes." There had not been, and was not to be, any enunciation of a general principle inviting all who were wronged to bring in their own words their complaints to the king's audience. The general prevalence of feudal justice, and of the world-old methods of supernatural probation (ordeals, battle, oaths sworn with oath-helpers), was to be theoretically respected; but in exceptional cases, which would soon begin to devour the rule, a royal remedy was to be open to anyone who could frame his case within the compass of some carefully-worded and prescript formula. With allusion to a remote stage in the history of Roman law, a stage of which Henry's advisers can have known little or nothing, we may say that a "formulary system" is established which will preside over English law until modern times. Certain actions, each with a name of its own, are open to litigants. Each has its own formula set forth in its original (or, as we might say, originating) writ; each has its own procedure and its appropriate mode of trial. The litigant chooses his writ, his action, and must stand or fall by his choice. Thus a book about royal justice tends to become, and Glanvill's book already is, a commentary on original writs.

Royal justice.

The precipitation of English law in so coherent a form as that which it has assumed in Glanvill's book is not to be explained without reference to the revival of Roman jurisprudence in Italy. Out of a school of Lombard lawyers at Pavia had come Lanfranc the Conqueror's adviser, and the Lombardists had already been studying Justinian's Institutes. Then at length the Digest came by its rights. About the year 1100 Irnerius was teaching at Bologna, and from all parts of the West men were eagerly flocking to hear the new gospel of civilization. About the year 1149 Vacarius was teaching Roman law in England. The rest of a long life he spent here, and faculties of Roman and Canon law took shape in the nascent University of Oxford. Whatever might be the fate of Roman law in England, there could be no doubt that the Canon law, which was crystallizing in the *Decretum Gratiani* (*circ.* 1139) and in the decretals of Alexander III., would be the law of the English ecclesiastical tribunals. The great quarrel between Henry II. and Thomas of Canterbury brought this system into collision with the temporal law of England, and the king's ministers must have seen that they had much to learn from the methodic enemy. Some of them were able men who became the justices of Henry's court, and bishops to boot. The luminous *Dialogue of the Exchequer* (*circ.* 1179), which expounds the English fiscal system, came from the treasurer, Richard Fitz Nigel, who became bishop of London; and the treatise on the laws of England came perhaps from Glanvill, perhaps from Hubert Walter, who was to be both primate and chief justiciar. There was healthy emulation of the work that was being done by Italian jurists, but no meek acceptance of foreign results.

Bracton.

A great constructive era had opened, and its outcome was a large and noble book. The author was Henry of Bratton (his name has been corrupted into Bracton), who died in 1268 after having been for many years one of Henry III.'s justices. The model for its form was the treatise of Azo of Bologna ("master of all the masters of the laws," an Englishman called him), and thence were taken many of the generalities of jurisprudence: maxims that might be regarded as of universal and natural validity. But the true core of the work was the practice of an English court which had yearly been extending its operations in many directions. For half a century past diligent record had been kept on parchment of all that this court had done, and from its rolls Bracton cited numerous decisions. He cited them as precedents, paying special heed to the judgments of two judges who were already dead, Martin Pateshull and William Raleigh. For this purpose he compiled a large Note Book, which was discovered by Prof. Vinogradoff in our own day. Thus at a very early time English "common law" shows a tendency to become what it afterwards definitely became, namely "case law." The term "common law" was just being taken over from the canonists by English lawyers, who used it to distinguish the general law of the land from local customs, royal prerogatives, and in short from all that was exceptional or special. Since statutes and ordinances were still rarities, all expressly enacted laws were also excluded from the English lawyer's notion of "the common law." The Great Charter (1215) had taken the form of a grant of "liberties and privileges," comparable to the grants that the king made to individual men and favoured towns. None the less, it was in that age no small body of enacted law, and, owing to its importance and solemnity, it was in after ages regarded, and is by English lawyers regarded at the present day, as the first article of a statute book. There it is followed by the "provisions" issued at Merton in 1236, and by those issued at Marlborough after the end of the Barons' War. But during Henry III.'s long reign the swift development of English law was due chiefly to new "original writs" and new "forms of action" devised by the Chancery and sanctioned by the court. Bracton knew many writs that were unknown to Glanvill, and men were already perceiving that limits must be set to the inventive power of the Chancery unless the king was to be an uncontrollable law-maker. Thus the common law was losing the power of rapid growth when Bracton summed the attained results in a book, the success of which is attested by a crowd of manuscript copies. Bracton had introduced just enough of Roman law and Bolognese method to save the law of England from the fate that awaited German law in Germany. His book was printed in 1569, and Coke's head was full of Bracton.

The comparison that is suggested when Edward I. is called the English Justinian cannot be pressed very far. Nevertheless, as is well known, it is in his reign (1272–1307) that English institutions finally take the forms that they are to keep through coming centuries. We already see the Parliament of the Three Estates, the Convocations of the Clergy, the King's Council, the Chancery or secretarial department, the Exchequer or financial department, the King's Bench, the Common Bench, the Commissioners of Assize and Gaol Delivery, the small group of professionally learned judges, and a small group of professionally learned lawyers, whose skill is at the service of those who will employ them. Moreover, the statutes that were passed in the first eighteen years of the reign, though their bulk seems slight to us nowadays, bore so fundamental a character that in subsequent ages they appeared as the substructure of huge masses of superincumbent law. Coke commented upon them sentence by sentence, and even now the merest smatterer in English law must profess some knowledge of *Quia emptores* and *De donis conditionalibus.* If some American states have, while others have not, accepted these statutes, that is a difference which is not unimportant to citizens of the United States at the dawn of the 20th century. Then from 1292 comes the first "law report" that has descended to us. It is the precursor of the long series of Year Books (Edw. II.–Hen. VIII.) which runs through the residue of the Middle Ages. Lawyers, we perceive, are already making and preserving notes of the discussions that take place in court: French notes that will be more useful to them than the formal Latin records inscribed upon the plea rolls. From these reports we learn that there are already, as we should say, a few "leading counsel," some of whom will be retained in almost every important cause. Papal decretals had been endeavouring to withdraw the clergy from secular employment. The clerical element had been strong among the judges of Henry III.'s reign: Bracton was an archdeacon, Pateshull a dean, Raleigh died a bishop. Their places begin to be filled by men who are not in orders, but who have pleaded the king's causes for him—his serjeants or servants at law—and beside them there are young men who are "apprentices at law," and are learning to plead. Also we begin to see men who, as "attorneys at law," are making it their business to appear on behalf of litigants. The history of the legal profession and its monopoly of legal aid is intricate, and at some points still obscure; but the influence of the canonical system is evident: the English attorney corresponds to the canonical proctor, and the English barrister to the canonical advocate. The main outlines were being drawn in Edward I.'s day; the legal profession became organic, and professional opinion became one of the main forces that moulded the law.

The study of English law fell apart from all other studies, and the impulse that had flowed from Italian jurisprudence was ebbing. We have two comprehensive text-books from Edward's reign: the one known to us as *Fleta*, the other as *Britton*; both of them, however, quarry their materials from Bracton's treatise. Also we have two little books on procedure which are attributed to Chief-

Justice Hengham, and a few other small tracts of an intensely practical kind. Under the cover of fables about king Alfred, the author of the *Mirror of Justices* made a bitter attack upon king Edward's judges, some of whom had fallen into deep disgrace. English legal history has hardly yet been purged of the leaven of falsehood that was introduced by this fantastic and unscrupulous pamphleteer. His enigmatical book ends that literate age which begins with Glanvill's treatise and the Treasurer's dialogue. Between Edward I.'s day and Edward IV.'s hardly anything that deserves the name of book was written by an English lawyer.

14th and 15th centuries.

During that time the body of statute law was growing, but not very rapidly. Acts of Parliament intervened at a sufficient number of important points to generate and maintain a persuasion that no limit, or no ascertainable limit, can be set to the legislative power of king and Parliament. Very few are the signs that the judges ever permitted the validity of a statute to be drawn into debate. Thus the way was being prepared for the definite assertion of parliamentary "omnicompetence" which we obtain from the Elizabethan statesman Sir Thomas Smith, and for those theories of sovereignty which we couple with the names of Hobbes and Austin. Nevertheless, English law was being developed rather by debates in court than by open legislation. The most distinctively English of English institutions in the later Middle Ages are the Year-Books and the Inns of Court. Year by year, term by term, lawyers were reporting cases in order that they and their fellows might know how cases had been decided. The allegation of specific precedents was indeed much rarer than it afterwards became, and no calculus of authority so definite as that which now obtains had been established in Coke's day, far less in Littleton's. Still it was by a perusal of reported cases that a man would learn the law of England. A skeleton for the law was provided, not by the Roman rubrics (such as public and private, real and personal, possessory and proprietary, contract and delict), but by the cycle of original writs that were inscribed in the Chancery's *Registrum Brevium.* A new form of action could not be introduced without the authority of Parliament, and the growth of the law took the shape of an explication of the true intent of ancient formulas. Times of inventive liberality alternated with times of cautious and captious conservatism. Coke could look back to Edward III.'s day as to a golden age of good pleading. The otherwise miserable time which saw the Wars of the Roses produced some famous lawyers, and some bold doctrines which broke new ground. It produced also Sir Thomas Littleton's (d. 1481) treatise on Tenures, which (though it be not, as Coke thought it, the most perfect work that ever was written in any human science) is an excellent statement of law in exquisitely simple language.

Education.

Meanwhile English law was being scholastically taught. This, if we look at the fate of native and national law in Germany, or France, or Scotland, appears as a fact of primary importance. From beginnings, so small and formless that they still elude research, the Inns of Court had grown. The lawyers, like other men, had grouped themselves in gilds, or gild-like "fellowships." The fellowship acquired property; it was not technically incorporate, but made use of the thoroughly English machinery of a trust. Behind a hedge of trustees it lived an autonomous life, unhampered by charters or statutes. There was a hall in which its members dined in common; there was the nucleus of a library; there were also dormitories or chambers in which during term-time lawyers lived celibately, leaving their wives in the country. Something of the college thus enters the constitution of these fellowships; and then something academical. The craft gild regulated apprenticeship; it would protect the public against incompetent artificers, and its own members against unfair competition. So the fellowship of lawyers. In course of time a lengthy and laborious course of education of the mediæval sort had been devised. He who had pursued it to its end received a call to the bar of his inn. This call was in effect a degree. Like the doctor or master of a university, the full-blown barrister was competent to teach others, and was expected to read lectures to students. But further, in a manner that is still very dark, these societies had succeeded in making their degrees the only steps that led to practice in the king's courts. At the end of the Middle Ages (*circ.* 1470) Sir John Fortescue rehearsed the praises of the laws of England in a book which is one of the earliest efforts of comparative politics. Contrasting England with France, he rightly connects limited monarchy, public and oral debate in the law courts, trial by jury, and the teaching of national law in schools that are thronged by wealthy and well-born youths. But nearly a century earlier, the assertion that English law affords as subtle and civilizing a discipline as any that is to be had from Roman law was made by a man no less famous than John Wyclif. The heresiarch naturally loathed the Canon law; but he also spoke with reprobation of the "paynims' law," the "heathen men's law," the study of which in the two universities was being fostered by some of the bishops. That study, after inspiring Bracton, had come to little in England, though the canonist was compelled to learn something of Justinian, and there was a small demand for learned civilians in the Court of Admiralty, and in what we might call the king's diplomatic service. No mediæval Englishman did anything considerable for Roman law. Even the canonists were content to read the books of French and Italian masters, though John Acton (*circ.* 1340) and William Lyndwood (1430) wrote meritorious glosses. The Angevin kings, by appropriating to the temporal forum the whole province of ecclesiastical patronage, had robbed the decretists of an inexhaustible source of learning and of lucre. The work that was done by the legal faculties at Oxford and Cambridge is slight when compared with the inestimable services rendered to the cause of national continuity by the schools of English law which grew within the Inns of Court.

Chancery.

A danger threatened: the danger that a prematurely osseous system of common law would be overwhelmed by summary justice and royal equity. Even when courts for all ordinary causes had been established, a reserve of residuary justice remained with the king. Whatever lawyers and even parliaments might say, it was seen to be desirable that the king in council should with little regard for form punish offenders who could break through the meshes of a tardy procedure, and should redress wrongs which corrupt and timid juries would leave unrighted. Papal edicts against heretics had made familiar to all the notion that a judge should at times proceed *summarie et de plano et sine strepitu et figura justitiæ.* And so extraordinary justice of a penal kind was done by the king's council upon misdemeanants, and extraordinary justice of a civil kind was ministered by the king's chancellor (who was the specially learned member of the council) to those who "for the love of God and in the way of charity," craved his powerful assistance. It is now well established that the chancellors started upon this course, not with any desire to introduce rules of "equity" which should supplement, or perhaps supplant, the rules of law, but for the purpose of driving the law through those accidental impediments which sometimes unfortunately beset its due course. The wrongs that the chancellor redressed were often wrongs of the simplest and most brutal kind: assaults, batteries, and forcible dispossessions. However, he was warned off this field of activity by Parliament; the danger to law, to lawyers, to trial by jury, was evident. But just when this was happening, a new field was being opened for him by the growing practice of conveying land to trustees. The English trust of land had ancient Germanic roots, and of late we have been learning how in far-off centuries our Lombard cousins were in effect giving themselves a power of testation by putting their lands in trust. In England, when the forms of action were crystallizing, this practice had not been common enough to obtain the protection of a writ; but many causes conspired to make it common in the 14th century; and so, with the general approval of lawyers and laity, the chancellors began to enforce by summary process against the trustee the duty that lay upon his conscience. In the next century it was clear that England had come by a new civil tribunal. Negatively, its competence was defined by the rule that when the common law offered a remedy, the chancellor was not to intervene. Positively, his power was conceived as that of doing what "good conscience" required, more especially in cases of "fraud, accident, or breach of confidence." His procedure was the summary, the heresy-suppressing (not the ordinary and solemn) procedure of an ecclesiastical court; but there are few signs that he borrowed any substantive rules from legist or decretist, and many proofs that within the new field of trust he pursued the ideas of the common law. It was long, however, before lawyers made a habit of reporting his decisions. He was not supposed to be tightly bound by precedent. Adaptability was of the essence of the justice that he did.

A time of strain and trial came with the Tudor kings. It was questionable whether the strong "governance" for which the weary nation yearned could work within the limits of a parliamentary system, or would be compatible with the preservation of the common law. We see new courts appropriating large fields of justice and proceeding *summarie et de plano:* the Star Chamber, the Chancery, the Courts of Requests, of Wards, of Augmentations, the Councils of the North and Wales; a little later we see the High Commission. We see also that judicial torture which Fortescue had called the road to hell. The stream of law reports became intermittent under Henry VIII.; few judges of his or his son's reign left names that are to be remembered. In an age of humanism, alphabetically arranged "abridgments" of mediæval cases were the best work of English lawyers: one comes to us from Anthony Fitzherbert (d. 1538), and another from Robert Broke (d. 1558). This was the time when Roman law swept like a flood over Germany. The modern historian of Germany will speak of "the Reception" (that is, the reception of Roman law), as no less important than the Renaissance and Reformation with which it is intimately connected. Very probably he will bestow hard words on a movement which disintegrated the nation and consolidated the tyranny of the princelings. Now a project that Roman law should be "received" in England occurred to Reginald Pole (d. 1558), a humanist, and at one time a reformer, who with good fortune might have been either king of England or pope of Rome. English law, said the future cardinal and archbishop, was barbarous; Roman law was the very voice of nature pleading for "civility" and good princely governance. Pole's words were brought to the ears of his majestic cousin, and, had the course of events been somewhat other than it was, King Henry might well have decreed a reception. The rôle of English Justinian would have perfectly suited him, and there are distinct traces of the civilian's Byzantinism in the doings of the Church of England's supreme head. The academic study of the Canon law was prohibited; regius professorships of the civil law were founded; civilians were to sit as judges in the ecclesiastical courts. A little later, the Protector Somerset was deeply interested in the establishment of a great school for civilians at Cambridge. Scottish law was the own sister of English law, and yet in Scotland we may see a reception of Roman jurisprudence which might have been more whole-hearted than it was, but for the drift of two British and Protestant kingdoms towards union. As it fell out, however, Henry could get what he wanted in church and state without any decisive supersession of English by foreign law. The omnicompetence of an Act of Parliament stands out the more clearly if it settles the succession to the throne, annuls royal marriages, forgives royal debts, defines religious creeds, attaints guilty or innocent nobles, or prospectively lends the force of statute to the king's proclamations. The courts of common law were suffered to work in obscurity, for jurors feared fines, and matter of state was reserved for council or Star Chamber. The Inns of Court were spared; their moots and readings did no perceptible harm, if little perceptible good.

The Tudor Age.

Yet it is no reception of alien jurisprudence that must be chronicled, but a marvellous resuscitation of English mediæval law. We may see it already in the Commentaries of Edward Plowden (d. 1585) who reported cases at length and lovingly. Bracton's great book was put in print, and was a key to much that had been forgotten or misunderstood. Under Parker's patronage, even the Anglo-Saxon dooms were brought to light; they seemed to tell of a Church of England that had not yet been enslaved by Rome. The new national pride that animated Elizabethan England issued in boasts touching the antiquity, humanity, enlightenment of English law. Resuming the strain of Fortescue, Sir Thomas Smith, himself a civilian, wrote concerning the Commonwealth of England a book that claimed the attention of foreigners for her law and her polity. There was dignified rebuke for the French jurist who had dared to speak lightly of Littleton. And then the common law took flesh in the person of Edward Coke (1552-1634). With an enthusiastic love of English tradition, for the sake of which many offences may be forgiven him, he ranged over nearly the whole field of law, commenting, reporting, arguing, deciding,—disorderly, pedantic, masterful, an incarnate national dogmatism tenacious of continuous life. Imbued with this new spirit, the lawyers fought the battle of the constitution against James and Charles, and historical research appeared as the guardian of national liberties. That the Stuarts united against themselves three such men as Edward Coke, John Selden, and William Prynne, is the measure of their folly and their failure. Words that, rightly or wrongly, were ascribed to Bracton rang in Charles's ears when he was sent to the scaffold. For the modern student of mediæval law many of the reported cases of the Stuart time are storehouses of valuable material, since the lawyers of the 17th century were mighty hunters after records. Prynne (d. 1669), the fanatical Puritan, published ancient documents with fervid zeal, and made possible a history of Parliament. Selden (d. 1654) was in all Europe among the very first to write legal history as it should be written. His book about tithes is to this day a model and a masterpiece. When this accomplished scholar had declared that he had laboured to make himself worthy to be called a common lawyer, it could no longer be said that the common lawyers were *indoctissimum genus doctissimorum hominum.* Even pliant judges, whose tenure of office depended on the king's will, were compelled to cite and

Coke.

discuss old precedents before they could give judgment for their master; and even at their worst moments they would not openly break with mediæval tradition, or declare in favour of that "modern police-state" which had too often become the ideal of foreign publicists trained in Byzantine law.

The current of legal doctrine was by this time so strong and voluminous that such events as the Civil War, the Restoration, and the Revolution hardly deflected the course of the stream. In retrospect, Charles II. reigns so soon as life has left his father's body, and James II. ends a lawless career by a considerate and convenient abdication. The statute book of the restored king was enriched by leaves excerpted from the Acts of a Lord Protector; and Matthew Hale (d. 1676), who was, perhaps, the last of the great record-searching judges, sketched a map of English law which Blackstone was to colour. Then a time of self-complacency came for the law, which knew itself to be the perfection of wisdom, and any proposal for drastic legislation would have worn the garb discredited by the tyranny of the Puritan Cæsar. The need for the yearly renewal of the Mutiny Act secured an annual session of Parliament. The mass of the statute law made in the 18th century is enormous; but, even when we have excluded from view such Acts as are technically called "private," the residuary matter bears a wonderfully empirical, partial, and minutely particularizing character. In this "age of reason," as we are wont to think it, the British Parliament seems rarely to rise to the dignity of a general proposition, and in our own day the legal practitioner is likely to know less about the statutes of the 18th century than he knows about the statutes of Edward I., Henry VIII., and Elizabeth. Parliament, it should be remembered, was endeavouring directly to govern the nation. There was little that resembled the permanent civil service of to-day. The choice lay between direct parliamentary government and royal "prerogative"; and lengthy statutes did much of that work of detail which would now be done by virtue of the powers that are delegated to ministers and governmental boards. Moreover, extreme and verbose particularity was required in statutes, for judges were loath to admit that the common law was capable of amendment. A vague doctrine, inherited from Coke, taught that statutes might be so unreasonable as to be null, and any political theory that seemed to derive from Hobbes would have been regarded with not unjust suspicion. But the doctrine in question never took tangible shape, and enough could be done to protect the common law by a niggardly exposition of every legislating word. It is to be remembered that some main features of English public law were attracting the admiration of enlightened Europe. When Voltaire and Montesquieu applauded, the English lawyer had cause for complacency.

Hale.

The common law was by no means stagnant. Many rules which come to the front in the 18th century are hardly to be traced farther. Especially is this the case in the province of mercantile law, where Mansfield's (d. 1793) long presidency over the King's Bench marked an epoch. It is too often forgotten that, until Elizabeth's reign, England was a thoroughly rustic kingdom, and that trade with England was mainly in the hands of foreigners. Also in mediæval fairs, the assembled merchants declared their own "law merchant," which was considered to have a supernational validity. In the reports of the common law courts it is late in the day before we read of some mercantile usages which can be traced far back in the statutes of Italian cities. Even on the basis of the excessively elaborated land law—a basis which Coke's Commentary on Littleton seemed to have settled for ever—a lofty and ingenious superstructure could be reared. One after another, delicate devices were invented for the accommodation of new wants within the law; but only by the assurance that the old law could not be frankly abolished can we be induced to admire the subtlety that was thus displayed. As to procedure, it had become a maze of evasive fictions, to which only a few learned men held the historical clue. By fiction the courts had stolen business from each other, and by fiction a few comparatively speedy forms of action were set to tasks for which they were not originally framed. Two fictitious persons, John Doe and Richard Roe, reigned supreme. On the other hand, that healthy and vigorous institution, the Commission of the Peace, with a long history behind it, was giving an important share in the administration of justice to numerous country gentlemen who were thus compelled to learn some law. A like beneficial work was being done among jurors, who, having ceased to be regarded as witnesses, had become "judges of fact." No one doubted that trial by jury was the "palladium" of English liberties, and popularity awaited those who would exalt the office of the jurors and narrowly limit the powers of the judge.

But during this age the chief addition to English jurisprudence was made by the crystallization of the chancellor's equity. In the 17th century the Chancery had a narrow escape of sharing the fate that fell on its twin sister the Star Chamber. Its younger sister the Court of Requests perished under the persistent attacks of the common lawyers. Having outlived troubles, the Chancery took to orderly habits, and administered under the name of "equity" a growing group of rules, which in fact were supplemental law. Stages in this process are marked by the chancellorships of Nottingham (1673-5) and Hardwicke (1737-56). Slowly a continuous series of Equity Reports began to flow, and still more slowly an "equity bar" began to form itself. The principal outlines of equity were drawn by men who were steeped in the common law. By way of ornament a Roman maxim might be borrowed from a French or Dutch expositor, or a phrase which smacked of that "nature-rightly" school which was dominating continental Europe; but the influence exercised by Roman law upon English equity has been the subject of gross exaggeration. Parliament and the old courts being what they were, perhaps it was only in a new court that the requisite new law could be evolved. The result was not altogether satisfactory. Freed from contact with the plain man in the jury-box, the chancellors were tempted to forget how plain and rough good law should be, and to screw up the legal standard of reasonable conduct to a height hardly attainable except by those whose purses could command the constant advice of a family solicitor. A court which started with the idea of doing summary justice for the poor became a court which did a highly refined, but tardy justice, suitable only to the rich.

Equity.

About the middle of the century William Blackstone, then a disappointed barrister, began to give lectures on English law at Oxford (1758), and soon afterwards he began to publish (1765) his *Commentaries.* Accurate enough in its history and doctrine to be an invaluable guide to professional students and a useful aid to practitioners, his book set before the unprofessional public an artistic picture of the laws of England such as had never been drawn of any similar system. No nation but the English had so eminently readable a law-book, and it must be doubtful whether any other lawyer ever did more important work than was done by the first professor of English law. Over and over again the *Commentaries* were edited, sometimes by

Blackstone

distinguished men, and it is hardly too much to say that for nearly a century the English lawyer's main ideas of the organization and articulation of the body of English law were controlled by Blackstone. This was far from all. The Tory lawyer little thought that he was giving law to colonies that were on the eve of a great and successful rebellion. Yet so it was. Out in America, where books were few and lawyers had a mighty task to perform, Blackstone's facile presentment of the law of the mother country was of inestimable value. It has been said that among American lawyers the *Commentaries* "stood for the law of England," and this at a time when the American daughter of English law was rapidly growing in stature, and was preparing herself for her destined march from the Atlantic to the Pacific Ocean. Excising only what seemed to savour of oligarchy, those who had defied King George retained with marvellous tenacity the law of their forefathers. Profound discussions of English mediæval law have been heard in American courts; admirable researches into the recesses of the Year-Books have been made in American law schools; the names of the great American judges are familar in an England which knows little indeed of foreign jurists; and the debt due for the loan of Blackstone's *Commentaries* is being fast repaid. Lectures on the common law delivered by the present Chief-Justice of Massachusetts (O. W. Holmes) may even have begun to turn the scale against the old country. No chapter in Blackstone's book nowadays seems more antiquated than that which describes the modest territorial limits of that English law which was soon to spread throughout Australia and New Zealand and to follow the dominant race in India.

Long wars, vast economic changes, and the conservatism generated by the French Revolution piled up a monstrous arrear of work for the English Legislature. Meanwhile, Jeremy Bentham (d. 1832) had laboured for the overthrow of much that Blackstone had lauded. Bentham's largest projects of destruction and reconstruction took but little effect. Profoundly convinced of the fungibility and pliability of mankind, he was but too ready to draw a code for England or Spain or Russia at the shortest notice; and, scornful as he was of the past and its historic deposit, a code drawn by Bentham would have been a sorry failure. On the other hand, as a critic and derider of the system which Blackstone had complacently expounded he did excellent service. Reform, and radical reform, was indeed sadly needed throughout a system which was encumbered by noxious rubbish, the useless leavings of the Middle Ages: trial by battle and compurgation, deodands and benefit of clergy, John Doe and Richard Roe. It is perhaps the main fault of "judge-made law" (to use Bentham's phrase) that its destructive work can never be cleanly done. Of all vitality, and therefore of all patent harmfulness, the old rule can be deprived, but the moribund husk must remain in the system doing latent mischief. English law was full of decaying husks when Bentham attacked it, and his persistent demand for reasons could not be answered. At length a general interest in "law reform" was excited; Romilly and Brougham were inspired by Bentham, and the great changes in constitutional law which cluster round the Reform Act of 1832 were accompanied by many measures which purged the private, procedural, and criminal law of much, though hardly enough, of the mediæval dross. Some credit for rousing an interest in law, in definitions of legal terms, and in schemes of codification, is due to John Austin (d. 1859) who was regarded as the jurist of the reforming and utilitarian group. But, though he was at times an acute dissector of confused thought, he was too ignorant of the English, the Roman, and every other system of law to make any considerable addition to the sum of knowledge; and when Savigny, the herald of evolution, was already in the field, the day for a "Nature-Right"—and Austin's projected "general jurisprudence" would have been a Nature-Right—was past beyond recall. The obsolescence of the map of law which Blackstone had inherited from Hale, and in which many outlines were drawn by mediæval formulas, left intelligent English lawyers without a guide, and they were willing to listen for a while to what in their insularity they thought to be the voice of cosmopolitan science. Little came of it all. The revived study of Germanic law in Germany, which was just beginning in Austin's day, seems to be showing that the scheme of Roman jurisprudence is not the scheme into which English law will run without distortion.

Bentham.

In the latter half of the 19th century some great and wise changes were made by the Legislature. Notably in 1875 the old courts were merged in a new Supreme Court of Judicature, and a concurrent administration of law and equity was introduced. Successful endeavours have been made also to reduce the bulk of old statute law, and to improve the form of Acts of Parliament; but the emergence of new forces whose nature may be suggested by some such names as "socialism" and "imperialism" has distracted the attention of the British Parliament from the commonplace law of the land, and the development of obstructive tactics has caused the issue of too many statutes whose brevity was purchased by disgraceful obscurity. By way of "partial codification" some branches of the common law (bills of exchange, sale of goods, partnership) have been skilfully stated in statutes; but a draft criminal code, upon which much expert labour was expended, lies pigeon-holed and almost forgotten. British India has been the scene of some large legislative exploits, and in America a few big experiments have been made in the way of code-making, but have given little satisfaction to the bulk of those who are competent to appreciate their results. In England there are large portions of the law which, in their present condition, no one would think of codifying: notably the law of real property, in which may still be found numerous hurtful relics of by-gone centuries. So omnipresent are statutes throughout the whole field of jurisprudence, that the opportunity of doing any great feat in the development of law can come but seldom to a modern court. More and more, therefore, the fate of English law depends on the will of Parliament, or rather of the ministry. The quality of legal text-books has steadily improved; some of them are models of clear statement and good arrangement; but no one has with any success aspired to be the Blackstone of a new age. In the matter of legal education it is to be feared that England has fallen behind America. The civil law that was taught in the two universities began to lose its interest in the 17th century. The domain which nominally belonged to its doctors, the old ecclesiastical domain, was being covered by English statutes and English precedents; the Chancery stole work from the ecclesiastical courts, and diplomatists of the modern type appropriated a field in which civilians had been active. On the other hand, the scholastic scheme which obtained in the Inns of Court quickly degenerated into a course of perfunctory exercises, and finally into a course of dinners supplemented by such instruction as a busy barrister might or might not give to his private pupils. Endeavours to remedy this state of things have been made, both by the Inns and by the Universities, but no plan of legal education that can be unreservedly commended has yet been established. Owing to the non existence of flourishing schools of law, England has hardly taken the share which should by rights have been hers in that systematic study of the history of law which was one of the main tasks of the 19th century. (F. W. M.)

English Literature (*since* 1879).—If we take up the history of English literature at the close of 1879 the first thing we notice is that the moment was one of a highly transitional character. In other words, it was remarkable not so much for what was being done as for what had lately been done, and for what was still suffusing through the country the warmth and colour of life. The aspect of literature in England when 1880 opened was brilliant; but we can see now what we could not see then, that the nature of its brilliance belonged to sunset and not to sunrise. The list of living men of letters at that moment was an extraordinarily splendid one. It ranked, in that matter, with the most shining instants that English literature has ever enjoyed. At that moment, on the 1st of January 1880, there were alive in Great Britain, Carlyle, Darwin, Tennyson, Browning, Ruskin, Matthew Arnold, Lord Beaconsfield, Stanley, Froude, Freeman, George Eliot, Huxley, Tyndall, Dante Gabriel and Christina Rossetti, Patmore, William Morris, R. L. Stevenson, Walter Pater, and Edward FitzGerald. Of men who in pure literature could at that time, or in the next decade, be for one moment named with these twenty, only four were still alive in 1902—Mr Herbert Spencer, Mr Swinburne, Mr George Meredith, Mr John Morley. Perhaps there are only two dates in English literary history—1600 and 1810—which could compete with 1880 in the magnificence of the living names producible on a bare list. But we see at once that to compare 1880 with either of the earlier dates would be to resign ourselves to a fallacy. The fact, just mentioned, of the deaths of so large a proportion of the illustrious persons would be enough to make us suspect a condition of things which a close examination of the circumstances shows to be the truth. Let it then be said at once, the concluding portion of the 19th century is remarkable, first and foremost, for the extinction of the great representative lights of that century. If we strain to the utmost our appreciation of what younger men have achieved, it is impossible to give it the importance of the passing away of the elder spirits. When we look broadly at the period we see above all else the quenching of the lights. It has been pre-eminently a period of great funerals. Death has followed death until we were tempted to believe that the stage would be left to us altogether darkened and empty. Nor, if again we look closer still, shall we find that a large proportion of the very eminent persons who adorned the opening of these later years contributed anything to the period. Most of them, or many, belonged to it merely by the accident of longevity. We must begin our history, then, by a record of these silenced voices.[1]

General survey.

The first to pass away was George Eliot (1819–1880), who had written no work of imagination for four years, and who, though probably unimpaired in power, gave signs of having finished saying what she had been born with the special gift to say. Charles Reade (1814–1884), although after his death a surprising number of unimportant volumes were extracted from his papers, had ceased for several years to be a contributor to current literature. Anthony Trollope (1815–1882), on the other hand, was in the full flow of active invention when he died, and must be considered as a living element in the very beginning of our period. But the main body of Charles Darwin's work (1809–1882) was done, although his lively and interesting monograph on *The Formation of Vegetable Mould* belongs to 1881. Beaconsfield (1804–1881) closed his long career as a novelist with *Endymion* just as our period was opening. Arthur Penrhyn Stanley (1815–1881) was writing to the last, but published nothing of more importance than the *Christian Institutions* of 1881. Of a still earlier generation, Carlyle (1795–1881), a portent of mysterious celebrity, in the melancholy isolation and decay of extreme old age, had long ceased to take the least part in the movement of letters. He survived, unseen, unheard, scarcely putting pen to paper during the last ten years of his existence. Nor though Newman (1801–1890) lived on so late, has he much more claim to count as an active factor in the literature of this period. One or two trifles, privately printed, alone reminded the circle of his disciples that he was thinking of them in his cell at Edgbaston. The literary life of Dante Gabriel Rossetti (1828–1882) had closed with the publication of his *Ballads and Sonnets*. Edward FitzGerald (1809–1883) had never been active; he had long been entirely indolent before his death. Of the greatest names, therefore, which we began by enumerating as the principal glory of 1880, we have already eliminated half as having no part whatever in the production of the subsequent years.

The presence and activity of Tennyson, Browning, Ruskin, Froude, and Mr Herbert Spencer, with the authority of certain writers a little younger than these, in particular Matthew Arnold, Huxley, Tyndall, and Mr George Meredith, formed a feature of literary life in the 'eighties which cannot be overlooked. It constituted, indeed, the principal fact of that particular decade. English literature was held, to a very remarkable, perhaps to an unprecedented, degree under the sway of a group of very old men of genius, who showed no tendency to disappear. These very old men were supported by those who were but slightly their juniors, and who might be expected to survive them and take their place. As a matter of fact, Tennyson, whose figure was the most dignified and most imposing of all, survived several of them, and continued intellectually active to the very last. The result of this governance by the aged was very curious. In some degree it may be held to have checked the productive enthusiasm of the newest men. Certainly the young writers occasionally groaned under what they took to be a gerontocracy, a tyranny by the aged. They—or some of them at least—were in a great hurry to come to the throne, neglectful of the fact that but one monarch is accustomed to hold it at a time. It may well be that a youthful poet could not hope, from 1880 to 1890, to publish a volume of verse which should interest even his friends so much as a new volume by Tennyson or Browning. But if this was a disadvantage to him, it is not certain that it was a disadvantage to the literary profession. It is a matter of immense importance in the practice of a living literature to have certain dignified figureheads to point to. It was a useful, because a steadying and sobering, thing to have even the silent Carlyle and Newman to look up to—great accepted masters of the art of writing, who had passed out of the dust of battle and become half-divine, who were recognized as giant figures challenged no longer. It was a far more inspiring and stimulating thing to have Browning, Ruskin, and Tennyson there, equally lifted out of mere vain discussion, and yet still actively engaged in composition. It gave just such a dignity to the mere art and tradition of authorship as is missing when no great

[1] In the present article it has been thought well to confine the attention of the reader strictly to the movement of English literature during the years 1879–1902, the article ENGLISH LITERATURE in the 9th edition of the *Ency. Brit.* having been published in 1879. In order, however, to cover the gap between the earlier and the later periods, reference should be made to the various biographies of prominent deceased authors, which will be found either in the 9th edition of the *Ency. Brit.*, as in the cases of Dickens, Macaulay, Thackeray, Kingsley, D. G. Rossetti, and many others, or in the course of the present Supplement, as in the cases of Newman, Tennyson, Carlyle, Browning, George Eliot, and Ruskin.

and unchallengeable reputation is before the public of a country. During the decade 1880–1890 the number and dignity of these figureheads was greater, perhaps, than it had ever been before; it was so great that it is with them—with the astonishing group of veterans—that the honours of the period lie. It was salutary that it should be so. Every one who loves the literature of his country will say with Jean Paul, "Gott, segne die Menschen mit grossen Menschen."

Poetry. In the history of the poetry of the period the earliest event which served as a landmark in the passage of time was the death of Dante Gabriel Rossetti (1828–1882). This was in itself of little importance, as the health of the poet had long been in a condition which could only point to the total obscuration of his genius. But the passing of Rossetti was the earliest public intimation of the fact that the so-called pre-Raphaelite school of English poetry, which had occupied so large a share of public attention for fifteen years, had now reached its height, and had even begun to decline. This school had been combative and full of audacity; it had shaken the coteries, and had made the recognized masters question the bases of their own authority. It had presented, pre-eminently, the aspect of militant youth, and thus the general public continued to regard it. After the death of the brilliant Rossetti, in physical and mental decay, it was impossible quite to regard it so any longer, and, indeed, as will presently be seen more in detail, its work as a school was over. But on this withdrawal of the rich pre-Raphaelite influences there followed a phenomenon of rare historical interest. This was the revival, the fresh outburst of sustained energy, of the two most celebrated poets of an earlier generation. In 1879 Tennyson (1809–1892) was in his seventy-first year; Browning three years younger. Each of these illustrious men had been before the public for half a century, had overcome misconception and detraction, had accustomed an ever-widening public to their mannerisms, and might well have been expected to withdraw into a dignified enjoyment of their fame. But this neither was content to do. In the face of advanced years, in the face of successive generations of more youthful rivals, they competed with the youngest and bore away, like the octogenarian Sophocles, prize after prize. Through the 'seventies Tennyson had mainly devoted his attention, since the completion of the *Idylls of the King*, to drama. Few were prepared, therefore, for the volume of *Ballads* in 1880 that enriched English poetry by such masterpieces as "Rizpah," "The Revenge," and "The Voyage of Maeldune." These may have been earlier in time of composition, but the same can hardly have been the case with the *Tiresias* volume of 1885, which contained "To Virgil" and "Frater ave atque vale." All doubt about the amazing and sustained fecundity of Tennyson's genius was set at rest by his publishing in the very next year a fresh volume of miscellanies, *Locksley Hall Sixty Years after.* At the age of eighty (1889) he put forth *Demeter*, a volume of narratives and lyrics in which there was, at last, a certain decline of energy, but in which such pieces as "Parnassus" and "Crossing the Bar" showed the old poet in the quintessence of his talent. Even this was not the latest of his appearances, for *The Foresters* appeared in the year of his death (1892) and *The Death of Œnone* a few weeks later than that event.

Robert Browning (1812–1889) showed a similar persistence, if it was, as must be confessed, combined with less charm. His works were extended by the publication of five considerable collections of short poems, from the second series of *Dramatic Idylls* (1880) to *Asolando*, published on the very day of his death. The intellectual element was stronger than the poetical in the bulk of these productions, which we may now look back upon as interesting and characteristic, but in the main not beautiful. To the essential work of Browning which posterity will read and value, these volumes (with the exception of *Asolando* in certain pages) added little, and in this respect he compared unfavourably with Tennyson, who preserved to the very last the key to the mystery of beauty. But the moral effect of Browning's punctual activity was not less marked than that of Tennyson. If what the former published was too hard and crabbed for unabated admiration, it showed no lessening of intellectual power. The giant was there, and still lusty and voluble. All through the decade 1879–1889, in spite of the heaped-up years, the interest of readers continued to centre in Tennyson and Browning.

At the death of Tennyson, Mr Algernon Charles Swinburne (*b.* 1837) was left without a rival as the principal living poet of England. He had originally been identified with the pre-Raphaelites, but he had long severed himself from them. He was moving on, upon his own planetary course, without any reference to any of his contemporaries. No poet has been less affected, since his early youth, by the example of other writers or by the presumable taste of the public. In isolation he has repeated his effects and dwelt upon such chords of life and literature as personally attracted him. His earliest publications in our period were *Mary Stuart* (1881), in which he completed his Scots trilogy, and *Tristram of Lyonesse* (1882), a short romantic epic, followed by a collection of lyrics. These are volumes so typical that if the other works of Mr Swinburne were unhappily to be lost they could almost be reconstructed on the pattern of these. Since that time eight or nine volumes of verse have testified to Mr Swinburne's untiring persistency; he will doubtless become, he is perhaps already, one of the most prolific of all the English poets. It is a matter of history that the position of Mr Swinburne greatly altered during the last twenty years of the century. In 1880 he was the most eminent of the younger writers, and seemed to the public more youthful still on account of his ebullience and literary courage. He carried high the flag of revolutionary ardour, although careful observers might even in 1880 have noted that it was no longer driven by so fierce a wind of feeling as it had been in 1870. Since then Mr Swinburne has not changed so much as his public has. New aspects of art and politics and conduct have attracted the minds of Englishmen, and Mr Swinburne, in his unflinching and unbending attitude, has been left more and more solitary. He no longer leads the army of impatient youth, but in a dignified isolation, never stooping for a moment to win the ear of a capricious public, he states the old formulas and insists upon the old ideals, a figure universally respected, but without a perceptible following.

The death of D. G. Rossetti, in 1882, has already been mentioned. The two authors who were particularly identified with him at the outset survived much longer, but did not add very largely to their poetical assets. During the last twenty years of the life of William Morris (1834–1896) he was mainly occupied with the socialist propaganda and with the practice of the decorative arts. The latest of his great poems, *Sigurd the Volsung*, does not come under our cognizance here, and in our period almost his only serious contributions to verse were contained in the collection of *Poems by the Way* (1891). But the abundance of Morris's fancy was bound to find some outlet, and he invented or adapted from the late mediæval romances a form of prose-poem, a wild and solemn narrative, out of place, out of time, which he cultivated without a rival or an imitator. The first of these was the *Tale of the House of the Wolfings* (1891), and the eighth and last, *The Water* *of the Wondrous Isles* (1897), was posthumous. Archaistic in language, closely parallel in mode of evolution to the old French romances, extremely artificial in their elaborate artlessness, these curious books form a little province of recent literature all by themselves. Christina G. Rossetti (1830–1894) never quitted the recognized methods of lyrical writing, and she continued to write and to publish until near the time of her death. Yet she also, as a poet, mainly belongs to the period prior to 1880. Her blossoming-time as a writer of secular verse had closed by 1875, and what is most remarkable and most beautiful in her later religious poetry (*Time Flies*, 1885; *Verses*, 1893) is mainly a variation on themes which she had invented in her earlier volumes. Her *Goblin Market*, nearly twenty years old when our period commenced, continued to contain the most perfect revelation of her genius. An interesting feature of the history of this time was the revival of the fame of Coventry Patmore (1823–1896). Exceedingly popular in his youth, Patmore had fallen into desuetude and ridicule, and his finest work, his irregular *Odes*, had passed almost entirely unnoticed. About 1880, however, a new generation rediscovered Patmore, not as the too domestic idyllist of *The Angel in the House*, but as the austere and mystic singer of *The Unknown Eros.* During the last sixteen years of his life he wrote no more verse, but he steadily increased in fame, and died leaving a little school of ardent disciples. A greater than any we have mentioned, except the two *dioscuri* themselves, was Matthew Arnold (1822–1888), whose career came abruptly to a close at the very moment when he seemed about to cross, in the fulness of health and energy, the threshold of a dignified old age. It was Arnold who, it was hoped and supposed, would step into the places ultimately left by Tennyson, Browning, and Ruskin, and would be the central ornament of the living world of thought for another generation. Had this been the case the advantage to literature from so dignified a figure-head might have proved inestimable. In point of fact, he died before all these his elders, even before the still more aged Newman. His additions to poetry, moreover, since 1879 had been extremely slight, and we meet with him again farther on. The most venerable of the British poets of this time, Mr Aubrey de Vere (1814–1902), survived all whom we have mentioned, and did not cease to publish poems until 1890. With him the latest of the pure Wordsworthians passed away.

The name of the "Parnassian School" has been given to a group of poets who belonged to the generation succeeding that of the Rossettis and William Morris, and who were more in sympathy, perhaps, with Arnold. In this title, which has no other recommendation, there seems to be a reference to the French poets who were the contemporaries of these particular writers, and who made their first appearance together in the *Parnasse Contemporain.* The poets of this group had not the ample flight of their predecessors, and attempted smaller effects. They were united, with all their individual distinctions, in a common effort after great technical precision and perfection of form. Whether in the lighter or the graver mood, they aimed at exactitude of verbal expression, the careful record of shades of emotion, delicate phenomena, avoidance of hackneyed or rhetorical phrases. In their different ways these poets were artists in miniature, and relied on the freshness and sharpness of their touch. Such writers rarely attain to a great prominence in the history of literature, for they never move the masses. But if they live, they live by the sincerity of their workmanship, and at certain epochs the meticulous production of such artists in verse is salutary for language as well as for literature. The group of later Victorian poets of which mention is here made possessed considerable influence between 1880 and 1890, but since then none of them have been so active in verse-writing.

The death of Tennyson (October 1892) was followed by a positive "crisis" in poetry. The field seemed almost empty, and it was freely predicted that it would remain uncultivated. Like most prophecies, this was not fulfilled. Within a few months of Tennyson's ceremonious public funeral a whole army of new poets made their appearance, and were greeted, in some cases, with extravagant approval. One or two writers who had struggled in vain to win attention to their poetry suddenly found it widely welcomed. The years from 1893 to 1895 saw the arrival of a surprising number of candidates for the laurel. Of these newest poets, two or three of whom possess unquestionable touches of genius, it may be said collectively that they aimed rather at suggesting an effect than at toilsomely producing it. In other words, the excessive attention to form, to technical perfection, which had been carried so far by the Parnassians, failed to please, and broader modes of expression were aimed at. Into this entered what has been called the "Celtic" spirit, by which music rather than painting, the ear rather than the eye, is appealed to. Here again, as so often in recent English poetical history, some distant analogy with French fashions was to be perceived, and several of the youngest and most promising British poets might be welcomed as brothers by the Symbolists across the Channel. Yet another movement, in extreme opposition to this, has been the Imperialist or Nationalist school of poetry, of which the fountain and origin has certainly been the much-discussed and disputed talent of Mr Rudyard Kipling (*b.* 1865), whose influence as a force in recent English literature the most adverse criticism could not dream of denying. This kind of poetry, about which it is not unfair to say that—for better or for worse—it abandons the slopes of Parnassus for the hustings and the music-hall, has attracted to its practice several writers of talent and a host that have no talent at all. On the whole, although poetry is still cultivated in England, the opening of the 20th century could not be said to find it in a very wholesome condition, and in its best forms it seems to be as remote as ever from the sympathies of the public.

The novel.

To turn from the consideration of the poetry of our period to that of its prose fiction is to enter upon a field of observation at once complicated and bewildering. In later Victorian poetry, despite its record of losses and of broken activities, we can at least trace certain definite movements, which, whatever their direction, have a share in the general development of literary art. Certain traditions are common to the craft; a thread of continuity combines the scattered groups. But the record of the novel during this period is tangled, confused, amorphous. So many interests other than those of pure literature have interfered in its development that it is difficult to trace any definite progress at all. At first sight the field presents the appearance of an overgrown, neglected garden,—not, indeed, devoid of flowers of beauty and rarity,—but so crowded with weeds and undergrowth that the paths and beds can scarcely be distinguished. The history of the novel since 1879 presents, however, one feature in common with that of poetry: its early record is one of depopulation. The leading figures of Victorian fiction do not, it is true, enter upon our period at all. Thackeray (1811–1863) had been dead seventeen years, and Dickens (1812–1870) ten, before our survey commences. Other losses of paramount importance to the novel followed during the 'seventies; Lytton's career closed in 1873, and the notes of gaiety and chivalry lost much of their resonance with the silencing of Lever (1806–1872) and of Kingsley (1819–1875). Then again, at the threshold of our inquiry, George Eliot (1819–1880) ceases to exercise her strenuously intellectual influence; and her death is followed in quick succession by those of Lord Beaconsfield (1881), Anthony Trollope (1882), and Charles Reade (1884). Thus many various and widely diverse schools of fiction were deprived of their legitimate leaders. The philosophical study of character, the political and social satire, the kindly but critical portraiture of British domesticity, and the intrepid crusade against current abuses—all those forms of fiction were suddenly left without a pilot. At such a crisis we might reasonably expect to find some paralysis, some sudden arrest of production. But this was far from being the case. The fecundity of fiction immediately increased with the magnitude of its losses, and from 1879 to 1901, when fewer novels of the highest order were published than during any equal period of the Victorian era, the positive number of novels issued was steadily advancing. Figures, we are often told, will prove any case; but in the present instance they are perhaps less fallacious than usual, since they rest upon the very accurate statistics of a central and authoritative bureau. In 1879, then, there were published 4294 new books in every class of literature, of which 607 only were works of fiction. Ten years later the number of new books was 4694 (no very great increase), but of this number no fewer than 1040 were novels. The proportion of fiction had therefore risen in ten years from less than one-seventh to very nearly one-fourth of the entire "literary output." By 1899 this proportion was actually increased. In that year 5971 new books were printed, and of these 1825 were novels. These figures take account only of first editions; but nowadays, when many novels are reprinted twenty or thirty times, it is hardly possible to overlook the claims of the reprint, especially as an indication of the kind of literature that the public welcomes most eagerly. If, then, we include the new editions in the statistics for 1899, we find that out of 7567 works issued from the press no fewer than 2561 were works of fiction, designed either for the old or young reader. The proportion has now become one-third, and the story-book is found to be riding roughshod over the entire field of literature.

When we proceed to examine this vast productivity rather more closely we are at once struck by one conspicuous characteristic. The recent history of the novel has no continuity; its succession is without method or development. It is true that the tendency of literature can only be observed with difficulty within the narrow limits of two decades; still, even within that period it ought to be possible to trace some significance in a phase of activity represented by considerably over 20,000 separate works. The curious analyst, however, will only be baffled if he seeks for a guiding thread running through the prose fiction that lies between the death of George Eliot and the opening of the 20th century. Not only is there no animating spirit in its production, but it is even shaken by every false wind of transient and passionate caprice. Fashion follows fashion without reason or excuse, for the gusts of taste and distaste that convulse the modern novel have scarcely any relation even to the passing fashions that affect society; they are manufactured for the moment in the offices of commercialism, and pass at once into exhaustion. We are thus confronted with the really regrettable fact that this form of representative and pictorial literature, which of all others ought to preserve the characteristics of the time, and hand on the natural lineaments of contemporary people to the remembrance of their children, has largely ceased to represent or depict anything of importance in British national life and character. Observation and consistency, its saving graces, are no longer preserved in any just proportion to the multiplicity of its energies. The novel of commerce has neither morality nor tendency: in the sifting fire of criticism it falls into ashes.

If we seek to find reasons for this, we can perhaps trace them in two principal defects of modern workmanship, the one subjective, the other affecting the author from without. The subjective defect is due to the extraordinary audacity with which the modern novelist plunges into the exercise of his craft. The great works of fiction had hitherto been produced by graduates in the university of life: men who had experienced and felt the various and poignant emotions of sorrow and aspiration; empirical judges fortified with culture. But nowadays a young man has no sooner concluded a desultory education, broken by every siren-charm of the river and cricket-field, than he is ready to attack the problems of life in the pages of a novel. Easy young spirits, with no leisure to look life in the face, scribbling against time in an atmosphere of sheltered ignorance,—what can these amateurs know of life or of their fellow-men? The result of their home-keeping energy is unfortunately harmful both to themselves and their "public"; for while the writer labours for his thirty or forty years in depicting conditions that never existed, the reader carries away from his yearly volumes an equally false ideal of life that clouds his own perception, and leaves him, at threescore years and ten, with the judgment of a child. Meanwhile from without there is the commercial temptation offered to young men of promise more lavishly every year. The man of business "sees money," as his phrase runs, in some imaginary aspect or problem; the book is suggested and commissioned: the warped and false philosophy maintained. Perhaps it is not so much to be wondered at that, under conditions so perilous to talent, so many bad novels should be produced, as that there should still be found men content to perfect themselves in their art by experience and observation, and to work upon the lines laid down for them by those unfailing allies, instead of succumbing to the easy persuasions of the market-place.

It will be interesting to look more closely at some of these fashions which have passed over the troubled field of fiction before we consider the small body of those who have risen above them. The most attractive, perhaps, is the romantic, adventurous story, clean-handed and clean-witted. In our own time there has been one master of this form of fiction, a master, too, of exquisite English, who, taking what was by descent the "boy's" story of Mayne Reid (1818–1883), moulded it to the noble uses of literature,—the fresh, humane, buoyant, humorous Robert Louis Stevenson (1850–1894). Few things should have been more helpful to literature than the fact that Stevenson chose this peculiarly popular form of novel for the exercise of his delightful genius; but unfortunately the full significance of his example has been but little felt. He has had one or two conscientious followers, and others have diverged from his wake into waters of a different but still pleasant romance; the majority, however, have missed his lessons of selection, elaboration, and style. In a spirit of more tremendously boyish vigour, roughly eloquent in a whirl of volcanic invention, Mr Rider Haggard (*b.* 1856) has dreamed dreams of inaccessible mountains, and lakes of molten gold. But too much of the purely popular romance of a later hour has lost the fervour of fancy altogether, and has wasted itself in purposeless pastiches and vague attempts to reconstruct Dumas for the use of the nursery-schoolroom. Invention, the quality most strained after by the mass of later English novelists, seems to be that most conspicuously lacking to them. It is not that realism, or more accurately naturalism, has found a congenial home in England; the English temperament will probably never be ready to accept a frankly naturalistic consideration of life,—it is certainly not ready yet. But there was, in the early 'nineties, a feverish attempt made, moribund at its birth, to combine the movement for Women's Rights with certain eternal but insoluble problems of sex. The attempt was made by women, and appealed chiefly to women. It produced much newspaper rhetoric, but no literature. Side by side with this movement, but unaffected by it, certain novelists have laboured with conscientious energy, but some lack of grace and persuasiveness, to establish, in the teeth of prejudice, a school of realism in British fiction; while in the very latest years of the 19th century one or two romance-writers succeeded in recovering the old flush and pulse of genuine imaginative invention, on semi-realistic lines.

The difficulty, however, of representing to the English novelist the true limits of realism and purpose in fiction is nowhere more apparent than in the strange, sensational, pseudo-religious form of fiction that has sprung up from a confusion of the methods of the two elements. These shapeless and gaudy productions, addressed often to the name of great causes and exquisite ideals, mar, by their entire lack of sensibility and reasonableness, the very loyalties which they profess, and render criticism of themselves impossible by their own violence. Their immense vogue only shows that there is still a vast English-speaking public untouched by appreciation of the literary spirit. No doubt, when over a thousand novels have to be produced every year to supply the demand of the circulating libraries, the difficulty of finding new subjects is responsible for many of these divagations. The same difficulty is probably the cause of the spread of the parochial novel, and more particularly of the Scottish parochial novel. Every corner of the United Kingdom has been ransacked in search of what the journalist calls "local colour," and Scottish village-life seems to have offered the most acceptable result. There was nothing new in this class of novel, which was originated by Sir Walter Scott, and worked out on the modern plan by Galt and Miss Ferrier, and which in the hands of Mr George MacDonald (*b.* 1824) was the delight of readers in the 'seventies. But it is a notable example of lack of judgment on the part of the public that while this Scottish movement produced at once some of the most exquisite and some of the most worthless literature of the decade 1890–1900, both classes, good and bad, were equally acclaimed, and blindly devoured. The public seemed to perceive no difference between the work of Stevenson or his delicate successor Mr J. M. Barrie (*b.* 1860) and the crudest vegetation of the kail-yard. Nor has the criticism of the press always helped the public to discernment.

Finally, among these shifting movements, we come to what is the most characteristic of the time, the literature of colonial imperialism, inspired by the extension of the British Empire, and its assumption of new interests and complexions. Here, at any rate, we have a movement which bears a definite relation to the history of the time. In the forefront of this moving army stands the figure of Mr Rudyard Kipling (*b.* 1865), whose literary appearance in England, in 1890, was so novel, so vigorous, so overwhelming in its sense of individuality and young life, as to raise him at once to a position in the public gaze brilliant enough almost to discountenance criticism. In India he had already published *Departmental Ditties* (1886) in verse, and the still more remarkable prose stories collected in 1887–89 under the general title of *Plain Tales from the Hills.* The reception of these Indian studies, so dazzling in their novelty, and that of the somewhat perverse romance, *The Light that Failed* (1890), led on to a still more brilliant success in the volume of poems which took its name from the *Barrack-Room Ballads* (1891). The youthful Anglo-Indian swept everything before him; no such world-wide notoriety had, perhaps, ever been obtained by an author so rapidly or so early in life. Since then Mr Kipling's work, from the *Many Inventions* of 1893 and *The Jungle Book* of 1894, down to the *Kim* of 1901, has been poured forth with great profusion, but has caused less critical amazement. It has naturally fallen into perspective, and taken its place in the general scheme. The picturesqueness of a new landscape, the persuasiveness of a new manner, have lost their first bewildering glitter, and criticism has not failed to note that these qualities are sometimes achieved at the cost of literary tone and moral distinction. He has had imitators, who have found some of his most effective tricks easy enough to catch. Still, among the new-comers Mr Kipling fills incomparably the most conspicuous place, and his influence upon the taste and thought of the mass of his countrymen is unparalleled among that of active men of letters at the opening of the 20th century.

In this brief survey we have considered many developments of the novel, but found in them little stability. But there are a few—unfortunately a very few—names that are found in none of these muster-rolls; for they are those of men who have been consistently faithful to an ideal of outlook and workmanship unaffected by passing fashions of taste. At the head of this little body of stalwarts stands Mr George Meredith (*b.* 1828), whose work was the unquestioned glory of English fiction during the last forty years of Queen Victoria's reign. Mr Meredith preserved the traditions of English fiction untarnished during one of its most prolific and most perilous periods. The preservation of the moral idea in fiction,—an idea standing as a backbone to the work, and itself sustained by the interaction of the characters displayed,—the preservation of this essential tradition is largely due to his loyal and unswerving devotion to the canons of literature. During the last years of the 19th century the abundance of his direct imitators among young men of ambition was curiously noticeable. With Mr Meredith is Mr Thomas Hardy (*b.* 1840), the master of modern English realism, in his stories of pastoral life in "Wessex." A third great figure was R. L. Stevenson, pure romanticist of an even purer style, the lineal descendant of Scott, touched with modernity and moved by more picturesque exotic interests than Scott ever knew. These three writers stand alone, towering above their fellows. In the prose fiction of the period there seems no fourth novelist quite on the same level. But Mr Joseph Henry Shorthouse (*b.* 1834) preserved the philosophical romance from extinction. Mrs Humphry Ward (*b.* 1851) sustained the tradition of George Eliot's later manner, and lent sincere intellectuality to the statement of hard and harassing problems of contemporary thought. Among earlier novelists Sir Walter Besant (1836–1901) and James Payn (1830–1899) worthily continued the humorous and humane tradition of Dickens. The moral and didactic side of fiction was supported by Charlotte Yonge (1823–1901). Wilkie Collins (1824–1889), Richard Doddridge Blackmore (1825–1900), and Margaret Oliphant (1828–1897) were eminent in their different fields. These have all passed away, but among their successors there are to be found, no doubt, a multiplicity of talent and many encouraging signs of the general vivacity of fiction. Yet it is not in the ranks of the triumphantly popular novel that these are found, and before recording the conquests of the few in this peculiarly deciduous class of contemporary literature the wise will probably prefer to wait and to see what the winnowing years will leave of genuine wheat in the mass of redundant vegetation.

To follow the achievement of a given period of modern history in pure criticism is rendered difficult by the prejudice which, in the minds of the vulgar, reduces this fine branch of literature to its basest expression, namely, to mere fault-finding, to the "picking of holes" in a particular product. Yet in the proper sense, criticism is not engaged with doling out blame or even praise, but with analysis, with the exact determination of the constituent parts of a work and their relation to one another. Applied to the past, it melts easily on one side into the history and on the other into the philosophy of literature or art. In recording, therefore, what was done well between 1879 and 1902, it will be found that there are many important factors which seem to have little connexion with one another, but which are so excellent as to deserve no less attention than is given to creative literature, being indeed at their best of the imaginative order, and that these have at last to be brought together under the general heading of criticism. Since 1880, although working against great difficulties, the leading English critics have shown, in their extreme and unfortunate diversity, one common tendency which is new. Their criticism, wherever and however directed, has tended to be subjective to a degree never acknowledged before. The two most famous English critics of the time were John Ruskin (1819–1900) and Matthew Arnold (1822–1888), alike in scarcely anything else than in their rejection of the objective vacuum. Each of them boldly essayed to recount, as M. Anatole France has put it, the adventures of a soul journeying among masterpieces. Neither of these great men belongs entirely or mainly to our period. But from 1880 to 1887 Ruskin was extremely active, and his work was remarkably characteristic of his genius. A sort of wild exuberance possessed him, and whether he wrote of the water-colour drawings of Turner and Prout, of the architecture of the Gothic cathedrals of Northern France, of English prosody, or of the principles of St George's Guild, his tone grew more and more unshackled, more and more violently personal. He measured his impressions less and less by tradition, even the tradition of his own earlier experience, and more and more by the eye and the mood of the moment. So that in *Fors Clavigera*, which did not cease to appear until 1884, we had at last one of the most stimulating, but at the same time one of the most reckless, contributions to autobiographical criticism which the world has ever seen. Immensely admired and closely studied by young people, although condemned to the last for his anarchical judgments by the organs of traditional opinion, the example of Ruskin in his fetterless old age was very widely felt. His tacit advice to every one was—Use your own eyes and ears; say how the object impresses you at such a moment, under such a light, in such a mood; and let the professors go hang. Ruskin never said this, of course, but this was the obvious effect of his system, and we have seen the result in much that is fresh and curious, as well as in much that is callow and pert.

Criticism.

Wholly distinct was the influence of Matthew Arnold. It is first to be remarked that although a younger man, he quitted the field of positive criticism sooner than Ruskin did. His *Irish Essays* of 1882 and his *Isaiah of Jerusalem* of 1883 indicated the direction which the mind of Matthew Arnold was taking at the end of his life. These, indeed, were criticisms of a sort, but not of that direct kind which influences literary workmanship. This latter had once been Arnold's peculiar province and glory; but neither his *Essays in Criticism*, nor *On Translating Homer*, nor *The Study of Celtic Literature* belongs to our period. These famous little books, indeed, were all published in the 'sixties. Arnold in his later years was drawn away from pure literature to speculations of a political, religious, and educational nature; into the treatment of these he brought his lucid temper and his elevated moral tone, but in such exercises he ceased to be a critic. The posthumous and valuable *Second Series of Essays in Criticism* is the only work of its class which mainly, though not entirely, belongs to dates subsequent to 1880, and as lately as 1886 Arnold was writing on Sainte Beuve. But the indifference of the English public to pure literature depressed and checked him more and more in the production of the kind of work in prose in which he was best fitted to stimulate and lead. The potency, however, of his early writings continued, and was never more an active force than between 1880 and 1890. During those years, it may be said that almost everything in the way of criticism which was really excellently done in English literature bore at least a faint relation to Arnold. Perhaps there was less than usual of Arnold and more of Ruskin, though surely most of all of the critic himself, in the criticism of Walter Pater (1839–1894)—so laborious, solid, and rich. His *Appreciations* (1889), his *Plato and Platonism* (1893), and two or three posthumous collections, have been read more and more widely since his death,—up to which time he was scarcely appreciated outside a narrow circle,—and have exercised an unquestionable force in contemporary writing. A critic of much acuteness and humour, prevented only, perhaps, by lack of concentrated effort from achieving the highest things, was Henry Duff Traill (1842–1900). Enthusiasm, wide knowledge, and a poetic habit of mind were combined with some laxity of judgment in the copious and illuminating, but not sufficiently concise, criticism of John Addington Symonds (1840–1893). Among veteran leaders of literary criticism in the elder generation in 1902 were Mr Leslie Stephen (*b.* 1832) and Mr Frederic Harrison (*b.* 1831). There has in general been no lack of acute, graceful, and personal criticism, but its influence has been weakened, and it has often been put out of sight altogether by the floods of what is called "reviewing" which darken the daily and weekly press, the incessant gabble of nobodies about the little books of other nobodies as ill-trained in judgment as themselves.

In history the work done has been solid and considerable, and it has had the advantage of moving on a more consistent plane than has been the case in other branches of literature. It is impossible to say that any particular school of poetry or fiction or criticism flourished pre-eminently in the period from 1880 onwards, but of an Oxford school of historians it is permissible to speak. These men were the direct successors and inheritors of the historians who, in the opening quarter of the 19th century, had determined that their first duty was to build the history of the country "upon unquestionable muniments." Of the leaders of this brilliant school, the eldest was James Anthony Froude (1818–1894), who was much exercised with the legacy of Carlyle's memoirs in the earlier part of our period, but who returned to his old investigations in his *Divorce of Catharine of Aragon* (1891), and his *Erasmus* (1894). He outlived his lifelong rival and opposite, Edward A. Freeman (1823–1892), whom, by a curious irony, Froude succeeded for a few months as regius professor at Oxford. Freeman was, on the whole, the most characteristically active historian of these years; during the first twelve of them he was ceaselessly at labour, and at his death he left a body of disciples engaged on important and prominent research according to his particular methods. Freeman's *William Rufus* belongs to 1882; his *History of Sicily* (1892–94) was unfinished at his death. During the interval he was incessantly working, and for eight years he was Professor at Oxford. Dr William Stubbs (1825–1901) had completed his *Constitutional History* before our period begins, and his later energies principally went out in the direction of diocesan work; in 1884 he was appointed bishop of Chester, and in 1889 translated to Oxford. His subsequent historical work was principally confined to the editing of one or two texts. The fourth of these great

History.

historians, Dr Samuel Rawson Gardiner (1829–1902), was engaged during the whole period with his patient delineation of the Commonwealth and the Protectorate. Two historians who derived their inspiration from the example of Stubbs and Freeman were John Richard Green (1837–1883) and Mandell Creighton (1843–1901), the former as much distinguished for the agreeable vivacity of his style as the latter for the austerity of his irreproachable search for truth. A historian who stood apart from the Oxford school was Sir John Robert Seeley (1834–1895), whose work on *The Expansion of England* (1883), and whose posthumously printed lectures on *The Growth of British Policy* (1895), had a very deep influence in inducing the development of imperialistic ideas in intelligent minds.

The essay.

The influences of the time have been very unfavourable to the essay as a branch of independent literature. This was, however, the field in which Robert Louis Stevenson (1850–1894) excelled before he was led away by the temptations of success to an almost exclusive cultivation of prose romance. The essay—from which criticism of books is here distinguished—tends more and more to disappear in journalism. It is very doubtful whether the successes of Sir Arthur Helps (1813–1875) or even of George Augustus Sala (1828–1895) could have been repeated in this generation. Perhaps the last of the specific essayists, who treated speculative themes in a dignified and yet popular manner, was Richard Holt Hutton (1826–1897), whose life, however, was almost entirely devoted to the best class of journalism. Several of the most distinguished critics of literature of the period, however, have divagated, in the composition of essays, to the criticism of life as well. The better kind of monthly reviews and magazines were open at the beginning of our epoch to the essay on abstract subjects, but the tendency of the monthly press has been to assimilate itself more and more with the newspaper. The brilliant writers of the present day, who might in other conditions have been essayists, give to the "leaders" of the daily journal what might have been matured and purified and made part of a book.

Biography.

A curious feature of English literary history during the last twenty years of the 19th century was the growth of the custom of biography. Almost entirely confined to England, this habit has struck Continental critics with amazement. During these years, and with an ever-increasing inevitability, few persons of any notoriety have died without the event being immediately followed by the publication of a "Life," very often—no matter how dull a correspondent the deceased had been—of a "Life and Letters." These books, in the vast majority entirely ephemeral, often enjoyed a momentary success of curiosity equalled only by that of the fashionable novel. Their "best stories" were quoted, and then they took their place with the lumber of the library. In no branch of literature was less skill shown, or the standard of merit kept so low, as it was in biography, and the best that can be said of most of these lives is that, where the subject happened to be one of any real note, the volumes remain as a storehouse of material available for the future critic. Several well-balanced and skilfully-built biographies were, in the period under discussion, produced by authors who had proved their distinction in other fields, but no biographer, pure and simple, was revealed to the world, and, as a rule, the last thing thought of in the preparation of these works was professional skill or a practised sense of proportion. In most cases, some one who had no experience of composition and no training in the art of portraiture was selected, merely because he (or she) was related to the subject of the book. In no branch of recent English literature is there less to boast of than in the conduct of biography.

Theology.

In theology the period has been remarkable for the extinction of a great many lives long surrounded by peace and respect, but around which in earlier years there raged the roar of battle. The High Church lost its intellectual protagonist in Edward Bouverie Pusey (1800–1882), and later luminaries in Bishop Joseph Barber Lightfoot (1828–1889), Dean R. W. Church (1815–1890), Canon Liddon (1829–1890), and Brooke Foss Westcott (1825–1901). The Church of Rome lost Newman (1801–1890) and Manning (1808–1892). The Broad Church had to mourn Mark Pattison (1813–1884) and Benjamin Jowett (1817–1893). Archbishop Edward White Benson (1829–1896) was one of the few English prelates who preserved an interest in general literature. The deaths of these venerable men changed the entire aspect of theology as a branch of current letters. As much in this province as in that of poetry, England was in 1880 under the rule of a body of old men who have passed away, removing with them the tradition of an eager and brilliant time of ardour and contest, but of those who took a prominent part in the Tractarian movement of 1835–1845, most of whom were still living in 1880, in 1902 not one was left. There has, however, been the beginning of a new treatment of certain old problems, auspiciously represented by *Lux Mundi* (1890), a collection of studies edited by Dr Charles Gore (*b.* 1853), now bishop of Worcester.

Modern tendencies.

The history of literature is, and always has been, diversified by inequalities of activity and merit. If a meteorological map of the subject could be devised it would be found to present, not straight lines, but great curves or undulations. It is difficult not to be persuaded that in 1880 English literature was near the height of one of its periodic waves, although perhaps the actual culmination should be placed a little farther back than that year. To pursue the image, the line was still high all through the 'eighties, although steadily descending. It has, if we can trust our observation, continued to descend, and whether there are as yet any signs of its recovery may be very gravely doubted. That pure literature of a very distinguished kind was, at the close of the 19th century, produced or encouraged to any signal degree—in comparison with the production and encouragement of it a quarter of a century earlier—is not to be maintained. But this is a very different thing from despairing of literature, from thinking that it is, as the phrase goes, "played out." At no time is the best kind of writing really welcome to the great mass of the population. It is kept alive by a minority; it appeals, in truth, to a small minority. But this minority is energetic, and at irregular periods its energy takes the form of forcing literature on the indifference of the public, of winning for it perforce an unwelcome warmth of consideration. The presence of men of genius—men, that is, of exceptional vitality, whose force of life is led along literary lines—greatly adds to this artificial predominance of letters, although that presence is not necessary to it, as the analogies of 1580 and 1790 may show us. But we are apt to forget how artificial it always is, how exaggerated—to put it plainly—are the fame and prominence of men of letters in comparison with the real part they bear in the experience of the millions. It would therefore be, perhaps, more true to say that 1875 was an exceptionally high-water mark of literary effort than to say that 1901 was a particularly low one. The latter was rather a return to the normal condition, an unbending of the bow, a relaxation of intellectual energy. We do not question for a moment that it will be followed, as every such period has been in history, by a fresh outbreak of effort, a fresh artificial insistence upon a kind of vitality interesting to, and indeed conceivable by, only a few persons. The authority of literature is mainly empirical, so far as the great world is concerned. The vast body of "men in the street" is not more capable of comprehending the difference between good writing and bad than it is of observing the difference between good painting or sculpture and bad. What is worse is that the cruder forms of education tend to encourage false judgment in these matters, so that bad books and bad pictures are deliberately preferred to good ones. This condition continues to extend, and to become more frequent and more threatening as the democracy becomes more and more confident. The absence of a recognized authority adds to the difficulty, and this is why, from time to time, the value of an Academy of Letters is maintained, in spite of its obvious defects and dangers. In the early months of 1902 several schemes of this nature were brought forward, with more definite purpose than ever before. It is now possible that an Academy, or better still, an Institute, embracing a cluster of academies, may yet be founded in England. That such institutions may be of very great value as a bulwark against the invasions of bad taste is not to be doubted, but we can hardly hope that a body with anything like the prestige of the French Academy will be seen in Great Britain, at least in our time. The great chance of such a foundation was lost when Charles II. hesitated in 1662. He created the Royal Society instead, and few would be found to deny that British science has benefited. But a Royal Society, founded now, would find it difficult to assert its authority; to be useful, such corporations must be venerable and must hand on a tradition. In the meantime, although the millions do not distinguish between a good book and a bad one, and although their tendency is to like the bad one best, there remains a distinction between good writing and bad. Experts disagree in detail about almost every contemporary product, but hitherto, and on large lines, they have agreed to a remarkable degree about what has been before the world for fifty years. As far as we can distinguish, no very worthless book—however successful in its own day—continues to collect suffrages half a century after its publication. It seems scarcely less certain that no remarkably fine book—however obscure when it was published—misses the meed of fame at last. If these conditions are to be repeated in the future, and there is every reason to suppose that they will, the winnowing of the wheat will remove even the remarkably abundant and flowering tares which are almost all that some despairing critics can see in the cornfield of to-day.

At the same time, it is not improbable that we may be on the edge of a much wider and more radical curve than any of those which have marked the course of English literature for one hundred years. Movements become exhausted, like men and races of men. It is unusual for one order of literary activity to last more than a century. After the course of a hundred years the varieties of expression are apt to become exhausted, the forms grow hard, all the obvious motives tend to express themselves no longer as thoughts but as clichés. The Romantic movement, in its different aspects, has entertained Europe for a century and more with little radical alteration. Between the various great poets of the Victorian age, for instance, no such difference is found as distinguished Herrick from Pope, or Goldsmith from Shelley. The distinctions have been matters of temperament, of execution, and of personal style. Wordsworth and Mr Swinburne, Byron and Browning, differ only as great poets must differ among themselves, as Ben Jonson, for example, does from Marlowe, or Corneille from Racine. Each and all belong to the modern English Romantic school, as it was founded in 1798. It is quite possible—one may go further and say it is not improbable—that the reduction of energy in literary creation of the first order, which we cannot prevent ourselves from recognizing as a feature of to-day, will be followed by a still more marked exhaustion and fatigue before the whole Romantic movement, having had its century, is swept away to make room for some wholly different mode of literary expression.

The years which followed 1880 were marked by a revival of the classical writers of English, and a persistency of investigation into their biography and text, which form a remarkable and creditable feature of the literary life of the time. Never before were the famous authors of past times, and of the second as well as of the first class, placed before readers with so exact a scholarship and in a form so attractive. The wide sale which these reprints have had should be taken into consideration as an important element in the culture of the time. In point of fact, while the abundance, beauty, and cheapness of reprints have added a very real disadvantage to the young author, who finds Milton and Fielding become his formidable rivals, yet at the same time, and from the point of view of the general education of taste, it cannot but be regarded as a very satisfactory thing that opportunities of studying what is best in the national literature should have been thus multiplied. To descend to particulars, the work of English scholars on Chaucer belongs, in its public results, almost wholly to this period. It culminated in the great edition of that poet by Professor Skeat (1896–97), in which for the first time Chaucer is presented to his own people in a really intelligent and intelligible form. In Shakespearean study, too, there has been an extraordinary revival of scholarship, conducted with discretion and good sense by Dr Aldis Wright, Mr Sidney Lee, Dr Furnivall, and many others. The work of editing the texts of the great Elizabethan poets has proceeded so actively that for the moment there seems little of importance left to do in this province, and for a few shillings each the reader might collect around him in 1901 the works of poets which hundreds of pounds would hardly have placed within his reach in 1880. The great *Dictionary of National Biography* (1882–1901) has been completed in time to be recorded here as a finished thing, and among the principal monuments raised to English scholarship in the period under consideration we can hardly hesitate to name this admirable dictionary. So much, indeed, has been achieved in historical and biographical work of this class, so exhaustively have the documents been examined, and so closely the existing records collated, that it is difficult to see what remains for future investigation to occupy itself upon. In elucidating the study of the early Scottish poets, of the Elizabethans, of Pope, of the writers of the centre of the 18th century, and finally, of the great poets of the beginning of the 19th century, so much has been done since 1880 that the main fields must, one is tempted to think, be permanently despoiled of their harvests. All this zeal for the writers of the past serves, no doubt, to counteract the frivolity and bad taste of uninstructed readers. The authority of the great dead is unimpeached, and every year it widens and deepens the bases on which it is built. It is of little moment what errors are popularly made as to the value of this or that contemporary author, if we all grow more and more sure of the degree and species of merit possessed by Dryden or Gibbon or Wordsworth. Sooner or later the products so wildly misjudged in contemporary popular esteem will have to be measured by this standard, and will inevitably take their right place in the harmony of literary history. It cannot be denied, however, that a great deal of talent and cleverness, and even weightier qualities, are wasted or are allowed to miss their fullest expression from neglect of the principles of literary art. Writing is pursued too rapidly, too perfunctorily, with too little previous study and present care. There is a want of unity of purpose in the literary products of the age which cannot but be deplored. When an author thinks that his chief business is to bow to the vague prejudice of crowds, the cause of pure literature is in a parlous state. It is not the large "returns," the reverberating and unprecedented "sales," which proclaim the author whose happiness it will be to live in the history of his country's literature. Good and careful writing is at this moment little approved of, and the conquering masses march gaily over it and leave it bleeding; but the true lover of letters and adept in style will disregard the gods of mere material success,—he will remember that *Victrix causa diis placuit, sed victa Catoni.* It is for the highest criticism to insist on playing the rôle of Cato.

A final reflection may be permitted. Through the history of English literature its vitality and health have been marked, in a manner curiously recurrent, by a curiosity to know what is being done in foreign literatures, and by a vigorous use of what can be adapted from them. In 1880 the reciprocity between England and the Continent in this matter was very close. There was a living curiosity to know what was being done by Russia in the novel, by Scandinavia in the drama, by France in criticism. This interest in foreign literature has steadily declined. The reasons may be perfectly intelligible; it remains that this is precisely one of the signs of a decline in native literary vitality which has never hitherto failed to be recognizable afterwards in history. (E. G.)

[As a supplement to the above survey, some others among the best-known writers of the period may be mentioned, excluding those to whom separate articles are devoted.

Poetry: Rev. H. C. Beeching (*b.* 1859. *In a Garden, &c.*, 1895). A. C. Benson (*b.* 1862. *Poems*, 1893). Wilfrid Scawen Blunt (*b.* 1840. *Love Sonnets of Proteus*, 1880). F. W. Bourdillon (*b.* 1852. *A Lost God*, 1891). Robert Bridges (*b.* 1844. *Shorter Poems*, 1890). W. J. Courthope (*b.* 1842. *The Paradise of Birds*, 1870). John Davidson (*b.* 1857. *Fleet Street Eclogues*, 1893, 1895). "Michael Field" (*The Tragic Mary*, 1885). Edmund Gosse (*b.* 1849. *Collected Poems*, 1896. In prose: *History of Modern English Literature*, 1897; *Gossip in a Library*, 1891; *Life of Donne*, 1899). A. P. Graves (*b.* 1846. *Songs of Killarney*, 1872). W. E. Henley (*b.* 1849. *Book of Verses*, 1888. In prose: *Views and Reviews*, 1890). Lionel Johnson (*b.* 1867. *Poems*, 1895. In prose: *The Art of Thomas Hardy*, 1894). Andrew Lang (*b.* 1844. *Ballads in Blue China*, 1880. In prose: *Custom and Myth*, 1884). Richard le Gallienne (*b.* 1866. *English Poems*, 1892. In prose: *George Meredith*, 1890; *Prose Fancies*, 1894, 1896). Sir Alfred C. Lyall (*b.* 1835. *Verses written in India*, 1889. In prose: *Asiatic Studies*, 1882). J. W. Mackail (*b.* 1859. Part author of *Love in Idleness*, 1883. In prose: *Life of William Morris*, 1899). Alice Meynell (*née* Thompson, 1850. *Preludes*, 1875; *Poems*, 1893. In prose: *The Rhythm of Life*, 1893). Henry Newbolt (*b.* 1862. *Admirals All*, 1897). Stephen Phillips (*b.* 1868. *Poems*, 1897). A. Mary F. Robinson (Madame Duclaux, previously Madame Darmesteter, *b.* 1857. *Collected Poems*, 1902. In prose: *The End of the Middle Ages*, 1888). Owen Seaman (*b.* 1861. *In Cap and Bells*, 1899). Arthur Symons (*b.* 1865. *Collected Poems*, 1901. In prose: *Studies in Two Literatures*, 1897). Francis Thompson (*b.* 1863. *Poems*, 1893). John Todhunter (*b.* 1839. *The Banshee*, 1888). William Watson (*b.* 1858. *Wordsworth's Grave*, 1890). Theodore Watts-Dunton (*b.* 1836. *The Coming of Love*, 1897. In prose: *Aylwin*, 1898). Margaret L. Woods (*née* Bradley, 1856. *Lyrics and Ballads*, 1889. In prose: *A Village Tragedy*, 1887). W. B. Yeats (*b.* 1865. *Poems*, 1895). "Violet Fane" (Lady Currie).

Prose Fiction: Grant Allen (*b.* 1848, *d.* 1899. *The Woman Who Did*, 1895. Also a popular writer on scientific subjects). "F. Anstey" (T. Anstey Guthrie, *b.* 1856. *Vice Versâ*, 1882). Rev. S. Baring-Gould (*b.* 1834. *Mehalah*, 1880) Rev. W. F. Barry (*b.* 1849. *The New Antigone*, 1887). E. F. Benson (*b.* 1867. *Dodo*, 1893). Miss Rhoda Broughton (*b.* 1840. *Belinda*, 1883). F. T. Bullen (*b.* 1857. *The Cruise of the Cachalot*, 1898). F. C. Burnand (*b.* 1836. *Happy Thoughts*, 1866). Mrs F. Hodgson Burnett (*b.* 1849. *Little Lord Fauntleroy*, 1886). Samuel Butler (*b.* 1835. *Erewhon*, 1872). T. H. Hall Caine (*b.* 1853. *The Christian*, 1897). Miss Marie Corelli (*A Romance of Two Worlds*, 1886). S. R. Crockett (*b.* 1860. *The Raiders*, 1894). A. Conan Doyle (*b.* 1859. *Adventures of Sherlock Holmes*, 1891). "George Egerton" (Mrs Clairmonte. *Keynotes*, 1893). Harold Frederic (*b.* 1856, *d.* 1898. *Illumination*, 1896). George Gissing (*b.* 1857. *Demos*, 1886). Sarah Grand (*The Heavenly Twins*, 1893). Anthony Hope Hawkins (*b.* 1863. *The Prisoner of Zenda*, 1894). Maurice H. Hewlett (*b.* 1861. *The Forest Lovers*, 1898). "John Oliver Hobbes" (Mrs Craigie, *b.* 1867. *Some Emotions and a Moral*, 1891). Jerome K. Jerome (*b.* 1859. *Idle Thoughts of an Idle Fellow*, 1889). "Vernon Lee" (Miss Violet Paget, *b.* 1859. *Baldwin*, 1886). "Edna Lyall" (Miss A. E. Bayly. *Donovan*, 1882). "Ian Maclaren" (Rev. J. Watson, *b.* 1850. *Beside the Bonnie Brier Bush*, 1894). "Lucas Malet" (Mrs Harrison. *The Wages of Sin*, 1891). W. H. Mallock (*b.* 1849. *The New Republic*, 1877. In sociology: *Aristocracy and Evolution*, 1898). H. Seton Merriman (*The Sowers*, 1896). George Moore (*Esther Waters*, 1894). Arthur Morrison (*b.* 1863. *Tales of Mean Streets*, 1894). W. E. Norris (*b.* 1846. *The Rogue*, 1888). Barry Pain (*b.* 1867. *Playthings and Parodies*, 1892). Gilbert Parker (*b.* 1862. *The Seats of the Mighty*, 1896). A. T. Quiller-Couch (*b.* 1863. *Dead Man's Rock*, 1887). W. Pett Ridge (*Mord Em'ly*, 1898). Mrs Richmond Thackeray Ritchie (*Miss Angel*, 1875). W. Clark Russell (*b.* 1844. *The Frozen Pirate*, 1877). "Mark Rutherford" (W. Hale White. *The Autobiography of Mark Rutherford*, 1885). Mrs F. A. Steel (*b.* 1847. *On the Face of the Waters*, 1896). G. R. Sims (*b.* 1847. *Rogues and Vagabonds*, 1885. Also *The Dagonet Ballads*). G. S. Street (*b.* 1867. *Autobiography of a Boy*, 1894). Frederick Wedmore (*b.* 1844. *Renunciations*, 1895). H. G. Wells (*b.* 1866. *The Time Machine*, 1895). Stanley J. Weyman (*b.* 1855. *Under the Red Robe*, 1894). Richard Whiteing (*b.* 1840. *No. 5, John Street*, 1899). "John Strange Winter" (Mrs Stannard, *b.* 1856. *Bootles' Baby*, 1874). Israel Zangwill (*b.* 1864. *Children of the Ghetto*, 1892). Others are: David Christie Murray (*b.* 1847), Silas Hocking (*b.* 1850), C. F. Keary, Robert Barr (*b.* 1850), R. H. Hichens (*b.* 1864), Egerton Castle (*b.* 1858), Frankfort Moore (*b.* 1855), Eden Philpotts (*b.* 1862), Percy White (*b.* 1852), J. A. Steuart (*b.* 1861), Morley Roberts (*b.* 1857), E. W. Hornung (*b.* 1866), Benjamin Swift (*b.* 1871), A. E. W. Mason (*b.* 1865), J. M. Cobban (*b.* 1849), Hamilton Aidé, Max Pemberton (*b.* 1863), G. A. Henty (*b.* 1832), G. Manville Fenn (*b.* 1831), Herman Merivale (*b.* 1839), H. B. Marriott Watson (*b.* 1863), Frank Harris (*b.* 1856), Henry Harland (*b.* 1861), W. W. Jacobs (*b.* 1865), Mrs B. M. Croker, Mrs Campbell-Praed, Mrs Alexander, Mrs Riddell, Mrs L. B. Walford, Mrs Hungerford, Mrs. E. Fuller-Maitland, Miss Betham-Edwards, M. E. Francis, E. Thorneycroft Fowler, Mary Cholmondeley, Beatrice Harraden, "Fiona Macleod," Emily Lawless, Jane Barlow, Adeline Sergeant, Helen Mathers.

History, Criticism, &c.: Evelyn Abbott (*b.* 1843, *d.* 1901. *History of Greece*). Canon Alfred Ainger (*b.* 1837. Editor of Lamb's Works). William Archer (*b.* 1856. *The Theatrical World*, 1893–1897). E. S. Beesly (*b.* 1831. *Queen Elizabeth*, 1892). Augustine Birrell (*b.* 1850. *Obiter Dicta*, 1884). J. E. C. Bodley (*b.* 1853. *France*, 1898). A. K. H. Boyd (*b.* 1825, *d.* 1897. *Recreations of a Country Parson*, 1859–61). J. Franck Bright (*b.* 1832. *History of England*). Rev. Stopford Brooke (*b.* 1832. *History of Early English Literature*, 1892. Also *Poems*, 1888). James Bryce (*b.* 1838. *The American Commonwealth*, 1888). J. B. Bury (*b.* 1861. *Later Roman Empire*, 1889). G. Birkbeck Hill (*b.* 1835. *Boswell's Johnson*, 1886). Oscar Browning (*b.* 1837. *Guelphs and Ghibellines*, 1894). Edward Caird (*b.* 1853. *The Evolution of Religion*, 1893). Rev. Professor Lewis Campbell (*b.* 1830. *Sophocles in English Verse*, 1883; *Religion in Greek Literature*, 1898). J. Churton Collins (*b.* 1848. *Ephemera Critica*, 1901). Sidney Colvin (*b.* 1845. *Life of Keats*, 1887). Sir Martin Conway (*b.* 1856. *The Alps from End to End*, 1895). W. L. Courtney (*b.* 1850. *Studies, New and Old*, 1888). Sir Henry Craik (*b.* 1846. *Life of Swift*, 1882). Lord Curzon of Kedleston (*b.* 1859. *Problems of the Far East*, 1894). Edward Dicey (*b.* 1832. *England and Egypt*, 1884). Edward Dowden (*b.* 1843. *Life of Shelley*, 1886). Rev. Dr Fairbairn (*b.* 1838. *Studies in the Philosophy of Religion*, 1896). C. H. Firth (*b.* 1857. *Oliver Cromwell*, 1900). J. G. Frazer (*b.* 1854. *The Golden Bough*, 1890). Richard Garnett (*b.* 1835. *Essays of an Ex-Librarian*, 1901. Also *Poems*, 1893). Frederick Greenwood (*b.* 1830. Publicist). Thomas Hodgkin (*b.* 1831. *Italy and her Invaders*, 1880–99). Sir Richard Jebb (*b.* 1841. *Sophocles*, 7 vols., 1883–96). Rev. Augustus Jessopp (*b.* 1824. *The Coming of the Friars*, 1885). W. P. Ker (*b.* 1855. *Epic and Romance*, 1897). Benjamin Kidd (*b.* 1858. *Social Evolution*, 1894). Professor W. A. Knight (*b.* 1836. *The Philosophy of the Beautiful*, 1891, 1893). W. S. Lilly (*b.* 1840. *On Shibboleths*, 1892). F. W. Maitland (*b.* 1850. *English Law and the Renaissance*, 1901). Rev. W. Robertson Nicoll (*b.* 1851. *Literary Anecdotes of the Nineteenth Century*, 1895). Henry Norman (*b.* 1858. *The Real Japan*, 1892). C. W. C. Oman (*b.* 1860. *The Art of War*, 1898). H. F. Pelham (*b.* 1846. *Roman History*, 1890). Sir Frederick Pollock, Bart. (*b.* 1845. *Principles of Contract*, 1876; *Spinoza*, 1880). G. W. Prothero (*b.* 1848. *Simon de Montfort*, 1877). Walter Raleigh (*b.* 1861. *Style*, 1897). Sir Wemyss Reid (*b.* 1842. *Life of W. E. Forster*, 1888). George E. B. Saintsbury (*b.* 1845. *A History of Criticism*, vol. i., 1900). G. W. Steevens (*b.* 1869, *d.* 1900. *With Kitchener to Khartum*, 1898). Sir Spencer Walpole (*b.* 1839. *History of England*, 1878–80).]

ENGRAVING.

Etching.

IN the article on Engraving in the 9th edition of this work Mr Hamerton devoted some paragraphs to that branch of engraving which is known as Etching; and the present writer was enabled to supplement those paragraphs by a later article on Méryon. In the interval much has passed—much remains to be said. To the greatest and almost the oldest living practitioner of etching a separate article is devoted (see WHISTLER): the writer's business in this place will chiefly be to discuss those etchers most or all of whose work has been accomplished since Mr Hamerton wrote; but opportunity shall first be taken to make good several omissions in Mr Hamerton's necessarily brief reference to comparatively recent etchers who may yet claim to be classics. The etchings of Andrew Geddes (1783–1844) and of Sir David Wilkie (1785–1841) somehow escaped him. Of these two men, Geddes was the finer artist with the needle; he it was whom Rembrandt best inspired; his work was in the grand manner. Of the rich and rare dry-points "At Peckham Rye" and "At Halliford-on-Thames," the deepest and most brilliant master of Landscape would have no need to be ashamed. David Wilkie's prints were, naturally, not less dramatic than his pictures, but the etcher's particular gift was possessed by him more intermittently: it is shown best in "The Receipt," a strong and vivid, dexterous sketch, quite full of character. Cotman's (1782–1842) etchings might have been mentioned, though they were "soft ground" for the most part. They show all his qualities of elegance and freedom as a draughtsman, and much of his large dignity in the distribution of light and shade. Turner too, who etched in outline the subjects for the *Liber Studiorum*, might have been mentioned as one who, while not seeking to rely upon etching for the completion of his effect, was yet singularly great in that selection of leading lines to which, as far as etching is concerned, he made it his business to confine himself. And Girtin (1775–1802), in the preparations for his views of Paris, was scarcely less happy.

Mr Hamerton had no space to devote to his own illustrious contemporaries, or he would have been amply eulogistic in his reference to Sir Seymour Haden (*b.* 1818), one of the most varied, prolific, and delightful of the etchers of Landscape. Between 1858 and 1879 Seymour Haden—the first president of the Royal Society of Painter Etchers—produced the vast majority of his plates, which have always good draughtsmanship, unity of effect, and a personal impression. They show a strong feeling for Nature. If, amongst nearly two hundred subjects, it were necessary to select one or two for peculiar praise, they might probably have to be the "Breaking up of the *Agamemnon*," the almost perfect "Water Meadow," the masterly presentment of "Erith Marshes," and the later dry-point of "Windmill Hill." Alphonse Legros—Frenchman by birth, but Englishman by long residence—has been etching admirably, at various periods, since 1860. Great in expression and suggestive draughtsmanship, austere and economical in line, Legros's work (see LEGROS) is the grave record of the observation and the fancy of an imaginative mind. In poetic Portraiture, nothing can well exceed his etched vision of G. F. Watts; "La Mort du Vagabond" is noticeable for terror and homely pathos; "Communion dans l'Église St Médard" is perhaps the best instance of the dignity, vigour, and grave sympathy with which he addresses himself to ecclesiastical themes. Something of these latter qualities, in dealing with similar themes, Legros has passed on to his pupil, Charles Holroyd (*b.* 1861)—an etcher in the true vein; whilst an earlier pupil, prolific as himself, as imaginative, and sometimes more deliberately uncouth—William Strang (*b.* 1859)—carries on in his own way the tradition of that part of Legros's practice, the preoccupation with the humble, for which Legros himself found certain warrant in a portion of the great *œuvre* of Rembrandt. Frank Short, who, as with the very touch of Turner, has carried to completion great designs that Turner left unfinished, and who has translated into perfect mezzotint something that is most characteristic in De Wint and in Constable, has found in the interpretation of other men's visions an obstacle to the encouragement of fertility in his own. Time—not skill—has been wanting to him; for the delicacy of "Sleeping till the Flood," the curiously suggestive realism of "Wrought Nails"—a scene in the Black Country—entitle him to a lasting place in the list of the fine wielders of the etching needle. Oliver Hall, a good free sketcher, bringing into his prints a quite unusual sense of wind and tree movement, has learnt something from Seymour Haden and is yet thoroughly himself. D. Y. Cameron betrays the influence of Rembrandt in a noble etching, "Border Towers," and the influence of Méryon in the firm elaboration—the finality, one may say—and the weirdness besides, of such a print as that of "The Palace, Stirling." His London Set is to be cherished even more. The individuality of C. J. Watson is less marked, but his skill, chiefly in architectural work, is noticeable. Admirers of the studiously accurate portraiture of a great monument may be able to set Watson's print of "St. Étienne du Mont" by the side of Méryon's august and mysterious and ever memorable vision; but to the lover of high imaginative art such a juxtaposition is impossible.

Minna Bolingbroke and Elizabeth Armstrong (Mrs Watson and Mrs Stanhope Forbes) have done observant, dexterous work, on quite a high level. A painter of the popularity and charm of Alfred East has several times trifled happily with the copper. Robert Macbeth has set down upon it sometimes his first thoughts and sometimes his elaborate interpretation of his own and other men's pictures. Walter Sickert is an artist of graceful and vivid impromptus. Robert Goff, in more than a hundred coppers, has shown the readiest perception of an attractive and a suitable theme, and has carried the work far enough to suggest the impression, and never so far as to confuse it. Mortimer Menpes, in his Japanese etchings, has found almost an individual touch, and has been alert in the dainty suggestion of artificial as well as of natural light and shade. Whistler has influenced Percy Thomas, and yet more notably an artist who has etched much less, but who has etched convincingly—Raven Hill. Herkomer is at his best in "Gwenydd." J. P. Heseltine and Holmes May carry on the best traditions of the amateur—the amateur who, had circumstances allowed it, might have been a considerable artist. Roussel, an artist of refined performance in many a medium, has devoted much time to the perfection of his decorative methods of printing plates in several colours. The coloured etchings of Raffaëlli must be mentioned with these, and Menpes, named already, claims here a fresh place. Little known, but full of an observation that is his own, and thoroughly characteristic, are the exercises in black and white, upon the copper, of that audacious and yet subtle colourist, Besnard. Another Frenchman, J. J. Tissot, before he turned to sacred subjects, was in Etching an adept at the effective presentation of mundane themes; and he it was who first led to thoughts of etching that genius of a sketcher, Paul Helleu, whose "snapshots at the grace of women" are among the freshest, truest, and most delightful things that the art of etching has witnessed in its later history. Helleu's dry-points—frank sketches, with elegance as their motive—are very numerous, but as the artist does not tolerate the slightest deterioration, and as dry-point deteriorates almost at once, the impressions of each are almost inconceivably few. If any further remark requires absolutely to be made about contemporary Etching, it is one to this effect—that the tendency, manifested about 1875, to use the medium very greatly for interpretation and reproduction of painted work, has now already long been on the wane; and it is probable that while the medium may still, and always, do some useful work in that direction, it will continue to be resorted to mainly as a convenient and delightful vehicle for the swift yet well-considered record of personal feeling and thought about the aspects of the world. (F. WE.)

Mezzotint.

During the 19th century two veritable revolutions occurred in the British art of Mezzotinto Engraving—"la Manière Anglaise." The original defect of the method was the incapacity of the mezzotint "burr" on copper to yield as many fine impressions as other forms of engraving. To this defect was attributable the introduction in 1823 of steel instead of the soft copper plates previously used, —a change which, in conjunction with the endeavour to avoid inherent technical difficulties, led to the "mixed style," or combination of mezzotint with etching, and a general departure from the traditional form of the art, "pure mezzotint" on copper. The affinity of the method to painting in black and white which differentiates it from other kinds of engraving, and was the distinguishing charm of the mezzotints of the 17th and 18th centuries, was for a time lost, but a revival of pure mezzotint on copper beginning in 1880—a return, in fact, to the mode in which the classics of the art were engraved in the time of Sir Joshua Reynolds—was made possible by the invention of steel-facing. By this process engraved copper plates are electroplated with a film of steel, renewable when worn in course of printing; and a mezzotint on copper, so protected, yields more of fine impressions than if it had been engraved on steel, whilst the painter-like quality remains unimpaired.

Method of work. In "pure mezzotint" the design is evolved from dark to light entirely by scraping away more or less of the previously laid "ground," the original "burr" of which is left untouched in the extreme darks, and no acid, etching, or line-work is used in it at all. The usual short descriptions of the method are misleading, because they fail to explain that it is the "ground," and not the "burr" of it only, which is scraped away in greater or smaller degree to produce the varying tones of the design. The necessity of realizing that there are two constituents of the "ground," the "burr," and the indentations out of which the "burr" is raised, will be appreciated later. The "burr" consists of innumerable particles of copper (resembling velvet pile in the finished "ground") raised above the surface of the plate out of the indentations made in it by the teeth of the rocking-tool in laying the ground before scraping the design.

Assuming that a mezzotint is to be scraped from a lady's portrait by Sir Joshua Reynolds in which a piece of black drapery crosses a white dress—the engraver begins to work on a previously laid "ground" which would print uniformly black before scraping commences. In the extreme darks of the black drapery the raised "burr" is left untouched by the "scraper,"—a two-edged steel instrument resembling an ancient Roman sword-blade in miniature, but having a longer point. Working from dark to light, the engraver produces the varying tones of the folds of the black drapery by scraping the raised "burr" down more or less, lowering it in fact so that it will not hold so much ink as where it is left untouched in the extreme darks. In the highest lights of the black drapery all the raised "burr" will have been removed and the original surface of the plate reached, but as yet the engraver has not produced any tone lighter than middle tint (although he has completely modelled up the black drapery), because the indentations out of which the "burr" was raised still remain in the plate and hold ink in printing. In order to produce the infinite gradation of delicate tones in the white dress, or in a sky, the scraping is continued, the indentations being thus made shallower in the passages scraped and therefore less capable of holding ink, whilst they are obliterated almost entirely in the highest lights. When the mezzotint is finished, the black drapery will stand higher than the surface of the plate modelled in a relief composed of the raised "burr," whilst all the tones of the white dress from middle tint to pure white will be so many actual depressions in the plate, the highest lights being the deepest. The speck of light in the eye, for instance, is a pit in the plate, surrounded by a tract of more or less raised "burr," which provides the intense black of the pupil and the half tints of the iris. The difference of surface levels is very appreciable where high-lights impinge on strong darks, but it exists in varying degree all over the plate, and the greatest technical difficulty in pure mezzotint is to obtain adequate "edge" and definition, because the tendency is to remove too much "ground" from the edges of adjacent darks in the course of the constant scrapings necessary to smooth and polish the depressed lights.

In printing a mezzotint a non-fluid ink is thoroughly worked into every part of the plate and the superfluities wiped off again, leaving as much ink as possible in the darks, the raised "burr." If the bottom of the small lights is not quite smooth, the ink sticks in the roughness and they print dark instead of light, or the printer has to wipe so hard to get the ink out of the depressed lights that he removes too much from the raised darks. In either case loss of definition and contrast of effect results. This inherent difficulty of scraping to a sharp edge caused the use of the "mixed" methods, in which the details were sharpened by outlining them with stipple or line-etching.

The scarcity of fine impressions of the pure mezzotints on copper of Sir Joshua's time was due to the "burr" which provides the extreme darks being raised above the surface of the plate, and thus exposed to all the wear and tear of printing processes, unlike the darks of an etching or line-engraving, which are protected by being sunk in the plate. The evanescence of the "burr" on copper led to the use of steel plates, and the temporary decay of the art.

Mezzotint is the best form of engraving for completeness of representation, but etching is better adapted for sketching from nature or for the expression of any fleeting idea. The two arts have distinct uses and limitations. The art function of true etching as practised by Rembrandt lies in economy of expressive line to suggest the artist's meaning, and that of mezzotint in completion of tonality to explain it. Artistic suggestion, which is not inherent in the solid tones of mezzotint, has to be imparted to the work entirely by the free play of the "scraper" on the "ground," much as the painter attains it on canvas with the brush. The best painter cannot, however, acquire the same facility with the "scraper" that he may possess in the use of the brush until he has had long practice in scraping and in "laying" grounds, even in texture, suitable to the subject to be engraved, and therefore offering the least possible resistance to his own idiosyncracies of execution with the "scraper."

History. The first reputed mezzotint was produced at Amsterdam in 1643 by Ludwig von Siegen, an officer in the service of the Landgrave of Hesse, and an amateur artist; but the work was rather a direct drawing on copper with an instrument of comparative precision resembling the roulette than a mezzotint, ground-laid with the rocking-tool and scraped from dark to light in the present manner of the art. Siegen's innovation was led up to by the previous stipple work of Giulio Campagnola and Janus Lutma; the roulette appears to have been used before his time; and though he shared in the evolution of the rocking-tool, he was not the sole inventor of it. The earliest works referable to the method at the Print Room of the British Museum afford evidence, though inconclusive, that Prince Rupert, to whom Siegen showed his mode of work in 1654, and possibly also their common friend Th. Caspar von Fürstenberger, and Rupert's assistant, Vallerant Vaillant, were more or less concerned in the gradual development of mezzotint engraving. The rocking-tool was apparently improved by Abraham Blooteling, a Dutch painter and engraver of fine portrait mezzotints, who worked in Holland and in England about the year 1680.

Rupert brought the new art over to England at the Restoration, and the portrait of Charles II., dated 1669, by William Sherwin, the first English mezzotinter, bears the engraver's acknowledgment of his indebtedness to Rupert for the secrets of the method. Mezzotint continued to be practised for a while on the Continent, but the successors of Sherwin in England so excelled in it that it early acquired abroad the title of "la manière anglaise," and has since become an exclusively British art. Though used for transcribing the subject-pictures of the great Italian masters, and of Rembrandt, Vandyck, and Rubens, almost every kind of subject being later engraved in it, the staple production in mezzotint has always been the portrait. Until the middle of the 18th century the tools continued somewhat archaic, causing in the prints an appearance of warp and woof, like that of ill-woven material, which detracted from reality of representation. The coarseness and unequal depth of the "grounds" offered so much resistance to freedom of execution with the "scraper" that, though the early engravers were quite as good artists as their successors, painter-like touch was not conspicuous in the work until M'Ardell and the interpreters of Sir Joshua Reynolds had improved the tools and technique.

Except for the collector, therefore, the chief attraction in the prints of F. Place and Luttrell, Beckett and Williams, and later those of John Simon, John Smith, and John Faber, jun., who were the principal exponents of mezzotint in the last years of the seventeenth and first half of the eighteenth centuries, lies in their long series of portraits after Vandyck, Lely, Kneller, and the Dutch painters then practising in England, representing such interesting personages as Charles II. and Nell Gwynn, Addison and Pope, Congreve and Wycherley, Locke, and the great Duke of Marlborough.

The classics of mezzotint engraving are to be found amongst the best plates after Sir Joshua Reynolds by James M'Ardell, J. R. Smith and Valentine Green, the Watsons, Dickinson, Fisher, Dixon, and some others, who worked during the last half of the 18th century. The brush-work of Reynolds was more in harmony with the mezzotint method than the slighter painting technique of Gainsborough and Romney, who were much less frequently engraved, perhaps because it is the highest technical difficulty in mezzotint to render the sharp edges of a sketch. For this reason a typical Gainsborough was never successfully engraved in the method. Though professional publishers and printers existed at this time and earlier, the word "excudit" on an old print implying "published," not "engraved," the authors of the "Sir Joshua" mezzotints in most cases printed, published, and sold their own works, and pure mezzotint, unmixed with etching, was almost exclusively the method they employed. Mezzotints were occasionally printed in colours, notably those engraved later after George Morland, the primary object being to conceal the worn-out condition of the plates.

The departure from pure mezzotint and temporary decay of the art began when, towards the end of the eighteenth century, Richard Earlom, otherwise a fine artist in the traditional method, notably in translations of Vandyck and Wright of Derby, began to outline the details of his plates with stipple etching in order to avoid the labour and difficulty of scraping them to a sharp edge, using the "ground" alone. Earlom, however, did not destroy the mystery of the rich velvety darks by etching into them. A demand then arose for larger editions than the soft copper plates would yield, and the engravers attempted to meet it by combining mezzotint with positive line-etching throughout the work, thus shortening the labour of scraping the details, and fortifying the darks with lines sunk below the surface of the plate. The harmony of line and tone in some of the prints in this style by S. W. Reynolds and Charles Turner, after Sir Joshua, Hoppner, and their contemporaries, was more convincing than the later "mixed style" of Samuel Cousins, because there was a certain artistic significance in the etched line itself apart from the mezzotint tone, but every touch of line in a mezzotint does something to destroy the painter-like quality, and a decadence was in progress.

The same mixed method on copper was used by J. W. M. Turner in his *Liber Studiorum* series of landscape plates, his object being to rival the pen-and-wash drawings of Claude's *Liber Veritatis.* Turner, however, was not so practised in etching or mezzotint as the engravers before mentioned, and the etched foundation of the *Liber* plates was too strong for the mezzotint tone, destroying the breadth of the light, the richness of the darks, and the artistic "keeping" of the whole effect. It is the grand design of Turner reflected in the plates, rather than any quality of mezzotint or etching in them, which appeals to the artist and the connoisseur. Perhaps the greatest success in harmonizing line and tone in one plate was achieved by David Lucas in his "English Landscape" series of mezzotint after John Constable, in which he sharpened his details with the roulette, or with a slight line put in with the point of the scraper as scraping proceeded, retaining the pure "burr" in his darks. Lucas, like Samuel Cousins and his contemporaries, was handicapped by being compelled to work on the steel plates introduced in 1823, and this was the cause of the chief defect of his plates, the excessive opposition of black and white. The warm general tone which assisted the picturesqueness of the 18th-century mezzotints was lost by the use of steel, because the ink did not cling to it as it does to the more porous copper. Steel being harder than copper, the rocking-tool penetrated less deeply, raising less "burr," and the consequent loss of force in the darks necessitated the scraping up of the lights to a higher key to force contrast of effect, which was also enhanced by the use of very white paper and a coarse black ink. It was soon found that the unfortified "burr," even on steel, would not yield the constantly increasing numbers of impressions demanded. The labour of scraping sharp lights was greatly enhanced, and though some pure mezzotints were engraved on steel, painter-like touch was practically unattainable on it, and the general effect was cold and uninteresting.

The early work of Samuel Cousins after Lawrence in the comparatively pure method, and the final development of the "mixed style" on steel in his later plates after Reynolds, Millais, and Landseer, are referred to in the article on Samuel Cousins.

For nearly forty years pure mezzotint ceased to be practised altogether, and the revival of it, which began in 1880, was led up to by the invention of steel-facing. The competition of photogravure, which steel-facing made a commercial possibility, for a time checked the new movement, but a photogravure, despite a mere surface resemblance to a mezzotint, is a photograph manipulated to imitate an engraving, and the qualities of artistic individuality are entirely wanting. In 1898 for the first time a Society of Mezzotint Engravers was formed to foster the art.

See also *British Mezzotinto Portraits*, by John Challoner Smith. London, 1878. This standard book of reference contains a long list of others at page xiv, part i. *Lectures on Etching and Mezzotint*, by Hubert von Herkomer, R.A. London, 1890. (The most useful work on the technique.) *Etching, Engraving, and other Methods of Printing Pictures*, by H. W. Singer and William Strang. London, 1897. *On the Making of Etchings*, by Frank Short. London, 1898. (Containing a slight reference to mezzotint technique.) *Art of Engraving*, by T. H. Fielding. London, 1854. *Masters of Mezzotint*, by Alfred Whitman. London, 1898. A little anonymous book, *A History of the Art of Engraving in Mezzotinto, from Its Origin to the Present Times* [by Dr James Chelsum], Winchester, 1786, is of considerable interest. Works on the technique are somewhat elementary, and no complete history of the art exists.

(G. P. R.)

Lithography.

In Great Britain the art of lithography, as distinct from its numerous commercial uses, was for all practical purposes killed by the competition of wood-engraving, which had been so largely developed in the years after 1860. (See Illustration.) In 1871 Thomas Way induced a number of artists to experiment with the process, the result being the publication of *Hogarth Sketches*, an interesting portfolio, which had, however, no immediate results. For some years no further attempt was made at a revival; the only art productions in any sense of the word being supplements, generally in colour,—those to various periodicals, such as *Vanity Fair*, *The Illustrated London News*, and *The Graphic* being the most noteworthy. There were also facsimile reproductions of popular pictures. But in both these categories the artist had little to do with the actual lithography, a notable exception, however, existing in the case of J. McNeill Whistler, whose contributions to *The Whirlwind* and other short-lived periodicals were entirely his personal work. In 1893 T. R. Way demonstrated the possibilities of the use of lithographic transfer paper to a meeting of the Art Workers' Guild in London; and the interest thus excited again encouraged many artists to try the method, both by this means and by working on the stone direct. It thus became possible for Great Britain to be represented at the Paris Centenary Exhibition of Lithography (1896) by a series of lithographic drawings which were at all events by artists of good position in other branches of the fine arts. Some have continued to practise lithography from time to time; those of most note being Alphonse Legros, Frank Short, Oliver Hall, Will Rothenstein, Charles H. Shannon, William Strang, Thomas R. Way, and Charles J. Watson, the last a representative of a small circle of lithographers centred at Norwich who had kept up the old tradition. Working in England or France, the American artists, J. McNeill Whistler and Joseph Pennell, must also be counted with the foregoing. The numerous productions of the former are of extreme delicacy and great excellence, within their own limits. In France the great traditions left by Raffet, E. Isabey, "Gavarni" (H. G. S. Chevalier), Daumier, and Decamps, had been maintained chiefly by H. Fantin-Latour, whose first lithograph was published in 1876. His work was hardly known or appreciated in England until recently, but the splendid series exhibited in the Centenary Exhibition at South Kensington Museum did not a little towards a proper realization of his true place as a lithographer. A great revival of lithography in France came in the 'eighties, influenced mainly by the development of the pictorial poster; and thus the use of colour, so markedly absent in the unsubstantial effort of the English artists, became a characteristic of the French school, and of the Germans who took their cue from it. Among the leaders of this school may be signalized A. Willette, H. de Toulouse-Lautrec, Steinlen, H. Rivière, and A. Lunois. In Germany the art was warmly adopted, and about the year 1891 began the appearance of a series of plates in colour, many of extreme daring, but all of at least experimental interest. These were mainly done by artists of Munich, Dresden, and Carlsruhe, and are noteworthy for the attention paid in many of them to landscape effects, as compared with the French tendency to deal mainly with the figure. The chief exponents of the modern German school—Menzel belonging essentially to the past—are H. R. von Volkmann, F. Unger, Hans Thoma, Cornelia Paczka, G. Kampmann, H. Daur, and Otto Greiner. Th. van Hoytema and Jan Veth represent the same phase of art in Holland. Technically, the art of lithography stands very much where Senefelder left it, the only improvements being in the fine adjustment of printing machinery, and the adoption of certain modern photographic printing processes in combination with the old use of the stone. Successful work, especially in colour, has also been produced lately by algraphy—a process in which aluminium takes the place of the stone. (E. F. S.)

Wood-Engraving.

Since 1877 the position of wood-engraving in England has wholly changed. At that time it was the chief means of book and newspaper illustration, and a frequent method of fine-art reproduction; but by the beginning of the 20th century it had been all but driven out of the field by "process" work of various kinds. It still flourishes in its commoner style for commercial and mechanical work; it is still occasionally maintained in its finest form by a sympathetic publisher here and there, who deplores and would arrest its decay. But the photograph and its facsimile reproduction have captivated the public, who want "illustration" and who do not want "art." The great body of the wood-engravers have therefore found their occupation entirely gone, while the minority have found themselves forced to devote their skill to "re-touching" the process-block—sometimes carrying their work so far that the print from the finished block is a close imitation of a wood-engraving. This system has been carried farthest in America.

It is not only to considerations of economy that the supersession of engraving by "process" is due. The apparent superiority of truthfulness claimed by the photograph over the artist's drawing is a factor in the case—the public forgetting that a photographic print shows us what a thing or a scene looks like to the lens, rather than what it looks like to the two eyes of the spectator. The rank and file of the engravers—even those who can "engrave" after a picture as well as "cut" a "special artist's" sketch—have succumbed not only to the public, but to the artists themselves, who frequently insist upon the process-block for the translation of their work. They seem to prefer the greater truth of outline (though not necessarily of tone) yielded by "process," to all the inherent charm of the beautiful (and expensive) art of xylography.

In England a few engravers of high rank and ability still followed in 1901 the art which was raised to so high a pitch by W. J. Linton (died 1898). Such were Mr Charles Roberts, Mr Biscombe Gardner, Mr Comfort, Mr Ulrich, and a few more—the first two the better engravers for being also practising artists. But there is every reason to fear that if wood-engraving as a craft, for ordinary purposes, ceases to exist, wood-engraving as a fine art must disappear as well; as there would be nothing to support the young craftsman during the years of apprenticeship and practice required to make an "artist" of him, and nothing to compensate him if he fail to attain at once the highest accomplishment.

Another circumstance which has contributed to the overthrow of wood-engraving in England is the rapture begotten of the extraordinary perfection to which the art had been brought in America. These engravings, published in magazines and books, having wide circulation in England, awakened not an intelligent but a foolish appreciation among the public. Just as Finden's over-refinement of engraving on steel killed his art by stripping it of all interest, so the unsurpassable perfection of the American wood-engraver, by the law of paradox, effectually stifled xylography in England. The reason is simple. With the object of "disindividualizing" himself, as he called it, the engraver sought to suppress his own recognizable manner of craftmanship when translating the work of the artist for the public; and the more he succeeded in effacing himself, and the more he refined and elaborated his technique and imitated textures, and the more he developed extreme minuteness and excessive dexterity (so as to secure faithfulness and smoothness), the more closely did the result approximate to a photograph. The result, in fact, became the *reductio ad absurdum* of the passion for the minute and the perfection of technique. The result was amazing in its completeness, but curiously grey and monotonous; and matter-of-fact publishers and public alike preferred the photograph, which in their eyes did not differ so very much (except in being a little greyer and more monotonous) from the half-tone block, while the cost of the latter was but a fraction of that of the former. The extreme elaboration, satisfying a craving of an acrobatic kind, defeated its own end. The public were pleased, and the result has been disastrous for the art.

In England, in spite of the International Society of Wood-Engravers, there are but slight signs of a general revival, and it seems as if the art must be born again, so long as the public interest in photographs continues. Mr C. Ricketts has gone back to a Düreresque, or perhaps Florentine, manner of the Early Renaissance wood-cut, while others are striving to begin engraving where Bewick began it. There is hope that the true art may be restored, but such revival will rather be based on a revolt against the greyness of the process-block, and the offensively shiny surface of the chalk-coated paper on which it is printed, than on any æsthetic delight in intelligent wood-engraving, its expressive line, its delicate, pearly tones, and its rich, fat blacks.

In America, where the power of resuscitation is great, the miraculous technical perfection brought about by Mr Timothy Cole and the late Frederick Juengling, as leaders of the school, has promptly given way to a greater feeling for art and a lesser worship of mechanical achievement, and wood-engraving is saved. Curiously enough, Mr Cole (himself, by the way, an Englishman by birth) was equally a leader in recognizing the danger which his own brilliant proficiency had helped to bring about. The "decadent" *de luxe* who had overwhelmed his art in the refinements which threatened to destroy it, and who had been seconded by the splendid printing-presses of America (which might without exaggeration be called instruments of precision), gave up what may be termed hyper-engraving, and, surrendering his wonderful power of imitating surfaces and textures, Mr Cole changed his manner. He became broader in handling; his example was followed by others, and wood-engraving in a few hands still prospers in the United States.

In France, where the art has reached the highest perfection and the most consummate and logical development, it flourishes on the true artistic instinct of the engraver, on the taste of an intelligent and appreciative public, and on official recognition and encouragement. Nevertheless, it has been found necessary to establish a "Society of Wood-Engravers" (with a magazine of its own) to protect it against the inroad of the process-block. The art doubtless produces more engravers of skill than it can provide work for; but that is evidence rather of vitality than of decay. M. Lepère, M. Baude, M. Jonnard, are among the leaders who, in different styles of wood-engraving, sustain the extraordinarily high level which has been attained in France, and which is likely to be maintained by virtue of the encouragement on which it flourishes. Florian, who died in 1900, was a man who successfully sought to obtain effects of tone rather than line, leaving masses of unengraved surface to enhance the delicate beauty of his pearly greys. But in rebelling against the mechanical style so much affected in Germany, of indicating roundness of form by curved lines carried at right angles to the convexity, and in substituting longitudinal lines of shading, he sacrificed a good deal of the logic of form-rendering, and started a method that has not been entirely successful.

In Germany the artistic standard is lower than in France. It is true that few outside Germany could model a head as finely as Herr M. Klinkicht in his own style of a judicious mingling of the black line and the white line; but, as a rule, German engraving is far more precise, more mechanical, more according to formula, and more old-fashioned than that of either France or America. The art has been injured by the great "studios" or factories which flourish on strictly business principles, and which, in the education of the craftsman, have to some extent annihilated the artist. A few there are, however, of great ability and taste. The attempt to print wood-engravings in colours has done little to improve the status of the art. In other countries, however, "original" work has done much to raise the standard. Thus the work of Mr Elbridge Kingsley, who would sit down in the woods and engrave the scene before him directly on to the block, exercised no little influence in America. The similar ability of M. Lepère to engrave directly from nature, whether from the trees of Fontainebleau Forest or the towers of Westminster, has been much appreciated in his own country and in England. The efforts at block-printing by M. Charpentier and others, not only with colour, but by reinforcing it with blocks that print neither lines nor colour but "blind" pattern, raised or depressed upon the paper, prove that there is a movement afoot to seek new methods to interest the public. The immediate results may not be very serious; yet the fact shows the existence of a vitality that gives hope for the future. But while the practice of dry-printing upon "surface paper" is maintained, it is hopeless to expect in the immediate future, in England at least, any permanently good results from orthodox wood-engraving.

See (in addition to those works cited in the 9th edition):—W. J. LINTON. *The Masters of Wood-Engraving.* Folio; issued to subscribers only. London, Stevens, Charing Cross, 1889 and 1892.—W. J. LINTON. *Wood-Engraving.* G. Bell & Sons, London, 1884.—W. J. LINTON. *History of Wood-Engraving in America.* Chatto, 1882.—P. G. HAMERTON. *Drawing and Engraving.* A. & C. Black, 1892. An extended reprint of the article on "Engraving" in the 9th edition of the *Encyclopædia Brittanica.*—P. G. HAMERTON. *The Graphic Arts.* Seeley, 1882.—J. E. WOODBERRY. *History of Wood-Engraving.* S. Low, 1883.—W. S. BAKER. *American Engravers and their Work.* Philadelphia, 1875.

(M. H. S.)

LINE-ENGRAVING.

The record of the art of engraving in line upon copper or steel, since the 9th edition of this *Encyclopædia* was published, is one of continued decay. The impulse therein referred to has faded away. Technical improvements, it was hoped, might save the art; it was thought by some that the slight revival resultant on the turning back of the burin's cutting-point—whereby the operator pulled the tool towards him instead of pushing it from him—might affect much, in virtue of the time and labour saved by the device. At the beginning of the 20th century it is seen that pictorial line-engraving in England is practically non-existent, and that the spasmodic demand by publishers for engravers to cut new plates is unanswered. There are certainly a few men still working in line who are capable of touching-up old plates, and engraving new ones of a more or less mechanical kind. Mr C. W. Sherborn, the exquisite and facile designer and engraver of book-plates, has scarcely been surpassed in his own line, but his art is mainly heraldic, and he is himself a veteran. There are now no men capable of such work as that with which Doo, J. H. Robinson, and their fellows maintained the credit of the English School. Line-engraving has been killed by etching, mezzotint, and that bastard form of line-engraving known as the "mixed method"—a combination of etching, graving, and machine-ruling, such as is seen in Thomas Landseer's "Stag at Bay." The disappearance of the art is due not so much to the artistic objection that the personality of the line-engraver stands obtrusively between the painter and the public; it is rather that the public refuse to wait for several years for the proofs for which they have subscribed, when by another method they can obtain their plates more quickly. An important line plate may occupy a prodigious time in the engraving. Robinson's "Napoleon and the Pope" took about twelve years. The invention of steel-facing a copper plate would now enable the engraver to proceed more expeditiously; but even in this case he can no more compete with the etcher than the mezzotint-engraver can keep pace with the photogravure manufacturer. The Royal Academy has within recent years withdrawn from the list of school prizes the offer of a medal for line-engraving, for which for a long while previously there had been no competition; the late Mr Lumb Stocks, R.A., and the living Mr F. Stacpoole, (retired) A.R.A. (who is best known for his plates after Briton Riviere's "Circe," Lady Butler's "Roll-Call," and Holman Hunt's "Shadow of the Cross"), will have no successors on the list of Academicians; and the privilege of Academic recognition so fiercely won by Sir Robert Strange will lapse for lack of claimants. The Art Union of London has given what encouragement it could; but with the death of F. Bacon (1887) and J. Stephenson (1886) it was evident that all hope was gone. John Saddler came at last, in spite of his capacity to do original work, to spend most of his time in assisting Thomas Landseer to rule the skies on his plates, simply because there was not enough line-engraving to do. Since then there was some promise of a revival, and Mr Bourne engraved a few of the pictures by Gustave Doré. But little followed. It is not generally known that the last of the line-engravers of Turner's pictures died in the person of Sir Daniel Wilson, who, recognizing the hopelessness of his early profession, laid his graver aside, and in due time left Europe for Canada and eventually became President of the University of Toronto (died 1892).

If line-engraving still flourishes in France, it is due not a little to official encouragement and to intelligent fostering by collectors and connoisseurs. The prizes offered by the École des Beaux Arts would probably not suffice to give vitality to the art but for the employment afforded to the finished artist by the "Chalcographie du Musée du Louvre," in the name of which commissions are judiciously distributed. At the same time, it must be recognized that although French gravers are little less busy than they were in days when line-engraving was the only "important" method of picture-translation, they work for the most part for much smaller rewards. Moreover, the class of the work has entirely changed, partly through the reduction of prices paid for it, partly through the change of taste and fashion, and partly through the necessities of the situation. That is to say, that public impatience is but a partial factor in the abandonment of the fine broad sweeping trough cut deep into the copper which was characteristic of the earlier engraving, either simply cut or crossed diagonally so as to form the series of "lozenges" typical of engraving at about its finest and grandest period. That method was slow; but not less slow was the shallower work rendered possible by the steel plate or the steel-faced copper plate, by reason of the much greater degree of elaboration of which such plates were capable, and which the public was taught—mainly by Finden—to expect. The French engravers were therefore driven at last to simplify their work if they were to satisfy the public and live by the burin. To compensate for loss of colour, the art developed in the direction of elegance and refinement. Gaillard (died 1887), Blanchard, and Alphonse François (died 1888) were perhaps the earliest chiefs of the new school, the characteristics of which are the substitution of exquisite greys for the rich blacks of old, simplicity of method being often allied to extremely high elaboration. Yet the aim of the modern engraver has always been, while pushing the capability of his own art to the farthermost limit, to retain throughout the individual and personal qualities of the master whose work is translated on the plate. The height of perfection to which the art is reached is seen in the triptych of Mantegna by M. Achille Jacquet, to whom may perhaps be accorded the first place among several engravers of the front rank. This "Passion" (from the three pictures in the Louvre and at Tours, forming the predella of the San Zeno altarpiece in Verona) not only conveys the forms, sentiment, and colour of the master, but succeeds also in rendering the peculiar luminosity of the originals. M. Jacquet, who gained the *Prix de Rome* in 1870, has also translated the pictures of Sir Joshua Reynolds, and has engraved fine plates after Paul Dubois, Cabanel, Bouguereau, Meissonier, and Detaille. The freedom of much of his work suggests an affinity with etching and dry-point; indeed, it appears that he uses the etching-needle and acid to lay in some of his groundwork and outlines. M. Léopold Flameng's engraving after Jan van Eyck's "Virgin with the Donor," in the Louvre, is one of the most admirable works of its kind, retaining the quality and sentiment of the master, extreme minuteness and elaboration notwithstanding. M. Jules Jacquet is known for his work after Meissonier (especially the "Friedland") and after Bonnat; M. Adrien Didier for his plates after Holbein ("Anne of Cleves"), Raphael, and Paul Veronese, among the Old Masters, and Bonnat, Bouguereau, and Roybet among the new. M. Jazinski (Botticelli's "Primavera"), M. Sulpis (Mantegna and Gustave Moreau), M. Patricot (Gustave Moreau), M. Burney, and M. Champollion (died 1901), are among the leaders of the modern school. Their object is to secure the faithful transcript of the painter they reproduce, while readily sacrificing the power of the old method, which, whatever its force and its beauty, was easily acquired by mediocre artists of technical ability who were nevertheless unable to appreciate or reproduce anything beyond mechanical excellence.

The Belgian School of engraving is not without vitality. The veteran M. Gustave Biot is equally skilful in portraiture and subject (engraving after Gallait, Cabanel, Gustave Doré, among his best work); M. A. M. Danse has executed plates after leading painters, and has elaborated an effective "mixed method" of graver-work and dry-point; and M. de Meerman has engraved a number of good plates; but private patronage is hardly sufficient in Belgium to maintain the school in a high state of prosperous efficiency.

In Germany, as might be expected, line-engraving retains not a little of its popularity in its more orthodox form. The novel Stauffer-Bern method, in which freedom and lightness are obtained with such delicacy that the fine lines, employed in great numbers, run into tone, and yield a supposed advantage in modelling, has not been without appreciation. But the more usual virtue of the graver has been best supported, and many have worked in the old-fashioned manner. Friedrich Zimmermann (died 1887) began his career by engraving such prints as Guido Reni's "Ecce Homo" in Dresden, and then devoted himself to the translation of modern German painters. Rudolf Pfnor was an ornamentist representative of his class; and Joseph Kohlschein, of Düsseldorf, a typical exponent of the intelligent conservative manner. His "Marriage at Cana" after Paul Veronese, "The Sistine Madonna" after Raphael, and "St Cecilia" after the same master, are all plates of a high order.

In Italy the art is well-nigh as moribund as in England. When Signor Vittorio Pica (of Naples) and Signor Conconi (of Milan) have been named, it is difficult to mention other successors to the fine school of the 19th century which followed Piranesi and Volpato. A few of the pupils of Rosaspina and Paolo Toschi lived into the last quarter of the century, but to the present generation Asiolo, Jesi, C. Raimondi, L. Bigola, and Antonio Isac are remembered rather for their efforts than for their success in supporting their art against the combined opposition of etching, process, and public indifference.

Outside of Europe line-engraving can no longer be said to exist. Here and there a spasmodic attempt may be made to appeal to the artistic appreciation of a limited public; but no general attention is paid to such efforts, nor, it may be added, are these inherently worthy of much notice. There are still a few who can engrave a head from a photograph or drawing, or a small engraving for book-illustration; there are more who are highly proficient in mechanical engraving for decorative purposes; but the engraving-machine is fast superseding this class. In short, the art of worthily translating a fine painting, outside France, Belgium, Germany, and perhaps Italy, can scarcely be said to survive.

P. G. HAMERTON. *Drawing and Engraving.* Edinburgh, 1892.—H. W. SINGER and W. STRANG. *Etching, Engraving,* and other methods of *Printing Pictures.* London, 1897.—LOSTALOT, A. DE. *Les Procédés de la Gravure.* Paris, 1882.—DELABORDE, LE COMTE HENRI. *La Gravure.* Paris. English translation, with a chapter on English engraving methods by WILLIAM WALKER. London, 1886.—H. W. SINGER. *Geschichte des Kupferstichs.* Magdeburg und Leipzig, 1895.—ALEX. WALDOW, &c. *Illustrirte Encyklopädie der Graphischen Kunste.* Leipzig, 1881-84.

(M. H. S.)

Ennis (Gaelic, *Innis*, an island; Irish, *Ennis* and *Inish*), an inland town and urban sanitary district in the county of Clare, Ireland, on the river Fergus, 25 miles west-north-west of Limerick by rail. It ceased to be a parliamentary borough in 1885. Population, about 5460.

Enniskillen, a market-town and urban sanitary district in the county of Fermanagh, Ireland, on an island in the river connecting the upper and lower lakes of Lough Erne, 102 miles north-west of Dublin by rail. It ceased to be a parliamentary borough in 1885. Steamers now ply between Enniskillen and Belleek on the lower lake, and between Enniskillen and Knockninny on the upper lake. Population (1881), 5900; (1891), 5570; (1901), about 5339.

Enns, an ancient town in Upper Austria (the Roman *Laureacum*), on the Enns near its confluence with the Danube. It possesses the oldest charter (1212) of any town in the monarchy. The walls are said to have been built with the ransom paid by England for the release of Richard Cœur de Lion. It has an old Gothic church, a 15th-century castle, and a Rathhaus erected in 1565. There are numerous ironworks in the adjoining Enns valley. Population (1890), with suburbs, 4674; (1900), 4371.

Enschede, a town in the province of Overyssel, Netherlands, near the Prussian frontier, about 45 miles south-east of Zwolle. As a centre of the cotton-spinning and weaving industry it has flourished greatly, the population (24,253 in 1900) having quadrupled since 1875. The transport of coal has been much increased by the construction of a railway to the coal-fields of the Ruhr, and over 44,000 tons are now carried annually. A new park has been opened, more especially for the benefit of the working classes, and an industrial trade school has been established.

Entomostraca.—This term, as now restricted, includes the Branchiopoda, Ostracoda, and Copepoda. The Ostracoda have the body enclosed in a bivalve shell-covering, and normally unsegmented. The Branchiopoda have a very variable number of body-segments, with or without a shield, simple or bivalved, and some of the post-oral appendages normally branchial. The Copepoda have normally a segmented body, not enclosed in a bivalved shell-covering, the segments not exceeding eleven, the limbs not branchial.

Under the heading CRUSTACEA the Entomostraca have already been distinguished not only from the Thyrostraca or Cirripedes, but also from the Malacostraca, and an intermediate group of which the true position is still disputed. The choice is open to maintain the last as an independent subclass, and to follow Claus in calling it the Leptostraca, or to introduce it among the Malacostraca as the Nebaliacea, or with Packard and Sars to make it an entomostracan subdivision under the title Phyllocarida. At present it comprises the single family Nebaliidæ. The bivalved carapace has a jointed rostrum, and covers only the front part of the body, to which it is only attached quite in front, the valve-like sides being under control of an adductor muscle. The eyes are stalked and movable. The first antennæ have a lamellar appendage at the end of the peduncle, a decidedly non-entomostracan feature. The second antennæ, mandibles, and two pairs of maxillæ may also be claimed as of malacostracan type. To these succeed eight pairs of foliaceous branchial appendages on the front division of the body, followed on the hind division by four pairs of powerful bifurcate swimming feet and two rudimentary pairs, the number, though not the nature, of these appendages being malacostracan. On the other hand, the two limbless segments that precede the caudal furca are decidedly non-malacostracan. The family was long limited to the single genus *Nebalia* (Leach), and the single species *N. bipes* (O. Fabricius). Recently Sars has added a Norwegian species, *N. typhlops*, not blind but weak-eyed. There are also now two more genera, *Paranebalia* (Claus, 1880), in which the branchial feet are much longer than in *Nebalia*, and *Nebaliopsis* (Sars, 1887), in which they are much shorter. All the species are marine.

BRANCHIOPODA.—In this order, exclusion of the Phyllocarida will leave three suborders of very unequal extent, the Phyllopoda, Cladocera, Branchiura. The constituents of the last have often been classed as Copepoda, and among the Branchiopods must be regarded as aberrant, since the "branchial tail" implied in the name has no feet, and the actual feet are by no means obviously branchial.

Phyllopoda.—This "leaf-footed" suborder has the appendages which follow the second maxillæ variable in number, but all foliaceous and branchial. The development begins with a free nauplius stage. In the outward appearance of the adults there is great want of uniformity, one set having their limbs sheltered by no carapace, another having a broad shield over most of them, and a third having a bivalved shell-cover within which the whole body can be enclosed. In accord with these differences the sections may be named Gymnophylla, Notophylla, Conchophylla. The equivalent terms applied by Sars are Anostraca, Notostraca, Conchostraca, involving a termination already appropriated to higher divisions of the Crustacean class, for which it ought to be reserved.

1. *Gymnophylla.*—These singular crustaceans have long soft flexible bodies, the eyes stalked and movable, the first antennæ small and filiform, the second lamellar in the female, in the male prehensile; this last character gives rise to some very fanciful developments. There are three families, two of which form companies rather severely limited. Thus the Polyartemiidæ, which compensate themselves for their stumpy little tails by having nineteen instead of the normal eleven pairs of branchial feet, consist exclusively of *Polyartemia forcipata* (Fischer, 1851). This species from the high north of Europe and Asia carries green eggs, and above them a bright pattern in ultramarine (Sars, 1896, 1897). The Thamnocephalidæ have likewise but a single species, *Thamnocephalus platyurus* (Packard, 1877), which justifies its title "bushy-head of the broad tail" by a singularity at each end. Forward from the head extends a long ramified appendage described as the "frontal shrub," backward from the fourth abdominal segment of the male spreads a fin-like expansion which is unique. In the ravines of Kansas, pools supplied by torrential rains give birth to these and many other phyllopods, and in turn "millions of them perish by the drying up of the pools in July" (Packard). The remaining family, the Branchipodidæ, includes eight genera. In the long familiar *Branchipus*, *Chirocephalus*, and *Streptocephalus* the males have frontal appendages, but these are wanting in the "brine-shrimp" *Artemia*, and the same want helps to distinguish *Branchinecta* (Verrill, 1869) from the old genus *Branchipus*. Of *Branchiopsyllus* (Sars, 1897) the male is not yet known, but in his genera of the same date, the Siberian *Artemiopsis* and the South African *Branchipodopsis* (1898), there is no such appendage. Of the last genus the type species *B. hodgsoni* belongs to Cape Colony, but the specimens described were born and bred and observed in Norway. For the study of fresh-water Entomostraca large possibilities are now opened to the naturalist. A parcel of dried mud, coming for example from Palestine or Queensland, and after an indefinite interval of time put into water in England or elsewhere, may yield him living forms, both new and old, in the most agreeable variety. Some caution should be used against confounding accidentally introduced indigenous species with those reared from the imported eggs. Those, too, who send or bring the foreign soil should exercise a little thought in the choice of it, since dry earth that has never had any Entomostraca near it at home will not become fertile in them by the mere fact of exportation.

2. *Notophylla.*—In this division the body is partly covered by a broad shield, united in front with the head; the eyes are sessile, the first antennæ are small, the second rudimentary or wanting; of the numerous feet, sometimes sixty-three pairs, exceeding the number of segments to which they are attached, the first pair are more or less unlike the rest, and in the female the eleventh have the epipod and exopod (flabellum and sub-apical lobe of Lankester) modified to form an ovisac. Development begins with a nauplius stage. Males are very rare. The single family Apodidæ contains only two genera, *Apus* and its very near neighbour *Lepidurus*. *Apus australiensis* (Spencer and Hall, 1896) may rank as the largest of the Entomostraca, reaching in the male, from front of shield to end of telson, a length of 70 mm., in the female of 64 mm. In a few days, or at most a fortnight, after a rainfall numberless

specimens of these sizes were found swimming about, "and as not a single one was to be found in the water-pools prior to the rain, these must have been developed from the egg." Similarly, in Northern India *Apus himalayanus* was "collected from a stagnant pool in a jungle four days after a shower of rain had fallen," following a drought of four months (Packard).

3. *Conchophylla.*—Though concealed within the bivalved shell-cover, the mouth-parts are nearly as in the Gymnophylla, but the flexing of the caudal part is in contrast, and the biramous second antennæ correspond with what is only a larval character in the other phyllopods. In the male the first one or two pairs of feet are modified into grasping organs. The small ova are crowded beneath the dorsal part of the valves. The development usually begins with a nauplius stage (Sars, 1896, 1900). There are four families:—(*a*) The Limnadiidæ, with feet from 18 to 32 pairs, comprise four (or five) genera. Of these, *Limnadella* (Girard, 1855) has a single eye. It remains rather obscure, though the type species originally "was discovered in great abundance in a roadside puddle subject to desiccation." *Limnadia* (Brongniart, 1820) is supposed to consist of species exclusively parthenogenetic. But when asked to believe that males never occur among these amazons, one cannot but remember how hard it is to prove a negative. (*b*) The Lynceidæ, with not more than twelve pairs of feet. This family is limited to the species, widely distributed, of the single genus *Lynceus*, established by O. F. Müller in 1776 and 1781, and first restricted by Leach in 1816 in the *Encyclopædia Britannica* (art. ANNULOSA, of that edition). Leach there assigns to it the single species *L. brachyurus* (Müller), and as this is included in the genus *Limnetis* (Lovén, 1846), that genus must be a synonym of *Lynceus* as restricted. (*c*) Leptestheriidæ. *Estheria* (Rüppell, 1837) was instituted for the species *dahalacensis*, which Sars includes in his genus *Leptestheria* (1898); but *Estheria* was already appropriated, and of its synonyms *Cyzicus* (Audouin, 1837) is lost for vagueness, while *Isaura* (Joly, 1842) is also appropriated, so that *Leptestheria* becomes the name of the typical genus, and determines the name of the family. (*d*) Cyclestheriidæ. This family consists of the single species *Cyclestheria hislopi* (Baird), reported from India, Ceylon, Celebes, Australia, East Africa, and Brazil. Sars (1887) having had the opportunity of raising it from dried Australian mud, found that, unlike other phyllopods, but like the Cladocera, the parent keeps its brood within the shell until their full development.

Cladocera.—In this suborder the head is more or less distinct, the rest of the body being in general laterally compressed and covered by a bivalved test. The title "branching horns" alludes to the second antennæ, which are two-branched except in the females of *Holopedium*, with each branch setiferous, composed of only two to four joints. The mandibles are without palp. The pairs of feet are four to six. The eye is single, and in addition to the eye there is often an "eye-spot," *Monospilus* being unique in having the eye-spot alone and no eye, while *Leydigiopsis* (Sars, 1901) has an eye with an eye-spot equal to it, or larger. The heart has a pair of venous ostia, often blending into one, and an anterior arterial aorta. Respiration is conducted by the general surface, by the branchial lamina (external branch) of the feet, and the vesicular appendage (when present) at the base of this branch. The "abdomen," behind the limbs, is usually very short, occasionally very long. The "postabdomen," marked off by the two postabdominal setæ, usually has teeth or spines, and ends in two denticulate or ciliate claws, or it may be rudimentary, as in *Polyphemus*. Many species have a special glandular organ at the back of the head, which *Sida crystallina* uses for attaching itself to various objects. The Leydigian or nuchal organ is supposed to be auditory and to contain an otolith. The female lays two kinds of eggs—"summer-eggs," which develop without fertilization, and "winter-eggs" or resting eggs, which require to be fertilized. The latter in the Daphniidæ are enclosed in a modified part of the mother's shell, called the ephippium from its resemblance to a saddle in shape and position. In other families a less elaborate case has been observed, for which Mr Scourfield has proposed the term protoephippium. In *Leydigia* he has recently found a structure almost as complex as that of the Daphniidæ. In some families the resting eggs escape into the water without special covering. Only the embryos of *Leptodora* are known to hatch out in the nauplius stage. *Penilia* (Dana, 1849) is perhaps the only exclusively marine genus. The great majority of the Cladocera belong to fresh water, but their adaptability is large, since *Moina rectirostris* (O. F. Müller) can equally enjoy a pond at Blackheath, and near Odessa live in water twice as salt as that of the ocean. In point of size a Cladoceran of 5 mm. is spoken of as colossal.

Dr Jules Richard in his revision (1895) retains the sections, proposed by Sars in 1865, Calyptomera and Gymnomera. The former, with the feet for the most part concealed by the carapace, is subdivided into two tribes, the *Ctenopoda*, or "comb-feet," in which the six pairs of similar feet, all branchial and non-prehensile, are furnished with setæ arranged like the teeth of a comb, and the *Anomopoda*, or "variety-feet," in which the front feet differ from the rest by being more or less prehensile, without branchial laminæ.

The *Ctenopoda* comprise two families: (*a*) the Holopediidæ, with a solitary species, *Holopedium gibberum* (Zaddach), queerly clothed in a large gelatinous involucre, and found in mountain tarns all over Europe, in large lakes of N. America, and also in shallow ponds and waters at sea-level; (*b*) the Sididæ, with no such involucre, but with seven genera, and rather more than twice as many species. Of *Diaphanosoma modiglianii* Richard says that at different points of Lake Toba in Sumatra millions of specimens were obtained, among which he had not met with a single male.

The *Anomopoda* are arranged in four families, all but one very extensive. (*a*) Daphniidæ. Of the seven genera, the cosmopolitan *Daphnia* contains about 100 species and varieties, of which Mr Thomas Scott (1899) observes that "scarcely any of the several characters that have at one time or another been selected as affording a means for discriminating between the different forms can be relied on as satisfactory." Though this may dishearten the systematist, Mr Scourfield (1900) reminds us that "It was in a water-flea that Metschnikoff first saw the leucocytes (or phagocytes) trying to get rid of disease germs by swallowing them, and was so led to his epoch-making discovery of the part played by these minute amœboid corpuscles in the animal body." For *Scapholeberis mucronata* (O. F. Müller), Mr Scourfield has shown how it is adapted for movement back downwards in the water along the under side of the surface-film, which to many small crustaceans is a dangerously disabling trap. (*b*) Bosminidæ. To *Bosmina* (Baird, 1845) Richard adds *Bosminopsis*, in 1895. (*c*) Macrotrichidæ. In this family *Macrothrix* (Baird, 1843) is the earliest genus, among the latest being *Grimaldina* (Richard, 1892) and *Jheringula* (Sars, 1900). Dried mud and vegetable débris from S. Paulo in Brazil supplied Sars with representatives of all the three in his Norwegian aquaria, in some of which the little *Macrothrix elegans* "multiplied to such an extraordinary extent as at last to fill up the water with immense shoals of individuals." "The appearance of male specimens was always contemporary with the first ephippial formation in the females." For *Streblocerus pygmæus*, grown under the same conditions, Sars observes: "This is perhaps the smallest of the Cladocera known, and is hardly more than visible to the naked eye," the adult female scarcely exceeding 0·25 mm. Yet in the next family *Alonella nana* (Baird) disputes the palm and claims to be the smallest of all known Arthropoda. (*d*) Chydoridæ. This family, so commonly called Lynceidæ, contains a large number of genera, among which one may usually search in vain, and rightly so, for the genus *Lynceus*. The key to the riddle is to be found in the *Encyclopædia Britannica* for 1816. There, as above explained, Leach began the subdivision of Müller's too comprehensive genus, the result being that *Lynceus* belongs to the Phyllopoda, and *Chydorus* (Leach, 1816) properly gives its name to the present family, in which the doubly convoluted intestine is so remarkable. Of its many genera, *Leydigia*, *Leydigiopsis*, *Monospilus*, have been already mentioned. *Dadaya macrops* (Sars, 1901), from South America and Ceylon, has a very large eye and an eye-spot fully as large, but it is a very small creature, odd in its behaviour, moving by jumps at the very surface of the water. "To the naked eye it looked like a little black atom darting about in a most wonderful manner."

The Gymnomera, with a carapace too small to cover the feet, which are all prehensile, are divided also into two tribes, the Onychopoda, in which the four pairs of feet have a toothed maxillary process at the base, and the Haplopoda, in which there are six pairs of feet, without such a process. To the Polyphemidæ, the well-known family of the former tribe, Sars in 1897 added two remarkable genera, *Cercopagis*, meaning "tail with a sling," and *Apagis*, "without a sling," for seven species from the Sea of Azov. The Haplopoda likewise have but a single family, the Leptodoridæ, and this has but the single genus *Leptodora* (Lilljeborg, 1861). Dr Richard (1895, 1896) gives a Cladoceran bibliography of 601 references.

Branchiura.—This term was introduced by Thorell in 1864 for the Argulidæ, a family which had been transferred to the Branchiopoda by Zenker in 1854, though sometimes before and since united with the parasitic Copepoda. Though the animals have an oral siphon, they do not carry ovisacs like the siphonostomous copepods, but glue their eggs in rows to extraneous objects. Their lateral, compound, feebly movable eyes agree with those of the Phyllopoda. The family are described by Claus as "intermittent parasites," because when gorged they leave their hosts, fishes or frogs, and swim about in freedom for a considerable period. The long-known *Argulus* (O. F. Müller) has the second maxillæ transformed into suckers, but in *Dolops* (Audouin, 1837) (Fig. 1), the name of which supersedes the more familiar *Gyropeltis* (Heller, 1857), these effect attachment by ending in strong hooks (Bouvier, 1897). A third genus, *Chonopeltis* (Thiele, 1900), has suckers, but has lost its first antennæ, at least in the female.

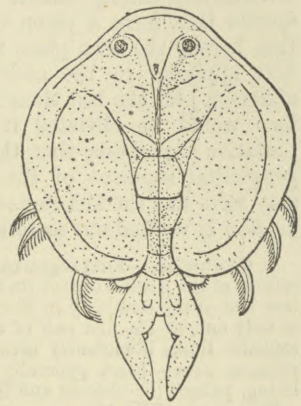


FIG. 1.—*Dolops ranarum* (Stuhlmann).

OSTRACODA.—The body, seldom in any way segmented, is wholly encased in a bivalved shell, the caudal part strongly inflexed, and almost always ending in a furca. The limbs, including antennæ and mouth organs, never exceed seven definite pairs. The first antennæ never have more than eight joints. The young usually pass through several stages of development after leaving the egg, and this commonly after, even long after, the egg has left the maternal shell. Parthenogenesis is frequent.

The four tribes instituted by Sars in 1865 were reduced to two by G. W. Müller in 1894, the Myodocopa, which almost always have a heart, and the Podocopa, which have none.

Myodocopa.—These have the furcal branches broad, lamellar, with at least three pairs of strong spines or ungues. Almost always the shell has a rostral sinus. Müller divides the tribe into three families, Cypridinidæ, Halocypridæ, and the heartless Polycopidæ, which constituted the tribe Cladocopa of Sars. From the first of these Brady and Norman distinguish the Asteropidæ (Fig. 3), remarkable for seven pairs of long branchial leaves which fold over the hinder extremity of the animal, and the Sarsiellidæ, still somewhat obscure, besides adding the Rutidermatidæ, knowledge of which is based on skilful maceration of minute and long-dried specimens. The Halocypridæ are destitute of compound lateral eyes, and have the sexual orifice unsymmetrically placed.

Podocopa.—In these the furcal branches are linear or rudimentary, the shell is without rostral sinus, and, besides distinguishing characters of the second antennæ, they have always a branchial plate well developed on the first maxillæ, which is inconstant in the other tribe. There are five families:—(*a*) Cyprididæ (? including Cypridopsidæ of Brady and Norman). In some of the genera parthenogenetic propagation is carried to such an extent that of the familiar *Cypris* it is said, "until quite lately males in this genus were unknown; and up to the present time no male has been found in the British Islands" (Brady and Norman, 1896). On the other hand, the ejaculatory duct with its verticillate sac in the male of *Cypris* and other genera is a feature scarcely less remarkable. (*b*) Bairdiidæ, which have the valves smooth, with the hinge untoothed. (*c*) Cytheridæ (? including Paradoxostomatidæ of Brady and Norman), in which the valves are usually sculptured, with toothed hinge. Of this family the members are almost exclusively marine, but *Limnicythere* is found in fresh water, and *Xestoleberis bromeliarum* (Fritz Müller) lives in the water that collects among the leaves of Bromelias, plants allied to the pine-apples. (*d*) Darwinulidæ, including the single species *Darwinula stevensoni*, Brady and Robertson, described as "perhaps the most characteristic Entomostracan of the East Anglian Fen District." (*e*) Cytherellidæ, which, unlike the Ostracoda in general, have the hinder part of the body segmented, at least ten segments being distinguishable in the female. They have the valves broad at both ends, and were placed by Sars in a separate tribe, called Platycopa.

The range in time of the Ostracoda is so extended that, in G. W. Müller's opinion, their separation into the families now living may have already taken place in the Cambrian period. Their range in space, including carriage by birds, may be coextensive with the distribution of water, but it is not known what height of temperature or how much chemical adulteration of the water they can sustain, how far they can penetrate underground, nor what are the limits of their activity between the floor and the surface of aquatic expanses, fresh or saline. In individual size they have never been important, and of living forms the largest is one of recent discovery, *Crossophorus africanus*, a Cypridinid about three-fifths of an inch, 15·5 mm. long; but a length of one or two millimetres is more common, and it may descend to the seventy-fifth of an inch. By multitude they have been, and still are, extremely important.

Though the exterior is more uniform than in most groups of crustacea, the bivalved shell or carapace may be strongly calcified and diversely sculptured (Fig. 2), or membranaceous and polished, hairy or smooth, oval or round or bean-shaped, or of some less simple pattern; the valves may fit neatly, or one overlap the other, their hinge may have teeth or be edentulous, and their front part may be excavated for the protrusion of the antennæ or have no such "rostral sinus." By various modifications of their valves and appendages the creatures have become adapted for swimming, creeping, burrowing, or climbing, some of them combining two or more of these activities, for which their structure seems at the first glance little adapted. Considering the imprisonment of the ostracod body within the valves, it is more surprising that the Asteropidæ and Cypridinidæ should have a pair of compound and sometimes large eyes, in addition to the median organ at the base of the "frontal tentacle," than that other members of the group should be limited to that median organ of sight, or have no eyes at all. The median eye when present may have or not have a lens, and its three pigment-cups may be close together or wide apart and the middle one rudimentary. As might be expected, in thickened and highly embossed valves thin spaces occur over the visual organ. The frontal organ varies in form and apparently in function, and is sometimes absent. The first antennæ, according to the family, may assist in walking, swimming, burrowing, climbing, grasping, and besides they carry sensory setæ, and sometimes they have suckers on their setæ (see Brady and Norman on *Cypridina norvegica*). The second antennæ are usually the chief motor-organs for swimming, walking, and climbing. The mandibles are normally five-jointed, with remnants of an outer branch on the second joint, the biting edge varying from strong development to evanescence, the terminal joints or "palp" giving the organ a leg-like appearance and function, which disappears in suctorial genera such as *Paracytherois*. The variable first maxillæ are seldom pediform, their function being concerned chiefly with nutrition, sensation, and respiration. The variability in form and function of the second maxillæ is sufficiently shown by the fact that G. W. Müller, our leading authority, adopts the confusing plan of calling them second maxillæ in the Cypridinidæ (including Asteropidæ), maxillipeds in the Halocypridæ and Cyprididæ, and first legs in the Bairdiidæ, Cytheridæ, Polycopidæ, and Cytherellidæ, so that in his fine monograph he uses the term first leg in two quite different senses. The first legs, meaning thereby the sixth pair of appendages, are generally pediform and locomotive, but sometimes unjointed, acting as a kind of brushes to cleanse the furca, while in the Polycopidæ they are entirely wanting. The second legs are sometimes wanting, sometimes pediform and locomotive, sometimes strangely metamorphosed into the "vermiform organ," generally long, many-jointed, and distally armed with retroverted spines, its function being that of an extremely mobile cleansing foot, which can insert itself among the eggs in the brood-space, between the branchial leaves of *Asterope* (Fig. 3), and even range over the external surface of the valves. The "brush-formed" organs of the Podocopa are medially placed, and, in spite of their sometimes forward situation, Müller believes

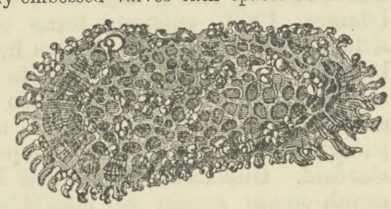


FIG. 2.—*Cythereis ornata* (G. W. Müller). One eye-space is shown above on the left.

among other possibilities, that they and the penis in the Cypridinidæ may be alike remnants of a third pair of legs, not homologous with the penis of other Ostracoda (Podocopa included). The furca is, as a rule, a powerful motor organ, and has its laminæ edged with strong teeth (ungues) or setæ, or both. The young, though born with valves, have at first a nauplian body, and pass through various stages to maturity.

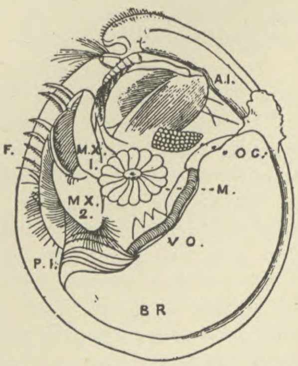


FIG. 3.—*Asterope arthuri*. Left valve removed. M, end of adductor muscle; OC, eye; AI, second antenna; MX. 1, first maxilla; MX. 2, second maxilla; P. 1, first foot; BR, seven branchial leaves; F, projecting ungues of the furca.

Brady and Norman, in their *Monograph of the Ostracoda of the North Atlantic and North-Western Europe*, 1889, give a bibliography of 125 titles, and in the second part, 1896, they give 55 more. The lists are not meant to be exhaustive, any more than G. W. Müller's literature-list of 125 titles in 1894. They do not refer to Latreille, 1802, with whom the term Ostracoda originates.

COPEPODA.—The body is not encased in a bivalved shell; its articulated segments are at most eleven, those behind the genital segment being without trace of limbs, but the last almost always carrying a furca. Sexes separate, fertilization by spermatophores. Ova in single or double or rarely several packets, attached as ovisacs or egg-strings to the genital openings, or enclosed in a dorsal marsupium, or deposited singly or occasionally in bundles. The youngest larvæ are typical nauplii. The next, the copepodid or cyclopid, stage is characterized by a cylindrical segmented body, with fore- and hind-body distinct, and by having at most six cephalic limbs and two pairs of swimming-feet.

The order thus defined (see Giesbrecht and Schmeil, *Das Tierreich*, 1898), with far over a thousand species (Hansen, 1900), embraces forms of extreme diversity, although, when species are known in all their phases and both sexes, they constantly tend to prove that there are no sharply dividing lines between the free-living, the semi-parasitic, and those which in adult life are wholly parasitic and then sometimes grotesquely unlike the normal standard. Giesbrecht and Hansen have shown that the mouth-organs consist of mandibles, first and second maxillæ, and maxillipeds; and Claus himself relinquished his long-maintained hypothesis that the last two pairs were the separated exopods and endopods of a single pair of appendages. Thorell's classification (1859) of Gnathostoma, Pœcilostoma, Siphonostoma, based on the mouth-organs, was long followed, though almost at the outset shown by Claus to depend on the erroneous supposition that the Pœcilostoma were devoid of mandibles. Brady added a new section, Choniostomata, in 1894, and another, Leptostomata, in 1900, each for a single species. Canu in 1892 proposed two groups, Monoporodelphya and Diporodelphya, the copulatory openings of the female being paired in the latter, unpaired in the former. It may be questioned whether this distinction, however important in itself, would lead to a satisfactory grouping of families. In the same year Giesbrecht proposed his division of the order into Gymnoplea and Podoplea.

In appearance an ordinary Copepod is divided into fore- and hind-body, of its eleven segments the composite first being the head, the next five constituting the thorax, and the last five the abdomen. The coalescence of segments, though frequent, does not after a little experience materially confuse the counting. But there is this peculiarity, that the middle segment is sometimes continuous with the broader fore-body, sometimes with the narrower hind-body. In the former case the hind-body, consisting only of the abdomen, forms a pleon or tail-part devoid of feet, and the species so constructed are Gymnoplea, those of the naked or footless pleon. In the latter case the middle segment almost always carries with it to the hind-body a pair of rudimentary limbs, whence the term Podoplea, meaning species that have a pleon with feet. It may be objected that hereby the term pleon is used in two different senses, first applying to the abdomen alone and then to the abdomen plus the last thoracic segment. Even this verbal flaw would be obviated if Giesbrecht could prove his tentative hypothesis, that the Gymnoplea may have lost a pre-genital segment of the abdomen, and the Podoplea may have lost the last segment of the thorax. The classification is worked out as follows:—

1. *Gymnoplea.*—First segment of hind-body footless, bearing the orifices of the genital organs (in the male unsymmetrically placed); last foot of the fore-body in the male a copulatory organ; neither, or only one, of the first pair of antennæ in the male geniculating; cephalic limbs abundantly articulated and provided with many plumose setæ; heart generally present. Animals usually free-living, pelagic (Giesbrecht and Schmeil).

This group, with 65 genera and four or five hundred species, is divided by Giesbrecht into tribes:—(*a*) Amphaskandria. In this tribe the males have both antennæ of the first pair as sensory organs. There is but one family, the Calanidæ, but this is a very large one, with 26 genera and more than 100 species. Among them is the cosmopolitan *Calanus finmarchicus*, the earliest described (by Bishop Gunner in 1770) of all the marine free-swimming Copepoda. Among them also is the peacock Calanid, *Calocalanus*

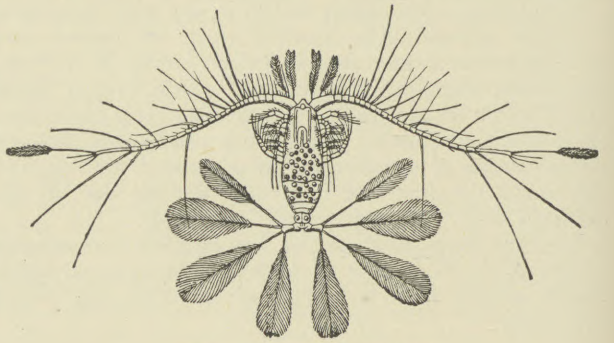
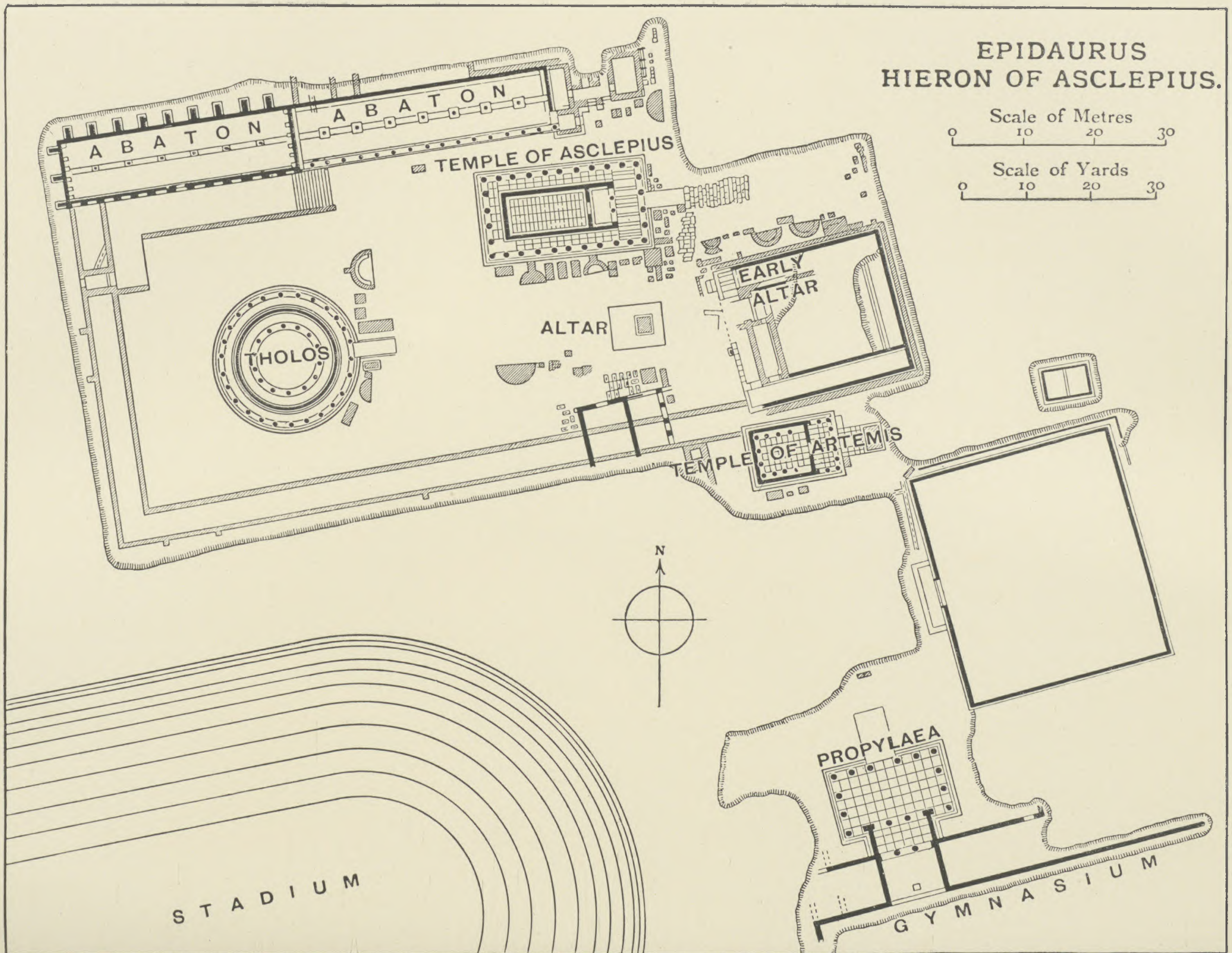


FIG. 4.—*Calocalanus pavo* (Dana).

pavo (Dana), with its highly ornamented antennæ and gorgeous tail, the most beautiful species of the whole order (Fig. 4). (*b*) Heterarthrandria. Here the males have one or the other of the first pair of antennæ modified into a grasping organ for holding the female. There are four families, the Diaptomidæ with 27 genera, the Pontellidæ with 10, the Pseudocyclopidæ and Candaciidæ each with one genus. The first of these families is often called Centropagidæ, but, as Sars has pointed out, *Diaptomus* (Westwood, 1836) is the oldest genus in it. Of 177 species valid in the family Giesbrecht and Schmeil assign 67 to *Diaptomus*. In regard to one of its species Dr Brady says: "in one instance, at least (Talkin Tarn, Cumberland), I have seen the net come up from a depth of 6 or 8 feet below the surface with a dense mass consisting almost entirely of *D. gracilis*." The length of this net-filling species is about a twentieth of an inch.

2. *Podoplea.*—The first segment of the hind-body almost always with rudimentary pair of feet; orifices of the genital organs (symmetrically placed in both sexes) in the following segment; neither the last foot of the fore-body nor the rudimentary feet just mentioned acting as a copulatory organ in the male; both or neither of the first pair of antennæ in the male geniculating; cephalic limbs less abundantly articulated and with fewer plumose setæ or none, but with hooks and clasping setæ. Heart almost always wanting. Free-living (rarely pelagic) or parasitic (Giesbrecht and Schmeil).

This group is also divided by Giesbrecht into two tribes, Ampharthrandria and Isokerandria. In 1892 he distinguished the former as those in which the first antennæ of the male have both members modified for holding the female, and the genital openings of the female have a ventral position, sometimes in close proximity, sometimes strongly lateral; the latter as those in which the first antennæ of the male are similar to those of the female, the function of holding her being transferred to the male maxillipeds, while the genital openings of the female are dorsal,



Walker & Cockerell sc.

though at times strongly lateral. In 1899, with a view to the many modifications exhibited by parasitic and semi-parasitic species, the definitions, stripped of a too hampering precision, took a different form :—(*a*) Ampharthrandria. "Swimming Podoplea with geniculating first antennæ in the male sex, and descendants of such ; first antennæ in female and male almost always differently articulated." The families occupy fresh water as well as the sea. Naturally "descendants" which have lost the characteristic feature of the definition cannot be recognized without some further assistance than the definition supplies. Of the families comprised, the Mormonillidæ consist only of *Mormonilla* (Giesbrecht), and are not mentioned by Giesbrecht in 1899 in the grouping of this section. The Thaumatoessidæ include *Thaumatoessa* (Kröyer), established earlier than its synonym *Thaumaleus* (Kröyer), or than *Monstrilla* (Dana, 1849). The species are imperfectly known. The defect of mouth-organs probably does not apply to the period of youth, which some of them spend parasitically in the body-cavity of worms (Giard, 1896). To the Cyclopidæ six genera are allotted by Giesbrecht in 1900. *Cyclops* (O. F. Müller, 1776), though greatly restricted since Müller's time, still has several scores of species abundantly peopling inland waters of every kind and situation, without one that can be relied on as exclusively marine like the species of *Oithona* (Baird). The Misophriidæ are now limited to *Misophria* (Boeck). The presence of a heart in this genus helps to make it a link between the Podoplea and Gymnoplea, though in various other respects it approaches the next family. The Harpacticidæ owe their name to the genus *Arpacticus* (Milne-Edwards, 1840). Brady in 1880 assigns to this family 33 genera and 81 species. Canu (1892) distinguishes eight sub-families, Longipediinæ, Peltidiinæ, Tachidiinæ, Amymoninæ, Harpacticinæ, Idyinæ, Canthocamptinæ (for which Canthocampinæ should be read), and Nannopinæ, adding Stenheliinæ (Brady) without distinctive characters for it. The Ascidicolidæ have variable characters, showing a gradual adaptation to parasitic life in Tunicates. Giesbrecht (1900) considers Canu quite right in grouping together in this single family those parasites of ascidians, simple and compound, which had been previously distributed among families with the more or less significant names Notodelphyidæ, Doropygidæ, Buproridæ, Schizoproctidæ, Kossmechtridæ, Enterocolidæ, Enteropsidæ. Further, he includes in it his own *Enterognathus comatulæ*, not from an ascidian, but from the intestine of the beautiful starfish *Antedon rosaceus*. The Asterocheridæ, which have a good swimming capacity, except in the case of *Cancerilla tubulata* (Dalyell), lead a semi-parasitic life on echinoderms, sponges, &c., imbibing their food. Giesbrecht, displacing the older name Ascomyzontidæ, assigns to this family 21 genera in five subfamilies, and suggests that the long-known but still puzzling *Nicothoë* from the gills of the lobster might be placed in an additional subfamily, or be made the representative of a closely related family. The Dichelestiidæ, on account of their sometimes many-jointed first antennæ, are referred also to this tribe by Giesbrecht. (*b*) Isokerandria. "Swimming Podoplea without geniculating first antennæ in the male sex, and descendants of such. First antennæ of male and female almost always articulated alike." To this tribe Giesbrecht assigns the families Clausidiidæ, Corycæidæ, Oncæidæ, Lichomolgidæ, Ergasilidæ, Bomolochidæ, Clausiidæ, Nereicolidæ. Here also must for the time be placed the Caligidæ, Philichthyidæ (Philichthydæ of Vogt, Carus, Claus), Lernæidæ, Chondracanthidæ, Sphæronellidæ (better known as Choniostomatidæ, from H. J. Hansen's remarkable study of the group), Lernæopodidæ, Herpyllobiidæ, Entomolepidæ. For the distinguishing marks of all these, the number of their genera and species, their habits and transformations and dwellings, the reader must be referred to the writings of specialists. Sars (1901) proposed seven suborders—Calanoida, Harpacticoida, Cyclopoida, Notodelphoida, Monstrilloida, Caligoida, Lernæoida.

AUTHORITIES.—(The earlier memoirs of importance are cited in GIESBRECHT's *Monograph of Naples*, 1892).—CANU. "Hersiliidæ," *Bull. Sci. France Belgique*, ser. 3, vol. i. p. 402, 1888 ; and *Les Copépodes du Boulonnais*, 1892.—CUENOT. *Rev. biol. Nord France*, vol. v. 1892.—GIESBRECHT. "Pelag. Copepoden," *F. u. Fl. des Golfes von Neapel*, Mon. 19, 1892.—HANSEN. *Entomol. Med.* vol. iii. pt. 5, 1892.—I. C. THOMPSON. "Copepoda of Liverpool Bay," *Trans. Liv. Biol. Soc.* vol. vii. 1893.—SCHMEIL. "Deutschlands Copepoden," *Bibliotheca Zoologica*, 1892–1897.—BRADY. *Journ. R. Micr. Soc.* p. 168, 1894.—T. SCOTT. "Entomostraca from the Gulf of Guinea," *Trans. Linn. Soc. London*, vol. vi. pt. 1, 1894.—GIESBRECHT. *Mitteil. Zool. Stat. Neapel*, vol. xi. p. 631 ; vol. xii. p. 217, 1895.—T. and A. SCOTT. *Trans. Linn. Soc. London*, ser. 2, vol. vi. p. 419, 1896.—HANSEN. "Choniostomatidæ," 1897.—SARS. *Proc. Mus. Zool. St Petersburg*, "Caspian Entomostraca," 1897.—GIESBRECHT and SCHMEIL, "Copepoda gymnoplea," *Das Tierreich*, 1898.—GIESBRECHT. "Asterocheriden," *F. u. Fl. Neapel*, Mon. 25, 1899.—BASSETT-SMITH. "Copepoda on Fishes," *Proc. Zool. Soc. London*, p. 438, 1899.—BRADY. *Trans. Zool. Soc. London*, vol. xv. pt. 2, p. 31, 1899.—SARS. *Arch. Naturv.* vol. xxi. No. 2, 1899.—GIESBRECHT. *Mitteil. Zool. Stat. Neapel*, vol. xiv. p. 39, 1900.—SCOTT. "Fish Parasites," *Scottish Fishery Board*, 18th Ann. Rep. p. 144, 1900.—STEBBING. *Willey's Zool. Results*, pt. 5, p. 664, 1900.—EMBLETON. *Journ. Linn. Soc. London*, vol. xxviii. p. 211, 1901.—SARS. *Crustacea of Norway*, vol. iv., 1901.

(T. R. R. S.)

Entre Rios, a province in the east of the Argentine Republic, bounded to the N. by Corrientes, to the S. by Buenos Ayres, to the E. by Uruguay, and to the W. by Santa Fé. Area, 28,784 miles. Population, about 300,000. The province is divided into 14 departments. The capital, Paraná, has a population of 24,098.

Enzymes. See PHYSIOLOGY OF PLANTS.

Epidaurus.—*Recent Archæological Discoveries.*—The Hieron of Asclepius, which lies inland about 8 miles from the town of Epidaurus, has been thoroughly excavated by the Greek Archæological Society since the year 1881, under the direction of M. Cavvadias. In addition to the sacred precinct, with its temples and other buildings, the theatre and stadium have been cleared; and several other extensive buildings, including baths, gymnasia, and a hospital for invalids, have also been found. The sacred road from Epidaurus, which is flanked by tombs, approaches the precinct through a gateway or propylæa. The chief buildings are grouped together, and include temples of Asclepius and Artemis, the Tholos, and the Abaton, or portico where the patients slept. In addition to remains of architecture and sculpture, some of them of high merit, there have been found many inscriptions, throwing light on the cures attributed to the god. The chief buildings outside the sacred precinct are the theatre and the stadium.

The temple of Asclepius, which contained the gold and ivory statue by Thrasymedes of Paros, had six columns at the ends and eleven at the sides; it was raised on stages and approached by a ramp at the eastern front. An inscription has been found recording the contracts for building this temple; it dates from about 460 B.C. The sculptor Timotheus—one of those who collaborated in the Mausoleum—is mentioned as undertaking to make the acroteria that stood on the ends of the pediments, and also models for the sculpture that filled one of them. Some of this sculpture has been found; the acroteria are Nereids mounted on sea-horses, and one pediment contained a battle of Greeks and Amazons. The great altar lay to the south of the temple, and a little to the east of it are what appear to be the remains of an earlier altar, built into the corner of a large square edifice of Roman date, perhaps a house of the priests. Just to the south of this are the foundations of a small temple of Artemis. The Tholos lay to the south-west of the temple of Asclepius; it must, when perfect, have been one of the most beautiful buildings in Greece; the exquisite carving of its mouldings is only equalled by that of the Erechtheum at Athens. It consisted of a circular chamber, surrounded on the outside by a Doric colonnade, and on the inside by a Corinthian one. The architect was Polyclitus, probably to be identified with the younger sculptor of that name. In the inscription recording the contracts for its building it is called the Thymele; and this name may give the clue to its purpose; it was probably the idealized architectural representative of a primitive pit of sacrifice, such as may still be seen in the Asclepianum at Athens. The foundations now visible present a very curious appearance, consisting of a series of concentric walls. Those in the middle are thin, having only the pavement of the cella to support, and are provided with doors and partitions that make a sort of subterranean labyrinth. There is no evidence for the statement sometimes made that there was a well or spring below the Tholos. North of the Tholos is the long portico described in inscriptions as the Abaton; it is on two different levels, and the lower or western portion of it had two storeys, of which the upper one was on a level with the ground in the eastern portion. Here the invalids used to sleep when consulting the god, and the inscriptions found here record not only the method of consulting the god, but the manner of his cures. Some of the inscriptions are contemporary dedications; but those which give us most information are long lists of cases, evidently compiled by the priests from the dedications in the sanctuary, or from tradition. There is no reason to doubt that most of the records have at least a basis of fact, for the cases are in accord with well-attested phenomena of a similar nature at the present day; but there are others, such as the miraculous mending of a broken vase, which suggest either invention or trickery.

In early times, though there is considerable variety in the cases treated and the methods of cure, there are certain characteristics common to the majority of the cases. The patient consulting the god sleeps in the Abaton, sees certain visions, and, as a result, comes forth cured the next morning. Sometimes there seem to be surgical cases, like that of a man who had a spear-head extracted from his jaw, and found it laid in his hands when he awoke in the morning, and there are many examples resembling those known at the present day at Lourdes or Tenos, where hysterical or other similar affections are cured by the influence of imagination or sudden emotion. It is, however, difficult to make any scientific use of the records, owing to the indiscriminate manner in which genuine and apocryphal cases are mingled, and circumstantial details are added. We learn the practice of later times from some dedicated inscriptions. Apparently the old faith-healing had lost its efficacy, and the priests substituted for it elaborate prescriptions as to diet, baths, and regimen which must have made Epidaurus and its visitors resemble their counterparts in a modern spa. At this time there were extensive buildings provided for the accommodation of invalids, some of which have been discovered and partially cleared; one was built by Antoninus Pius. They were in the form of great courtyards surrounded by colonnades and chambers.

Between the precinct and the theatre was a large gymnasium, which was in later times converted to other purposes, a small odeum being built in the middle of it. In a valley just to the south-west of the precinct is the stadium, of which the seats and goal are well preserved. There is a gutter round the level space of the stadium, with basins at intervals for the use of spectators or competitors, and a post at every hundred feet of the course, thus dividing it into six portions. The goal, which is well preserved at the upper end, is similar to that at Olympia; it consists of a sill of stone sunk level with the ground, with parallel grooves for the feet of the runners at starting, and sockets to hold the posts to which were fixed the strings that separated the tracks assigned to the various competitors. For these were submitted later a set of stone columns resembling those in the proscenium of a theatre. There was doubtless a similar sill at the lower end for the start of the stadium, this upper one being intended for the start of the diaulos and longer races.

The theatre still deserves the praise given it by Pausanias as the most beautiful in Greece. The auditorium is in remarkable preservation, almost every seat being still *in situ*, except a few where the supporting walls have given way on the wings. The whole plan is drawn from three centres, the outer portion of the curves being arcs of a larger circle than the one used for the central portion; the complete circle of the orchestra is marked by a sill of white limestone, and greatly enhances the effect of the whole. There are benches with backs not only in the bottom row, but also above and below the diazoma. The acoustic properties of the theatre are extraordinarily good, a speaker in the orchestra being heard throughout the auditorium without raising his voice. The stage buildings are not preserved much above their foundations, and show signs of later repairs; but their general character can be clearly seen. They consist of a long rectangular building, with a proscenium or column front which almost forms a tangent to the circle of the orchestra; at the middle and at either end of this proscenium are doors leading into the orchestra, those at the end set in projecting wings; the top of the proscenium is approached by a ramp, of which the lower part is still preserved, running parallel to the parodi, but sloping up as they slope down. The proscenium was originally about 14 feet high and 12 feet broad; so corresponding approximately to the Greek stage as described by Vitruvius. M. Cavvadias, who excavated the theatre, believes that the proscenium is contemporary with the rest of the theatre, which, like the Tholos, was built by Polyclitus (the younger); but Professor Dörpfeld maintains that it is a later addition. In any case, the theatre at Epidaurus ranks as the most typical of Greek theatres, both from the simplicity of its plan and the beauty of its proportions.

The excavations at Epidaurus have been recorded as they went on in the Πρακτικὰ of the Greek Archæological Society, especially for 1881–84 and 1889, and also in the Ἐφημερὶς Ἀρχαιολογική, especially for 1883 and 1885; see also Cavvadias, *Les fouilles d'Épidaure* and Τὸ Ἱερὸν τοῦ Ἀσκληπιοῦ ἐν Ἐπιδαύρῳ καὶ ἡ θεράπεια τῶν ἀσθενῶν; Defrasse and Lechat, *Épidaure*. (E. GR.)

Epsom, a market-town in the Epsom parliamentary division of Surrey, England, 15 miles south-west by south of London by rail. Recent erections are Christ Church (rebuilt), a town-hall, a cottage hospital, and a technical and art school. The Royal Medical Benevolent College has been enlarged. Area of urban district, 4424 acres. Population (1881), 6916; (1901), 10,915.

Erckmann-Chatrian, the joint names of two French writers whose collaboration made their work that of, so to speak, one personality. Émile Erckmann was born in 1822 at Phalsbourg, and Alexandre Chatrian in 1826 at Soldatenthal, Lorraine. In 1847 they began to write together, and continued doing so till 1889. Chatrian died in 1890 at Villemomble, and Erckmann at Lunéville in 1899. The list of their publications is a long one, ranging from *L'illustre docteur Mathéus* (1859), *L'ami Fritz* (1864), *Histoire d'un conscrit de 1813* (1864), *Waterloo* (1865), *Le blocus* (1867), *Histoire d'un Paysan* (1868), *L'histoire d'un plébiscite* (1872), to *Le grand-père Lebigre* (1880); besides dramas like *Le Juif Polonais* (1869), and *Les Rantzau* (1882). Without any special literary claim, their stories are distinguished by simplicity and genuine descriptive power, particularly in the battle scenes and in connexion with Alsatian peasant life, and also by their democratic spirit, to which was added, after the war of 1870, a markedly anti-German feeling.

Erdmann, Johann Eduard (1805–1892), German philosophical writer, was born at Wolmar in Livonia, 13th June 1805. He studied theology at Dorpat and afterwards at Berlin, where he fell under the influence of Hegel. From 1829 to 1832 he was a minister of religion in his native town; then finally resolved to devote himself to philosophy, and qualified in that subject at Berlin in 1834. In 1836 he was professor-extraordinary at Halle, became full professor in 1839, and died there 12th June 1892. He published many philosophical textbooks and treatises, and a number of sermons; but his chief claim to remembrance rests on his *Darstellung der Geschichte der Philosophie*, 3 vols. (1834–53), which has been translated into English, and is still the best work of the kind. Erdmann's special merit is that he does not rest content with being a mere summarizer of opinions, but tries to exhibit the history of human thought as a continuous and ever-developing effort to solve the great speculative problems with which man has been confronted in all ages. (H. ST.)

Erfurt, a town of Prussia, province of Saxony, 73 miles by rail south-west from Leipzig and 14 miles west from Weimar. On the west and south-west extensive new quarters have grown up within recent years—*e.g.*, Hirschbrühl. The town-hall (1869–75) has been adorned with legendary and historical pictures by Kämpffer and Janssen. Erfurt possesses also a picture gallery, library, antiquarian collection (in the hospital), musical academy, agricultural school, commercial school, and shoemaking school; also, a monument to Luther (1890). On the west side the old town is dominated by the two citadels of Petersberg and Cyriaxburg. The chief industry is still market-gardening and the production of vegetable and flower seeds. There is also a trade of some magnitude. Population (1885), 58,386; (1900), 85,828.

Erichsen, Sir John Eric, Bart. (1818–1896), British surgeon, born 19th July 1818, was the son of Eric Erichsen, a member of a well-known Danish family. He studied medicine at University College, London, and at Paris, devoting himself in the early years of his career to physiology, and lecturing on General Anatomy and Physiology at University College Hospital. In 1844 he was secretary to the Physiological Section of the British Association, and in 1845 he was awarded the Fothergillian Gold Medal of the Royal Humane Society for his essay on Asphyxia. In 1848 he was appointed Assistant Surgeon at University College Hospital, and in 1856 became full Surgeon, his lectures and clinical teaching being much admired; and in 1875 he joined the Consulting Staff. His *Science and Art of Surgery* (1853) went through many editions. He rose to be President of the College of Surgeons in 1880. From 1879 to 1881 he was President of the Royal Medical and Chirurgical Society. He was created a baronet in 1895, having been for some years Surgeon-Extraordinary to Queen Victoria. As a surgeon his reputation was world-wide, and he counts (says Sir W. MacCormac in his volume on the Centenary of the Royal College of Surgeons) "among the masters of modern surgery." He was a recognized authority on concussion of the spine, and was often called to give evidence in court on obscure cases caused by railway accidents, &c. He died 23rd September 1896.

Ericsson, John (1803–1889), naval engineer, was born at Langbanshyttan, Wermland, Sweden, on the 31st July 1803. He was the second son of Olaf Ericsson, an inspector of mines. Showing from his earliest years a strong mechanical bent, at the age of nine he was already skilled in the use of drawing instruments, and had made a very ingenious working model of a saw mill driven by water-power. At twelve he was employed as a draughtsman by the Swedish Canal Company, and at thirteen as an assistant leveller. The death of his father in 1818 left the family in very straitened circumstances; and though from 1820 to 1827 young Ericsson served in the army and attained the rank of captain, he was all the time working also as a draughtsman, and occupying his leisure with projects of invention. In 1826 he went to London, at first on leave of absence from his regiment, and in partnership with John Braithwaite constructed the "Novelty," a locomotive engine for the Liverpool and Manchester Railway competition at Rainhill in 1829, when the prize was won by Stephenson's "Rocket." In 1830 the firm constructed a steam fire-engine, which was proved at different fires to be effective, though prejudice for the time prevented it from coming into general use. The number of Ericsson's inventions at this period was very great. Among other things he worked out a plan for marine engines placed entirely below the water-line. Such engines were made for the *Victory*, for Captain Ross's voyage to the Arctic in 1829, but they did not prove satisfactory. In 1833 his caloric engine was made public. In 1836 he took out a patent for a screw-propeller, and though the priority of his invention could not be maintained, he was afterwards awarded a one-fifth share of the £20,000 given by the Admiralty for it. At this time he made the acquaintance of Captain Stockton, of the United States Navy, who gave an order for a small iron vessel to be built by Laird of Birkenhead, and to be fitted by Ericsson with engines and screw. This vessel reached New York in May 1839, thus giving a practical proof of the possibility of screw propulsion in the open sea. A few months later Ericsson followed his steamer to New York, and there he resided for the rest of his life, establishing himself as an engineer and a builder of iron ships. In 1848 he was naturalized as a citizen of the United States. He had many difficulties to contend with; he quarrelled with Stockton, for whom he had worked on an "understanding" without any definite agreement, and the Government denied his claims and left him a loser both in money and in credit. It was only by slow degrees that he established his fame and won his way to competence. Fortune, as it is understood in the United States, he never reached; at his death he seems to have been worth about £50,000. He was always busy over new ideas, attempting the solution of problems which were engaging the attention of many others. At one of these, the provision of defensive armour for ships of war, he had long worked, and had constructed plans and a model of a vessel lying low in the water, carrying one heavy gun in a circular turret mounted on a turn-table. His priority in this idea seems established. In 1854 he sent his design to the Emperor of the French, hoping that it might prove of use against the Russians, whom he regarded as the natural enemies of his native country. Louis Napoleon returned the plans with thanks, but declined to use them, being guided in this, we may suppose, by the skilled opinion of Dupuy de Lôme. They were then put on one side, till the American Civil War, and the report that the Confederates were converting the *Merrimac* into an ironclad, caused the Navy Department to invite proposals for the construction of armoured ships. Among others, Ericsson replied, and as it was thought that his design might be serviceable in inland waters, the first armoured turret ship, the *Monitor*, was ordered; she was launched on the 30th January 1862, and on the 9th March she fought the celebrated action with the Confederate ram *Merrimac*. The peculiar circumstances in which she was built, the tremendous importance of the battle, and the decisive nature of the result gave the *Monitor* an exaggerated reputation, which further experience did not confirm. Other turret ships were built and answered the immediate purpose; nine built for the United States proved of great service during the war, one crossed the Atlantic, and another rounded Cape Horn and reached San Francisco; but as seagoing vessels they were judged unsafe, and are now considered impracticable. Ericsson's work was marked by great ingenuity, but in no case does he seem to have attained an entirely satisfactory result, though his inventions served as finger-posts for others' guidance. In later years he devoted himself to the study of torpedoes and sun motors. He died at New York on 8th March 1889, and in the following year, on the request of the Swedish Government, his body was sent to Stockholm and thence into Wermland, where, at Filipstad, it was buried on the 15th September.

Ericsson's life has been written at length by William Conant Church, who had access to his letters and papers, and was personally acquainted both with him and his most intimate associates.

(J. K. L.)

Erie, capital of Erie county, Pennsylvania, U.S.A., in 42·07° N. lat. and 80·10° W. long., on the shore of Lake Erie, at an altitude of 684 feet. It is the only lake port of Pennsylvania, and has a large lake commerce, in grain, lumber, and iron ore as imports, and coal as an export. It is entered by four railways, the Lake Shore and Michigan Southern, the New York, Chicago, and St Louis, the Pennsylvania, and the Pittsburg, Bessemer, and Lake Erie, which give it great importance in inland traffic. It has an excellent water supply and sewerage system, and it is divided into six wards; the streets of the central part are paved with brick and asphalt. Its manufactures had in 1890 a capital of $12,800,000, employed 7029 hands, and had products valued at $12,765,768. One-third of these were foundry and machine-shop products, besides which flour and lumber were of great importance. The assessed valuation of property, real and personal, was, in 1900, $19,657,488; the net debt was but $765,040, and the rate of taxation was $24.00 per $1000. Population (1880), 27,737; (1900), 52,733. Death-rate (1900), 15·2.

Erith, a town in the Dartford parliamentary division of Kent, England, on the Thames, 14 miles east-south-east of London by rail. The churches are two Established, one ancient in Early English and later styles of architecture, containing ancient monuments and brasses, Roman Catholic, and various Nonconformist chapels. There is a public hall, a recreation ground (12 acres), and a sanatorium for infectious diseases. In the parish are the southern outfall works of the metropolitan main drainage system. The town has large engineering works and gun factories, and in the neighbourhood are powder works. Area of civil parish (an urban district), 3860 acres. Population (1881), 9812; (1901), 25,296.

Eritrea.—Under this name, which Italian taste for classical reminiscences resuscitated at the beginning of 1890, are designated the Italian possessions on the west coasts of the Red Sea and on the most northerly spurs of the Ethiopian high plateau. Originally the name covered both the territories really occupied and those over which a protectorate was claimed, but now Italy exercises suzerainty over all. It extends on the coast from Ras (Cape) Kasar (18° 2′ N. lat.), the limit fixed by the Anglo-Italian agreement of 1887, as far as Ras Dumeira (12° 42′ N. lat.), the southern boundary, settled by the Franco-Italian convention of January 1900, a coast-line of about 620 miles. In the vicinity of Ras Dumeira the territory extends inland for 38 miles, but to the north, towards Abyssinia, its boundary is marked by the torrents Muna and Belesa, and by the river Mareb as far west as the village of Mai Darò, whence it runs in a straight line to Tomat, a hut encampment situated at the confluence of the Setit and the Atbara. Towards the Sudan the frontier, as delimitated by the Anglo-Italian agreements of 1898–99, follows the watershed between the rivers Gash and Barka, and, on approaching the coast, crosses the northern slopes of the Haggar Nush plateau and follows the *Thalweg* of the torrent Carora to Ras Kasar. The Dahlak Archipelago and other groups of islands along the coast belong to Eritrea. The inhabitants of these islands live by fishing for mother-of-pearl, and the pearl-bearing oyster. The control of the fisheries is entrusted to a special company. The total area is about 88,500 square miles. The population is approximately 400,000, of which 1050 are whites, exclusive of soldiers. The inhabitants belong to many different tribes and races, much akin to those of Abyssinia (*q.v.*). Most of the tribes descend more or less directly from Ethiopian stock, and retain evident traces of their origin in their dialects.

Climate.—The climate is varied. The plateau, of which the average height is 6500 feet, but which at places rises to 10,000 feet (Sauria), the valleys of the Anseba and the Barka, and the lower course of the Mareb (or Gash) follow in their seasons the Ethiopian monsoon; some rain falls at the end of April, and abundant rain from June to September. The zone between the sea and 6500 feet has, on the other hand, abundant rain from November till March. At 6500 feet the temperature is mild, and grows cooler with increased altitude until, at 10,000 feet, it becomes almost cold. From the height of 3000 feet downwards the climate is torrid during the greater part of the year, and only becomes tolerable during the winter rains. In this zone malarial fevers prevail in winter. The heat is greatest at Massawa, where the mean temperature averages 88°, but where, in summer, the thermometer often rises to 120° in the shade. In the Barka Valley a like temperature is reached, but there it is rendered less trying by the breeze, the dry atmosphere, and the great difference between the temperatures of day and night.

Crops and Cultivation.—Almost all European cereals flourish on the high plateau, while the olive tree grows at more than 6500 feet, and covers the flanks of the plateau to within 3000 feet of sea-level. Lower down, *dhurra*, maize, and bultuc grow in profusion. Experiments in the cultivation of coffee, tobacco, and cotton have given good results in the intermediate zones. The fauna is similar to that of Abyssinia. Except for a short tract of land near the coast, and the locality of Sheb on the caravan route from Massawa and Monkullo to Keren, no part can be called a desert (atmur); but in the lower regions there are wide tracts, covered with mimosa and acacia trees, forming a kind of jungle which the natives term *khala*. The Danakil, Samhar, and Barka plains are broken by small chains of hills running in various directions; the torrents are covered by dense vegetation, and, especially in the Barka region, by the dum palm; in the dry season water is generally to be found in the torrent beds. The high plateau has a more fertile appearance. It is covered by rich, well-watered valleys, verdant plains and flat-topped hills with steep sides running in ranges or isolated.

Inhabitants.—The Mussulman inhabitants of the lower zone are for the most part semi-nomad shepherds, living on *dhurra* and milk; the inhabitants of the high zone are almost exclusively Coptic Christians with fixed abodes. They are agriculturists, living in round huts or in low, rectangular, flat-roofed houses. The nomad Mussulmans are, as a rule, docile, submissive, and pacific; the Christians, unruly and bellicose. Neither have succeeded in developing industry to any considerable extent, except mat-weaving, some little cotton-weaving, silver-working, and rudimentary iron and leather-working.

Centres of Population.—The principal places *on the coast* are Massawa, a city of more than 12,000 native and European inhabitants, built partly upon an island of the same name, partly on the island of Taudub, and partly on the small peninsula of Gherar and Abd-el-Kader. Formerly seat of the colonial government, it is now only the capital of the region between the sea and the lower slopes of the high plateau. It is well built in brick, is clean, and has considerable trade with the interior and with the other Red Sea ports. Assab, chief town of the Dankali region, is a small town to which converges the trade from Abyssinia across the Aussa country. The chief places *in the interior* are Asmarà, the present capital, formerly capital of the province of Hamasien, and favourite headquarters of Ras Alula. It is situated at nearly 6500 feet above the sea, and is beginning to assume the aspect of a European town. Several reefs of auriferous quartz of good promise have been found around it. Keren, centre of the tribal villages established to the north of the Anseba; Agordat, on the river Barka, a town on the road from Keren to Kassala, the centre of the Beni-Amer, Algheden and Sabdarat tribes; Mogolo, on the lower Mareb, rendezvous of the Barià and Bazà tribes. Towards Abyssinia the chief towns are Saganeiti (capital of the Okulé-Kusai province), Godofelassi and Adi-Ugri, the two latter situated in the fertile plain of the Seraè; Adiqualà, on the edge of the Mareb gorge; and Arrasà, the centre of the districts constituting the province of Deki-Tesfà. The whole territory is crossed by camel- and mule-paths between the sea and the high plateau and between various centres of population. Every valley that brings water to the Red Sea has a route leading to the high plateau. The great arteries, however, can be reasonably reduced to three, which, starting from Massawa by way of Asmarà, run, two to Abyssinia, and one to Kassala and Khartum. They are all more or less practicable for carts, and are flanked by a good telegraph line as long as they lie in Italian territory. The trade is indicated approximately by the Massawa harbour returns, which show an annual traffic (imports and exports) of £1,000,000. At Massawa there is a customs house, with branches at Assab, Edd, Meder, Mersa, Taclai, and Sabdarat.

Administration.—Eritrea is administered by a civil governor with a corps of colonial officers and clerks. It is divided into six provinces, each governed by a regional commissioner. Some tracts of frontier territory are detached from the various regions and entrusted to political residents, as, for instance, on the Abyssinian boundary, where strict surveillance is necessary to repress raiding incursions from Tigrè, and where the chief Intelligence Department is established. The six regions or principal provinces are:—Asmarà, which includes Hamasien and other small districts; Keren, which comprises the high territories to the north of the Anseba; Massawa, extending over all the tribes between the high plateau and the sea from the Habab to the Danakils; Assab, which extends from Edd to Raheita; Okulé-Kusai; Seraè, including Deki-Tesfà. The political residences are at present only three, namely, Shimenzana, which governs the district of the same name, and other small districts along the Belesà; Adiquala, having jurisdiction over the boundary from the Mareb-Belesà confluence to Mai Darò; the Barià, which governs that tribe as well as the Bazà, and watches over the lower course of the Mareb and over the frontier as far as Tomat. The regional commissioners and the political residents act either by means of the village headmen (*Shum* or *Chicca*); the chiefs of districts in the few localities where villages are still organized in districts; or by the headmen of tribes, and by the Councils of the Elders wherever these remain in vigour.

Justice.—Civil justice for natives is administered, in the first instance, by the headmen of villages, provinces, tribes, or Councils of Notables (*Shumagallè*); in Appeal, by the residents, regional commissioners, and regional tribunals, and, in the last instance, by the Colonial Court of Appeal. Europeans are under the jurisdiction of the commissioners, residents, regional tribunals, and Court of Appeal. Penal justice is administered by Italian judges only. An administrative tribunal settles, without appeal, questions of tribute, disputes concerning family, village, or tribal landmarks, as well as suits involving the colonial government. The civil laws for the natives are those established by local usage. Europeans are answerable to the Italian civil code. Penal laws are the same as in Italy, except where modified by local usages. Appeal to the Rome Court of Cassation is admitted against all penal and civil sentences. A company of Royal Carabineers, consisting partly of Italians and partly of natives, is entrusted with police service. The company is divided into the lieutenancies of Asmarà, Saganeiti, and Massawa, and subdivided into some twenty stations.

Defence.—Defence is entrusted to a corps of colonial troops, partly Italian and partly native; to a militia (*milizia mobile*) formed by natives who have already served in the colonial corps; and to the *chitet* or general levy which, in time of war, places all male able-bodied inhabitants under arms. The regional commissioners and political residents have at their disposal some hundreds of irregular, paid soldiers under native chiefs. In war time these irregulars form part of the colonial corps, but in time of peace serve as frontier police. The colonial corps is commanded by an Italian colonel. It is composed of (1) three companies of African light infantry (*Cacciatori d'Africa*), composed exclusively of Italians, and stationed at Asmarà, Keren, and Saganeiti, with a detachment at Massawa; (2) six battalions of native regulars, of which two battalions are stationed at Asmarà, one at Adi Cajeh, one at Saganeiti, one at Adi Ugri, one at Keren, with a company at Agordat; (3) a squadron of native cavalry stationed at Godofellassi; (4) two native batteries (six guns) of mountain artillery, one stationed at Keren and the other at Asmarà; (5) a native gunner company divided between Keren, Saganeiti, and Asmarà; (6) an engineer company with headquarters at Asmarà and detached sections at Keren and Saganeiti; (7) a train company with headquarters at Asmarà, and detachments at Ghinda and Saganeiti. All these troops have Italian cadres. They constitute a total force of about 6000 men. The irregular troops, on foot, or mounted on camels, at the disposal of the regional commissioners and political residents number about 1000 men. The militia, whose members are registered by name, consists of 3500 men of all arms, and is intended in time of war to reinforce the various divisions of the colonial corps, while any surplus constitutes a special division under Italian officers who are chosen for that command in time of peace. The *chitet* yields between 3000 and 4000 men, to be employed on the lines of communication or in caravan service. All these troops are intended to ward off a first attack, so as to allow time for the arrival of reinforcements from Italy. The customs and political surveillance along the coast is entrusted, afloat, to the Massawa naval station, and, ashore, to a coastguard company 400 strong stationed at Meder, with detachments at Assab, Massawa, Raheita, Edd, and Taclai.

Budget.—The administration and defence cost annually about £400,000, of which three-fourths are paid by the Italian Exchequer and one-fourth by the inhabitants. This expenditure has been much exceeded in the past, but may now and for the future be considered the normal *maximum*. Indeed, one-tenth of the £400,000 is available for useful public works. In the past the internal revenue has been small, on account of insecurity and of the wars against the Abyssinians and the Dervishes; but now, with the restoration of peace and tranquillity, tribute returns are constantly increasing, so that the contribution of the home exchequer will probably be progressively reduced. When all the resources have been explored and developed, and trade resumed with Northern Abyssinia—now suspended by the anarchy existing in Tigrè—its prosperity will reach a level corresponding to the fertility of its soil, the habits of its people, and the position of its ports on the Red Sea, and Eritrea will gradually cease to be a burden upon the home exchequer.

History.—Traces of the ancient Eritrean civilization are scarce. During the prosperous periods of ancient Egypt, Egyptian squadrons asserted their rule over the west Red Sea coast, and under the Ptolemies the port of Golden Berenice (Adulis ?) was an Egyptian fortress, afterwards abandoned. During the early years of the Roman Empire, Eritrea formed part of an important independent state—that of the Assamites. At the end of the reign of Nero, and perhaps even earlier, the King of the Assamites ruled over the Red Sea coast from Suakin to the strait of Bab el-Mandeb, and traded constantly with Egypt. This potentate called himself "King of Kings," commanded an army and a fleet, coined money, adopted Greek as the official language, and lived on good terms with the Roman Empire. The Assamites belonged originally to the Hamitic race, but the immigration of the Himyaritic tribes of Southern Arabia speedily imposed a new language and civilization. Therefore the ancient Abyssinian language, Gheez, and its living dialects, Amharic and Tigrin, are Semitic, although modified by the influence of the old Agau. Adulis (Adovlis), slightly to the north of Zula, was the chief Assamite port. Several traces remain of this emporium, which a Greek merchant of the time of Vespasian called a "well-arranged market"; namely, the ruins of a temple, fragments of columns and obelisks, and a Greek inscription of an Assamite king (Corpus Inscr. Gr. 51,276). From Adulis started the main road, which led across the high plateau to the capital Axomis (Axum). Along the road are still to be seen vestiges of cities and inscribed monuments, such as the Himyaritic inscriptions on the high plateau of Cohait, the six obelisks with a Saban inscription at Toeonda, and an obelisk with an inscription at Amba Sait. Other monuments exist elsewhere, as well as coins of the Assamite period with Greek and Ethiopian inscriptions. After the rise of the Ethiopian Empire the history of Eritrea is bound up with that of Ethiopia, but not so entirely as to be completely fused. The documents of the Portuguese expedition of the sixteenth century and other Ethiopian records show that all the country north of the Mareb enjoyed relative autonomy under a vassal of the Ethiopian emperor.

Michael, counsellor of Solomon, who was king of the country north of the Mareb, usurped the throne of Solomon during the reign of the Emperor Atziè Jasù II. (1729–1753), and, after proclaiming himself Ras of the Tigrè and "protector of the Empire," ceded the North Mareb country to an enemy of the rightful dynasty. Hence a long struggle between the dispossessed family and the occupants of the North Mareb throne. The Egyptians took advantage of the struggle to seize Keren and the Bogos country. Ras Uddenchiel, who had remained master of the North Mareb district, fought as ally of the Egyptians at Gura, but was betrayed to the Abyssinians and imprisoned upon an amba, or flat-topped mountain (1879), whence he only succeeded in escaping in 1890. In 1879 his territory was given by the Negus Johannes to Ras Alula, who retained it until, in August 1889, the Italians occupied Asmarà.

The purchase of Assab and the neighbouring territory from the Sultan Berehan of Raheita by the Italian Steamship Company Rubattino (1870) formed the nucleus of Italian possessions on the Red Sea. In 1882 the Italian Government took over the rights of the Rubattino Company. On 5th February 1885 an Italian expedition under Colonel Saletta landed at Massawa, which, in virtue of the treaty concluded between Admiral Hewett and the Negus Johannes (3rd June 1884), had been recognized as Egyptian territory. Besides Massawa, the Italians occupied Arafali (10th April) and Arkiko (12th April). Colonel Saletta's successor, General Gené, in order to protect caravans, occupied the wells of Wa (23rd November 1886) and Saati (14th January 1887). This was the signal for hostilities with Abyssinia. Ras Alula arrested an Italian mission bound for Ethiopia under Major Piano, and made an unsuccessful attack upon Saati (25th January). Next day, however, in the gorge of Dogali, he succeeded in destroying a detachment of Italian infantry under Colonel De Cristoforis. An expedition of 20,000 men under General di San Marzano was dispatched to avenge this disaster. In good relations with Menelek, king of Shoa, and after the failure of a British attempt at mediation made by Sir Gerald Portal (December 1887), hostilities were opened with Abyssinia. The Negus Johannes advanced towards the Italian lines at Saati, but finding them impregnable withdrew to the interior with the intention of chastening Menelek for his neutrality. The San Marzano expedition then returned to Italy, leaving General Baldissera, the first organizer of the colony, in command. A year later Johannes fell at Metemmeh fighting the Dervishes (March 10, 1889), and his succession was disputed between Mangashà, Ras of Tigrè, natural son of Johannes, and Menelek, who claimed descent from King Solomon and the Queen of Sheba. The Italians supported Menelek by threatening the chiefs of Tigrè and occupying Keren (June 2), Asmarà (August 3), and extending the Italian frontier to the Mareb, Belesa, and Muna. Menelek, having secured the imperial crown owing to Italian help, concluded with the Italian representative, Count Pietro Antonelli, a treaty at Ucciali (May 11, 1889), and sent to Rome a mission under one of his lieutenants, Makonnen, for the ratification of the treaty and the negotiation of a loan of £160,000. General Orero, who in the meantime had succeeded General Baldissera in the government of Eritrea, made a reconnaissance in force as far as Adowa towards the west and Makallè to the south. This move aroused the suspicions of both Menelek and Mangashà, who became reconciled at Ausien. Shortly afterwards Menelek disputed the Italian claim to the protectorate over Abyssinia, based on Article 17 of the treaty of Ucciali, and demanded for Ethiopia the Cis-Mareb provinces of Seraè and Okulé-Kusai. Almost simultaneously began a period of hostilities between Italy and the Dervishes. In June 1890 Dervish raiders plundered the Beni-Amer, an Arab tribe under Italian protection, but were defeated near Agordat by Captain Fara. The Italians then occupied and fortified Agordat. In consequence of this extension of territory an Anglo-Italian convention (March–April 1891) was concluded in order to delimitate the respective spheres of influence of the two countries. The convention also authorized Italy temporarily to occupy Kassala, if necessary. In June 1892 the Dervishes attacked the Italians, but were defeated at Sarobeiti (June 16) beyond Agordat. The Khalifa then ordered a holy war, but the Dervishes were routed with loss at Agordat (December 21, 1893). The Italians followed up their success by occupying Kassala on July 17, 1894, after surprising and defeating the Dervish garrison. Meanwhile Menelek and Mangashà prepared to attack the Italians, and fomented the rebellion of Batha-Agos, who had ruled the Okulé-Kusai, under Italian suzerainty. General Baratieri, however, with 3900 men defeated and killed Batha-Agos at Halai (December 18, 1894), marched upon Adowa, routed Mangashà at Coatit (January 13–14, 1895) and at Senafè (January 15), and prepared to conquer Tigrè. Meanwhile Menelek having collected a large army and secured the support of various chiefs, set out to reconquer Tigrè after the Feast of the Cross (September 27, 1895). A battalion under Major Toselli attempted, through a misunderstanding, to arrest the Abyssinian vanguard, 35,000 strong, and was annihilated at Amba Alagi (December 7). Pushing forwards, the Abyssinians, after taking the fort at Makallè (January 21, 1896), moved on to Adowa. Here their forces, numbering 90,000, armed with rifles, 8600 cavalry, and 42 guns, encountered the Italians. The Italian army, under General Baratieri, numbered less than 20,000 men, and was, moreover, molested by the rebellion of native bands. Nevertheless, the Italian commander decided to attack. A body of 12,500 men, of whom 10,450 were Italians, with 56 guns, divided into three columns under Generals Arimondi, Albertone, and Dabormida, and a reserve under General Ellena, moved against the Abyssinian camp at daybreak on March 1, 1896. The action developed into three separate and successive combats. Albertone was first defeated at Abba-Carima; Arimondi and Ellena later at Mounts Rajo and Rebbi-Arienni; and Dabormida at Mariam Shiavitù. The Italian losses were: killed, 6600, of whom 4600 were Italians; wounded, 1500, of whom 500 were Italians; prisoners, 1700, of whom 1500 were Italians. Among the dead were Generals Dabormida and Arimondi, Colonels Romero and Airaghi, and 264 other officers. The Abyssinian losses were: killed, 7000; wounded, 10,000. Among the dead were the Fitaurazi Jabeju, victor of Amba Alagi, and many other chieftains.

A few days later General Baldissera, reappointed Governor of Eritrea, reached Massawa with reinforcements. With a new army 16,000 strong he took the offensive and liberated the garrison of Adigrat. Menelek, discouraged by his heavy losses and lacking supplies, rapidly withdrew southwards. About the same time Colonel Stevani repelled a great Dervish invasion at Mount Mokram and at Tucruf, driving the invaders beyond the Atbara. Friendly relations between Abyssinia and Eritrea were re-established by the treaty of Addis Ababa (October 26, 1896), by which Italy revoked the treaty of Ucciali, and Abyssinia agreed to release the Italian prisoners on payment of an indemnity of 10,000,000 lire, and provisionally recognized the Mareb boundary. Kassala was handed over to Great Britain (December 25, 1897). The Government was placed upon a civil basis (October–November 1897); the frontiers were further regulated by a Franco-Italian Convention (January 24, 1900) fixing the limit between the French and Italian possessions at Ras Dumeira; and by agreements with Menelek, guaranteeing to Eritrea the possession in perpetuity of the Mareb-Belesa-Muna line.

AUTHORITIES.—LUIGI CHIALA. *La Spedizione di Massana.* Turin, 1888. *Abyssinian Greenbooks*, published at intervals in 1895 and 1896, covering the period from 1870 to the end of the Italo-Abyssinian War.—VICO MANTEGAZZA. *La Guerra in Africa.* Florence, 1896.—GENERAL BARATIERI. *Memorie d' Africa.* Rome, 1898.—C. DE LA JONQUIERE. *Les Italiens en Erythrée.* Paris, 1897. (L. ME.)

Erivañ, a province of Russia, Transcaucasia, having Kars on the W., Tiflis on the N., Elisabethpol on the E., Persia and Turkey on the S. It lies entirely on the surface of a plateau (6000–8000 ft.), covered with volcanic formations. Regular chains of mountains are only met with on its borders and in its eastern portion, but the whole surface of the plateau is covered with short ridges and isolated mountains of volcanic origin, of which Alaghöz (13,436 ft.) and Ararat (17,212 ft.) are the main ones. Both are volcanoes which must have been active in Tertiary times. Lake Gokcha is surrounded by such volcanoes, and the neighbourhood of Alexandropol is a "volcanic amphitheatre," the surface of which is entirely covered with superficial volcanic deposits. The same is true of the slopes leading to the Arax, the valley of the upper Arax being consequently a stone desert, refreshed only by irrigation, which is conducted with considerable difficulty owing to the character of the soil. It is watered by the Arax, which forms the boundary with Persia, and flows with an extreme rapidity in its stony bed—the height of its fall being 22 and 17 ft. per mile in its upper part, and 9 ft. at Ordubat, and 23 ft. lower down. The chief lakes are Gokcha and Balykh-göl; many small lakes, filling up volcanic craters, are of great depth. Wood is very scarce. There is a variety of useful minerals, but only rock-salt is obtained at Nakhichevañ and Kulp. The climate is extremely varied, the following being the average temperatures and mean rainfall at Alexandropol (alt. 5078 ft.) and Aralykh (2732 ft.):—year 42°, January 12°, July 65°, mean rainfall, 16·2 in. in Alexandropol; and year 53°, January 20°·5, July 79°, rainfall, 6·3 in. in Aralykh.

The population numbers 830,000 (only 375,086 women), of whom 82,278 lived in towns. They are chiefly Armenians (375,700), Azerbaijan Tatars (407,949), Kurds (36,484), and 4150 Russians to whom some Aisors, Greeks, and Jews must be added. Most Armenians are Gregorians (only 5753 Catholics), and the Tatars are mostly Shiite Mussulmans (only 29,723 Sunnites). The percentage of births was (1897) 3·9, and of mortality only 1·9.

While barley only can be grown on the high parts of the plateau, the cotton tree, the mulberry tree, the vine, and all sorts of fruit trees are cultivated in the Arax valley. The total corn crop (mainly wheat and barley) attained 1,178,000 in 1897, and there were about 90,000 acres under cotton crop and 17,000 acres under vineyards. Cattle-breeding is extensive, and there were 35,650 horses, 26,200 donkeys, 336,000, horned cattle and 584,500 sheep. Industry is in infancy, but cottons, carpets, felt goods, and so on are fabricated in the villages. A considerable foreign trade is carried on with Persia, but trade with Asia Minor is on decline.

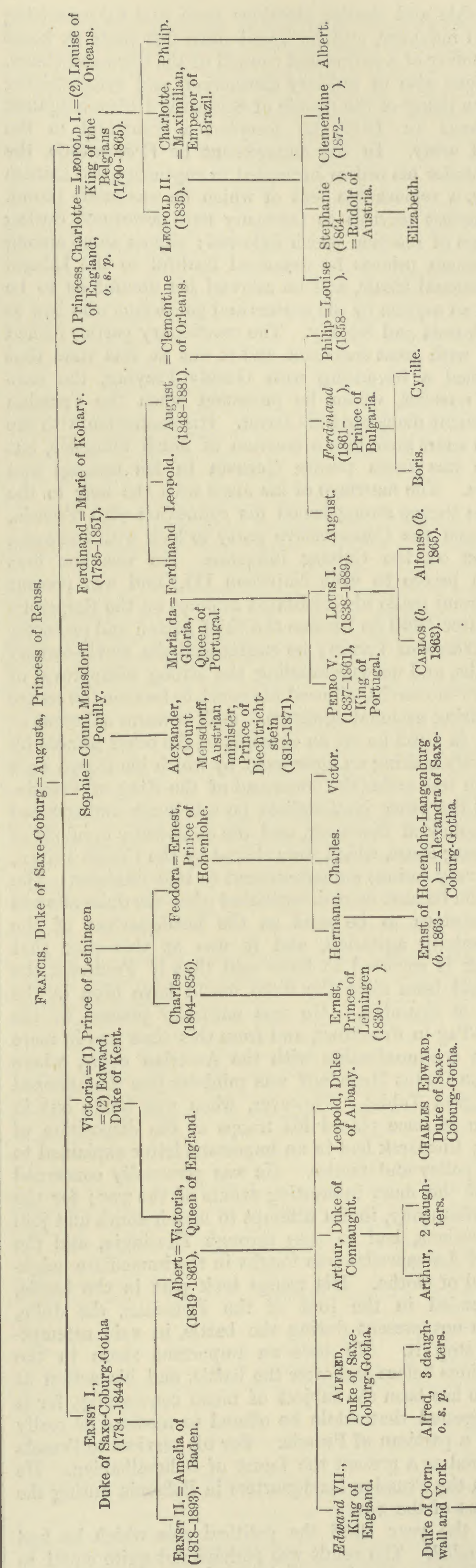
The government is divided into 7 districts:—Erivañ, Alexandropol, Echmiadzin (chief town, Vagarshapad), Nakhichevañ, Novobayazet, Surmalinsk (chief town, Igdyr), and Sharuro-Daralaghöz (chief town, Norashen). The main towns are: Erivañ, Alexandropol (32,018 inhabitants), Nakhichevañ (8845), Novobayazet (8507), and Vagarshapad (2910). (P. A. K.)

Erivañ, capital of the above government, is situated in 42° 14′ N., 44° 57′ E., 173 miles south-west of Tiflis, on Zanga river, from which a great number of irrigation canals are drawn. Altitude, 3087 ft. It has several remarkable relics of the Persian dominion in its old fortress. Population (1873), 11,938; (1897), 29,033.

Erlangen, a town of Bavaria, Germany, dist. Middle Franconia, on the river Regnitz, 15 miles by rail north from Nuremberg. Its chief importance centres in its university, which in 1900 was attended by 974 students, and had 69 professors. The principal buildings are those connected with the university, such as the library, which possesses 180,000 volumes, lecture halls (1889), and various scientific institutes and laboratories. Population (1885), 15,828; (1900), 22,953.

Erle, Sir William (1793–1880), English lawyer and judge, was born at Fifehead-Magdalen, Dorset, 1st October 1793, and was educated at Winchester and at New College, Oxford. Having been called to the Bar, he went the Western circuit, became counsel to the Bank of England, sat in Parliament from 1837 to 1841 for the city of Oxford, and, although of opposite politics to Lord Lyndhurst, was made by him a judge of the Common Pleas in 1845. He was transferred to the Queen's Bench in the following year, and in 1859 came back to the Common Pleas as Chief Justice upon the promotion of Sir Alexander Cockburn. He retired in 1866, receiving the highest eulogiums for the ability and impartiality with which he had discharged the judicial office. He died at his estate at Bramshott, Hampshire, on 28th January 1880; and a monument in his memory stands on the top of Hindhead.

Ernst II. [August Karl Johannes Leopold Alexander Eduard], duke of Saxe-Coburg-Gotha (1818–1893), was born at Coburg on the 21st of June 1818. He was the eldest son of Ernst I., duke of Saxe-Coburg-Saalfeld. In 1826, when the line of Saxe-Gotha became extinct, a rearrangement of the Saxon duchies took place. The duke of Coburg gave up the small territory of Saalfeld and acquired instead that of Gotha, and he changed his title to that of Ernst I. of Saxe-Coburg-Gotha. Ernst enjoyed a many-sided education; he studied at the University of Bonn with his brother Albert; his military training he received in the Saxon army. The widespread connexions of his family opened to him many courts of Europe; after he became of age he travelled much. The position of his uncle, who was King of the Belgians, and especially the marriage of his brother to the Queen of England, his cousin, gave him peculiar opportunities for becoming acquainted with the political problems of Europe. In 1840–41 he undertook a journey to Spain and Portugal; in the latter country another cousin was King-Consort. In 1844 he succeeded his father. His own character and the influence of the King of the Belgians, made him one of the most Liberal princes in Germany. He was able to bring to a satisfactory conclusion disputes with the Coburg estates. He passed through the ordeal of the Revolution with little trouble, for he anticipated the demands of the people of Gotha for a reform, and in 1852 introduced a new constitution by which the administration of his two duchies was assimilated in many points. The government of his small dominions did not afford sufficient scope for his restless and versatile ambition; his desire to play a great part in German affairs was probably increased by the feeling that, though he was the head of his house, he was to some extent overshadowed by the younger branches of the family which ruled in Belgium, England, and Portugal. He was one of the foremost supporters of every attempt made to reform the German constitution and bring about the unity of Germany. He took a warm interest in the proceedings of the Frankfort Parliament, and it was often said, probably without reason, that he hoped to be chosen Emperor himself. However that may be, he strongly urged the King of Prussia to accept that position when it was offered him in 1849; he took a very prominent part in the complicated negotiations of the following year, and it was at his suggestion that a congress of princes met at Berlin in 1850. He highly valued the opportunities



GENEALOGICAL TABLE OF SAXE-COBURG.

which this and similar meetings gave him for exercising political influence, and he would have felt most at home as a member of a permanent council of the German princes. Ambitious also of military distinction, and sympathizing with the rising of the people of Schleswig-Holstein against the Danes in 1849, he accepted a command in the Federal army. In the engagement of Eckernförde the troops under his orders succeeded in capturing two Danish frigates, a remarkable feat of which he was justly proud. His greatest services to Germany were performed during the years of reaction which followed; almost alone among the German princes he remained faithful to the Liberal and National ideals, and he allowed his dominions to be used as an asylum by the writers and politicians who had to leave Prussia and Saxony. The reactionary parties looked on him with great suspicion, and it was at this time that he formed a friendship with Gustav Freytag, the celebrated novelist, whom he protected when the Prussian Government demanded his arrest. His connexion with the English court gave him a position of much influence, but no one was more purely German in his feelings and opinions. The marriage of his niece with the heir to the Prussian throne strengthened his connexion with Prussia, but caused the Conservative party to look with increased suspicion on the Coburg influence. He was the first German prince to visit Napoleon III., and was present when Orsini made his celebrated attempt on the Emperor's life. After 1860 he became the chief patron and protector of the *National Verein*; he encouraged the newly-formed rifle clubs, and notwithstanding the strong disapproval of his fellow-monarchs, allowed his court to become the centre of the rising national agitation. Still a warm adherent of Prussia, in 1862 he set an example to the other princes by voluntarily making an agreement by which his troops were placed in war under the command of the King of Prussia. Like all the other Nationalists, he was much embarrassed by the policy of Bismarck, and the democratic opinions of the Coburg court, which were shared by the Crown Prince, were a very serious embarrassment to that minister. The opposition became more accentuated when the duke allowed his dominions to be used as the headquarters of the Augustenburg agitation, and it was at this time that Bismarck is reported to have said that if Frederick the Great had been alive the duke would have been in the fortress of Spandau. He was naturally present at the Fursten-Tag in Frankfort, and from this time was in more frequent communication with the Austrian court, where his cousin Count Mensdorff was minister (see the annexed Genealogical Table). However, when war broke out in 1866, he at once placed his troops at the disposition of Prussia; Bismarck had in an important letter explained to him his policy and tactics. He was personally concerned in one of the most interesting events of the war; for the Hanoverian army, in its attempt to march south and join the Bavarians, had to pass through Thuringia, and the battle of Langensalza was fought in the immediate neighbourhood of Gotha. His troops took part in the battle, which ended in the rout of the Prussians, the duke, who was not present during the battle, in vain attempting to stop it. He bore an important share in the negotiations before and after the battle, and his action at this time has been the subject of much controversy, for it was suggested that while he offered to mediate he really acted as a partisan of Prussia. For his services to Prussia he received as a present the forest of Schmalkalden. He was with the Prussian headquarters in Bohemia during the latter part of the war.

With the year 1866 the political rôle which he had played ended. The result was perhaps not quite equal to his expectations, but it must be remembered how difficult was the position of the minor German princes; and he quoted with great satisfaction the words used in 1870 by the Emperor William at Versailles, that "to him in no small degree was due the establishment of the empire." He was a man of varied tastes, a good musician—he composed several operas and songs,—and a keen sportsman, a quality in which he differed from his brother. Notwithstanding his Liberalism, he had a great regard for the dignity of his rank and family, and in his support of constitutional government would never have sacrificed the essential prerogatives of sovereignty. Several anonymous political pamphlets were attributed to him. He brought out, also, an account of travels in Egypt and Abyssinia, which he undertook in 1868; and in 1890 published his memoirs *Aus meinem Leben und meiner Zeit*, in three volumes, a work which contains much valuable information on the most critical period of German history; there is an English translation. See also *The Life of the Prince Consort*, by Sir THEODORE MARTIN; *The Early Years of the Prince Consort*, by Sir G. GREY; and for the war of 1866, HASSELL, *Geschichte Hannovers*, 1897–1901. He died on the 22nd of August 1893 at Reinhardsbrunn.

The Duke married, in the year 1842, Amelia, daughter of the Grand Duke of Baden. There was no issue to the marriage; the succession therefore passed on his death to the children of his younger brother. By the marriage contract of Prince Albert the duchy could not be held with the crown of England; it therefore passed to Prince Albert's second son, the Duke of Edinburgh. The latter's only son predeceased him, and therefore on his death it passed again to the Duke of Connaught; and he and his son passed on their claims to the Duke of Albany.

The genealogical table on p. 279 displays the widely-spread connexions of the family of Saxe-Coburg, and shows how large a part it has played in the recent history of Europe. (J. W. HE.)

Erode, a town of British India, in the Coimbatore district of Madras; situated in 11° 20′ N. lat. and 77° 46′ E. long., on the right bank of the river Cauvery, which is here crossed by an iron railway girder bridge of 22 spans. Population (1881), 9864; (1891), 12,238. Here the South Indian Railway joins the South-Western line of the Madras Railway, 243 miles from Madras. There are exports of cotton and saltpetre; and the town has a steam cotton press, a high school, and two printing-presses.

Error, Law of.—Error is defined in popular dictionaries as "deviation from truth"; and since truth commonly lies in a mean, while measurements are some too large and some too small, the term in scientific diction is extended to deviations of statistics from their average, even when that average—like the mean of human or barometric heights—does not stand for any real objective thing. A law of error is a relation between the extent of a deviation and the frequency with which it occurs: for instance, the proposition that if a digit is taken at random from mathematical tables, the difference between that figure and the mean of the whole series (indefinitely prolonged) of figures so obtained, namely, 4·5, will in the long run prove to be equally often ±0·5, ±1·5, ±2·5, ±3·5, ±4·5.[1] The more general term "law of frequency" is appropriate when there is no explicit reference to the mean, *e.g.*, the statement that one digit occurs as often as the other. The assignment of frequency to *discrete* values—as 0, 1, 2, &c., in the preceding example—is often replaced by a con-

Definition and division.

[1] See as to the fact and the evidence for it, Venn, *Logic of Chance*, 3rd ed., pp. 111, 114. Cp. *Ency. Brit.*, 8th ed., art. "Probability," p. 592.

tinuous curve with a corresponding equation. For example, it is found by Professor Pareto[1] that the number of incomes of different size (above a certain size) is approximately represented by the equation $y = A/x^a$, where x denotes the size of an income, y the number of incomes of that size, A and a are constants differing for different countries. Although this law is found to hold good for many countries, it is but *a* law of error or frequency; the right to be called *the* law of error is reserved for a function which is applicable not merely to one sort of statistics—such as digits or incomes—but to a great variety of miscellaneous groups generally at least, if not universally. What form is most deserving of this distinction is not decided by uniform usage: different authorities do not attach the same weight to the grounds on which the claim is based, the extent of cases to which the law may be applicable, the closeness of the application, and the presumption prior to specific experience in favour of the law. Three conceptions of the law of error, characterized by different degrees of these qualifications, will be considered here (sections 1 to 47, 48 to 51, 52 to 54); a fourth division (sections 55 to end) is required for certain derivative laws which may be expected to result from the law of error if prevalent in any of the three senses.

1. The simplest and best recognized statement of the law of error, often called the "normal law," is the equation

$$z = \frac{1}{\sqrt{\pi}c} e^{\frac{-(x-d)^2}{c^2}};$$

more conveniently written $(1/\sqrt{\pi}\,c)\exp-(x-d)^2/c^2$, where x is the magnitude of an observation or "statistic,"[2] *e.g.*, the stature of an individual man, z is the proportional frequency of observations measuring x, d is the arithmetic mean of the group (supposed indefinitely[3] multiplied) of similar statistics: c is a constant sometimes called the "modulus"[4] proper to the group; and the equation signifies that if any large number N of such a group is taken at random, the number of observations between x and $x + \triangle x$ is (approximately) equal to the right-hand side of the equation multiplied by $N\triangle x$.

Normal law of error: à priori proof.

2. An *à priori* proof of this law was given by Herschel[5] as follows: "The probability of an error depends solely on its magnitude and not on its direction"; positive and negative errors are equally probable. "Suppose a ball dropt from a given height with the intention that it should fall on a given mark," errors in all directions are equally probable, and errors in perpendicular directions are independent. Accordingly, the required law, "*which must necessarily be general and apply alike in all cases, since the causes of error are supposed alike unknown*,"[6] is for one dimension of the form $\phi(x^2)$, for two dimensions $\phi(x^2+y^2)$; and $\phi(x^2+y^2) \equiv \phi(x^2) \times \phi(y^2)$; a functional equation of which the solution is the function above written. A reason which satisfied Herschel is entitled to attention, especially if it is endorsed by Thomson and Tait.[7] But it must be confessed that the claim to universality is not, without some strain of interpretation,[8] to be reconciled with experience.

3. This objection is not equally applicable to a second form of *à priori* proof, which seems to have been first stated in all its generality by Dr Glaisher.[9] According to this view, the normal law of error is a first approximation to the frequency with which different values are apt to be assumed by a variable magnitude dependent on a great number of independent variables, each of which assumes different values in random fashion over a limited range, according to *a* law of error, not in general *the* law, nor in general the same for each variable. The normal law prevails in nature because it often happens—in the world of atoms, in organic and in social life—that things depend on a number of independent agencies. The validity of the explanation may best be tested by considering its application to the different classes of phenomena in which the normal law of error is approximately fulfilled.

4. (*a*) First in respect of simplicity, not practical importance, is the class of *games of chance*, or, more generally, *sortitions*, defined by the circumstance that we have a knowledge prior to specific[10] experience of the proportion of what Laplace calls favourable cases[11] to all cases—a category which includes, for instance, the distribution of digits obtained by random extracts from mathematical tables, as well as the distribution of the numbers of points on dominoes.

Games of chance.

The genesis of the law of error is most clearly illustrated by the simplest sort of "game," that in which the sortition is between two alternatives, Heads or Tails, Hearts or not-Hearts, or, generally, success or failure, the probability of a success being p and that of a failure q, where $p+q=1$. The number of such successes in the course of n trials may be considered as an aggregate made up of n independently varying elements, each of which assumes the values 0 or 1 with respective frequency q and p. The frequency of each value of the aggregate is given by a corresponding term in the expansion of $(q+p)^n$, and by a well-known theorem[12] this term is approximately equal to $\frac{1}{\sqrt{\pi 2npq}} e^{-\nu^2/2npq}$; where ν is the number of integers by which the term is distant from np (or an integer close to np); provided that ν is of (or below) the order $\sqrt{n}$. Graphically, let the sortition made for each element be represented by the taking or not taking with respective frequency p and q a step of length i. If a body starting from zero take successively n such steps, the point at which it will most probably come to a stop is at npi (measured from zero); the probability of its stopping at any neighbouring point within a range of $\pm\sqrt{n}i$ is given by the above-written law of frequency, νi being the distance of the stopping-point from npi. Put $\nu i = x$ and $2npqi^2 = c^2$; then the probability may be written $(1/\sqrt{\pi}\,c)\exp-x^2/c^2$.

5. It is a short step, but a difficult one, from this case, in which the element is *binomial*—Heads or Tails,—to the general case, in which the element has several values, according to any law of frequency—consists, for instance, of the number of points presented by a randomly-thrown die. According to the general theorem, if Q is the sum[13] of numerous elements, each of which assumes different magnitudes according to a law of frequency, $z = f_r(x)$, the function f being in general different for different elements, the number of

[1] *Cours d'Économie politique*, vol. ii. p. 306.

[2] The corresponding curve—often called the "probability-curve"—is represented in the art. on "Probability," *Ency. Brit.*, 9th ed., vol. xix.

[3] On this conception see below, § 15.

[4] *E.g.*, in the art. on "Probability" in the 9th ed. of the *Ency. Brit.*; also by Airy and other authorities. Bravais, in his article *Sur la probabilité des erreurs*. . . . "Mémoires présentés par divers savants," 1846, p. 257, takes as the "modulus or parameter" the inverse square of our c. Doubtless different parameters are suited to different purposes and contexts; c when we consult the common tables; $k(=\frac{1}{2}c^2)$ when we investigate the formation of the probability-curve out of independent elements (below, § 5); $h(=1/c^2)$ when we are concerned with weights or precisions (below, § 26). If one form of the coefficient must be uniformly adhered to, probably $\sigma(=c/\sqrt{2})$, for which Professor Pearson expresses a preference, appears the best. It is called by him the "standard deviation."

[5] *Edinburgh Review*, 1850, vol. xcii. p. 19.

[6] The italics are in the original. The passage continues: "And it is on this ignorance, and not on any peculiarity in cases, that the idea of probability in the abstract is formed." Cp. below, § 24.

[7] *Natural Philosophy*, part i. Art. 391. For other *à priori* proofs see Czuber, *Theorie der Beobachtungsfehler*, Th. i. [8] Cp. note to § 19.

[9] *Memoirs of Astronomical Society*, 1878, p. 105. Cp. Morgan Crofton, "On the Law of Errors of Observation," *Trans. Roy. Soc.*, 1870, vol. clx. part i. p 178.

[10] Not prior to *all* experience, not literally knowledge based on "ignorance," but on a rough general experience, according to the view indicated below, § 24.

[11] *Théorie analytique*, *Introduction*, p. iv.

[12] By the use of Stirling's and Bernouilli's theorems, Todhunter, *History of Probabilities*. Cp. art. on "Probability," *Ency. Brit.*, 9th ed., § 8, p. 772, vol. xix.

[13] The statement includes the case of a linear function, since an element multiplied by a constant is still an element. For a statement of some of the assumptions required by the theory see below, § 9.

times that Q assumes magnitudes between x and $x+\triangle x$ in the course of N trials is $\mathrm{N}z\triangle x$, if $z=(1/\sqrt{2\pi k})\ \exp-(x-a)^2/2k$; where a is the sum of the arithmetic means of all the elements, any one of which $a_r, =\left[\int x f_r(x)dx\right]$, the square brackets denoting that the integrations extend between the extreme limits of the element's range, if the frequency-locus for each element is continuous, it being understood that $\left[\int f_r(x)dx\right]=1$; and k is the sum[1] of the mean squares of error for each element,[2] $=\Sigma\left[\int \xi^2 f_r(a_r+\xi)d\xi\right]$, if the frequency-locus for each element is continuous, where a_r is the arithmetic mean of one of the elements, and ξ the deviation of any value assumed by that element from a_r, Σ denoting summation over all the elements. When the frequency-locus for the element is not continuous, the *integrations* which give the arithmetic-mean and mean-square of error for the element must be replaced by *summations*. For example, in the case of the dice above instanced, the law of frequency for each element is that it assumes equally often each of the values 1, 2, 3, 4, 5, 6. Thus the arithmetic mean for each element is 3·5, and the mean square of error $\{(3{\cdot}5-1)^2+(3{\cdot}5-2)^2+\text{etc.}\}/6=2{\cdot}91\dot{6}$. Accordingly, the sum of the points obtained by tossing a large number, n, of dice at random will assume a particular value x with a frequency which is approximately assigned by the equation

$$z=(1/\sqrt{\pi 5{\cdot}8\dot{3}n})\ \exp-(x-3{\cdot}5)^2/5{\cdot}8\dot{3}n.$$

The rule equally applies to the case in which the elements are not similar; one might be the number of points on a die, another the number of points on a domino, and so on. Graphically, each element is no longer represented by a step which is either null or i, but by a step which may be, with an assigned probability, one or other of several degrees between those limits, the law of frequency and the range i being different for the different elements.

6. The evidence for these statements can only be indicated here. The best-known proof that the sum of *multinomial* elements will vary according to the normal law of error approximately is that which was given by Laplace for elements with one and the same law of frequency of (almost) any kind; and was extended by Poisson to elements with different laws of frequency.[3] A simpler proof of the general theorem has been given by De Forest,[4] based on certain proportions respecting the multiplication of multinomials of the form $(a_0+a_1z+a_2z^2+\ .\ .\ .+a_nz^n)$. Another simple proof is based by Mr Morgan Crofton[5] on certain partial differential equations which must be satisfied in order that the taking in of a new element should not alter the form, but only the constants, of the resulting law of frequency.

7. The three proofs which have been mentioned have been extended to errors in two (or more) dimensions.[6] Let Q be the sum of a number of elements, each of which, being a function of two variables, x and y, assumes different pairs of values according to a law of frequency $z_r=f_r(x,y)$, the functions being in general different for different elements. The frequency with which Q assumes values of the variables between x and $x+\triangle x$ and between y and $y+\triangle y$ is $z\triangle x\triangle y$, if

$$z=\frac{1}{2\pi\sqrt{km-l^2}}\ \exp\ -\ \frac{m(x-a)^2-2l(x-a)(y-b)+k(y-b)^2}{2(km-l^2)};$$

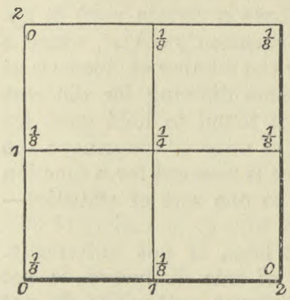
where, as in the simpler case, $a=\Sigma a_r$, a_r being the arithmetic mean of the values of x assumed in the long run by one of the elements, b is the corresponding sum for values of y, and

$$k=\Sigma\left[\iint(x-a_r)^2 f_r(x,y)dxdy\right]$$

$$m=\Sigma\left[\iint(y-b_r)^2 f_r(x,y)dxdy\right]$$

$$l=\Sigma\left[\iint(x-a_r)(y-b_r)f_r(x,y)dxdy\right];$$

the summation extending over all the elements, and the integration between the extreme limits of each; supposing that the law of frequency for each element is continuous, otherwise summation is to be substituted for integration. For example, let each element be constituted as follows. Three coins having been tossed, the number of Heads presented by the first and second coins together is put for x, the number of Heads presented by the second and third coins together is put for y. The law of frequency for the element is represented by the annexed diagrams, the integers outside denoting the values of x or y, the fractions inside probabilities of particular values of x and y concurring.



If i is the distance from 0 to 1 and from 1 to 2 on the abscissa, and i' the corresponding distance on the ordinate, the mean of the values of x for the element—$\triangle a$, as we may say,—is i, and the corresponding mean square of horizontal deviations is $\frac{1}{2}i^2$. Likewise $\triangle b=i'$; $\triangle m=\frac{1}{2}i'^2$; and $\triangle l=\frac{1}{8}(+i\times+i'-i\times-i')=\frac{1}{4}ii'$. Accordingly, if n such elements are put together (if n *steps* of the kind which the diagram represents are taken), the frequency with which a particular pair of aggregates x and y will concur, with which a particular point on the plane of xy, namely, $x=ri$ and $y=r'i'$, will be reached, is given by the equation

$$z=\frac{1}{2\pi}\sqrt{\frac{16}{3n}}\ \exp-\ \frac{8}{3n}\left[(r-n)^2i^2-(r-n)(r'-n)ii'+(r'-n)i'^2\right]^{7}.$$

8. A verification is afforded by a set of statistics obtained with dice by Professor Weldon, and here reproduced by his permission. A *success* is in this experiment defined, not by obtaining a Head when a coin is tossed, but by obtaining a face with more than three points on it when a die is tossed; the probabilities of the two events are the same, or rather would be if coins and dice were perfectly symmetrical.[8] Professor Weldon virtually took six *steps* of the sort above described when, six painted dice having been thrown, he added the number of successes in that painted batch to the number of successes in another batch of six to form his x, and to the number of successes in a *third* batch of six to form his y. The result is represented in the annexed diagram, where each

	0	1	2	3	4	5	6	7	8	9	10	11	12
12													
11							1	1	5	1		1	
10						2	6	28	27	19	2		
9				1	2	11	43	76	57	54	15	4	
8				6	18	49	116	138	118	59	25	5	
7				12	47	109	208	213	118	71	23	1	
6			9	29	77	199	244	198	121	32	3		
5		3	12	51	119	181	200	129	69	18	3		
4		2	16	55	100	117	91	46	19	3			
3		2	14	28	53	43	34	17	1				
2			7	12	13	18	4	1	1				
1			2	4	1	2	1						
0													

degree on the axis of x and y respectively corresponds to the i and i' of the preceding paragraphs, and $i=i'$. The observed frequencies being represented by numerals, a general correspondence between the facts and the formula is apparent. The maximum frequency is, as it ought to be, at the point $x=6i$, $y=6i'$. The density is particularly great along a line through that point, making 45° with the axis of x; particularly small in the complementary direction. This also is as it ought to be. For if the centre is made the origin by substituting x for $(x-a)$ and y for $(y-b)$, and then new co-ordinates X and Y are taken, making an

[1] Or rather what that sum would be if the series of observation could be indefinitely prolonged. Cp. below, § 15.

[2] In the case of binomial, $k=n(pq^2+qp^2)=npq$.

[3] Laplace, *Théorie analytique des Probabilités*, bk. ii. ch. iv.; Poisson, *Recherches sur la Probabilité des jugements*. Good restatements of this proof are given by Todhunter, *History of Probabilities*, Art. 1004, and by Czuber, *Theorie der Beobachtungsfehler*, Art. 38 and Th. 2, § 4.

[4] *The Analyst* (Iowa), vols. v., vi., vii. *passim*; and especially vol. vi. pp. 142–47, vol. vii. pp. 173–74.

[5] *Ency. Brit.*, 9th ed., art. "Probability." Cp. *Trans. Roy. Soc.*, 1870, vol. clx. pt. i., "On the Proof of the Law of Errors."

[6] The first by Mr Burbury, in *Phil. Mag.*, 1894, vol. xxxvii. p. 145, the second by its author in the *Analyst* for 1881, the third by the present writer in *Phil. Mag.*, 1896, xli. p. 247.

[7] Compare the formula for the simple case, above, § 4.

[8] On the irregularity of the dice with which Professor Weldon experimented, see Professor Pearson, *Phil. Mag.*, 1900, p. 167.

angle θ with x and y respectively, the curve which is traced on the plane of zX by its intersection with the surface is of the form

$$z = \mathrm{J}\ \exp - \mathrm{X}^2[\mathrm{k}\sin^2\theta - 2\,\mathrm{l}\cos\theta\sin\theta + \mathrm{m}\cos^2\theta]/2(\mathrm{km} - \mathrm{l}^2),$$

a probability-curve which will be more or less spread out according as the factor $\mathrm{k}\sin^2\theta - 2\,\mathrm{l}\cos\theta\sin\theta + \mathrm{m}\cos^2\theta$ is less or greater. Now this expression has a minimum or maximum when $(\mathrm{k}-\mathrm{m})\sin\theta - 2\,\mathrm{l}\cos 2\theta = 0$; a minimum when $(\mathrm{k}-\mathrm{m})\cos 2\theta + 2\,\mathrm{l}\sin 2\theta$ is positive, and a maximum when that criterion is negative; that is, in the present case, where $\mathrm{k}=\mathrm{m}$, a minimum when $\theta = \frac{1}{4}\pi$ and a maximum when $\theta = \frac{3}{4}\pi$.

9. The law which has been stated, that if numerous elements, each independently varying (in one or more dimensions) according to (almost) *any* law of frequency, are added together, the sum is apt to vary according to *the* (normal) law of error, may be called the *law of great numbers*.[1] As may be presumed from the examples just given, in order that there should be some approximation to the normal law the number of elements need not be very great. A very tolerable imitation of the probability-curve has been obtained by superposing *three* elements, each obeying a law of frequency quite different from the normal one,[2] that simple law according to which one value of a variable occurs as frequently as another between the limits within which the variation is confined ($y = \frac{1}{2\mathrm{a}}$, between limits $x = +\mathrm{a}$, $x = -\mathrm{a}$). If the component elements obey unsymmetrical laws of frequency, the compound will indeed be to some extent unsymmetrical, unlike the "normal" probability-curve. But, as the number of the elements is increased, the portion of the compound curve in the neighbourhood of its centre of gravity tends to be rounded off into the normal shape. The portion of the compound curve which is sensibly identical with a curve of the "normal" family becomes greater the greater the number of independent elements; *ceteris paribus*, and granted certain conditions as to the equality and the range of the elements. It will readily be granted that if one component predominates, it may unduly impress its own character on the compound. But it should be pointed out that the characteristic with which we are now concerned is not average magnitude, but deviation from the average. The component elements may be very unequal in their contributions to the average magnitude of the compound without prejudice to its "normal" character, provided that the fluctuation of all or many of the elements is of one and the same order. The proof of the law of great numbers (by way of partial differential equations) requires that the contribution made by each element to the mean square of deviation for the compound, k (see §§ 5–7), should be small, capable of being treated as differential with respect to k. It is not necessary that all these small quantities should be of the same order, but only that they should admit of being rearranged, by massing together those of a smaller order, as a numerous set of independent elements in which no two or three stand out as *sui generis* in respect of the magnitude of their fluctuation. For example, if one element consist of the number of points on a domino (the sum of two digits taken at random), and other elements, each of either 1 or 0 according as Heads or Tails turn up when a coin is cast, the first element, having a mean square of deviation 16·5, will not be of the same order as the others, each having 0·25 for its mean square of deviation. But *sixty-six* of the latter taken together would constitute an independent element of the same order as the first one, and accordingly if there are several times sixty-six elements of the latter sort, along with one or two of the former sort, the conditions for the generation of the normal distribution will be satisfied. These propositions would evidently be unaffected by altering the average magnitude, without altering the deviation from the average, for any element, that is, by adding a greater or less *fixed* magnitude to each element. The propositions are adapted to the case in which the elements fluctuate according to a law of frequency other than the normal. For if they are already normal, the aforesaid conditions are unnecessary. The normal law will be obeyed by the sum of elements which each obey it, even though they are not numerous and not independent and not of the same order in respect of the extent of fluctuation. A similar distinction is to be drawn with respect to some further conditions which the reasoning requires. A limitation as to the range of the elements is not necessary when they are already normal, or even have a certain affinity to the normal curve. Very large values of the element are not excluded, provided they are sufficiently rare. What has been said of curves with special reference to one dimension is of course to be extended to the case of surfaces and many dimensions. In all cases the theorem that under the conditions stated the normal law of error will be generated is to be distinguished from the hypothesis that the conditions are fairly well fulfilled in ordinary experience.

10. (β) The principles won by studying the sort of model which games of chance present are now to be applied to important concrete cases; among which errors-of-observation occupy a leading place. The *law of great numbers* is brought to bear on this case by the hypothesis that an error is the algebraic sum of numerous elements, each varying according to a law of frequency special to itself. This hypothesis involves two assumptions: (1) that an error is dependent on numerous independent causes; (2) that the function expressing that dependence can be treated as a linear function, by expanding in terms of ascending powers (of the elements) according to Taylor's theorem and neglecting higher powers,[3] or otherwise. The first assumption seems, in Dr Glaisher's words, "most natural and true. In any observation where great care is taken, so that no large error can occur, we can see that its accuracy is influenced by a great number of circumstances, which ultimately depend on independent causes: the state of the observer's eye and his physiological condition in general, the state of the atmosphere, of the different parts of the instrument, &c., evidently depend on a great number of causes, while each contributes to the actual error."[4] The second assumption seems to be frequently, but by no means universally, realized in nature. This rationale is applicable not only to the fallible perceptions of the senses, but also to impressions into which a large ingredient of inference enters, such as estimates of a man's height or weight from his appearance,[5] and even higher acts of judgment.[6] Aiming at an object is an act similar to measuring an object, misses are produced by much the same variety of causes as mistakes; and, accordingly, it is found that shots aimed at the same bull's eye are apt to be distributed according to the normal law, whether in two dimensions on a target or according to their horizontal deviations, as exhibited below (§ 47).

Errors proper.

11. (γ) A residual class comprises miscellaneous statistics, physical as well as social, in which the normal law of error makes its appearance, presumably in consequence of the action of numerous independent influences. Well-known instances are afforded by human heights and other bodily measurements, as tabulated by Quetelet[7] and others.[8] The tendency of social phenomena to conform to the normal law of frequency is well exemplified by Mr Bowley's grouping of the wages paid to different classes.[9]

Miscellaneous statistics.

12. Instances of the normal law might also be divided into two classes: observations which stand for a real objective thing, and such statistics as are not thus representative of something outside themselves, groups of which the mean is called "subjective"

Subdivisions.

[1] This definition is not identical with Poisson's use of the term "law of great numbers" in his *Recherches sur la Probabilité des jugements.*

[2] *Journ. Stat. Soc.*, March 1900, p. 73, referring to Dr Burton, *Phil. Mag.*, 1883, vol. xvi. p. 301.

[3] Let $\mathrm{F}(x'_1 + x_1,\ x'_2 + x_2 \cdots x'_{\mathrm{n}} + x_{\mathrm{n}})$ represent a variable quantity depending on n elements $x'_1 + x_1$ $x'_2 + x_2$, &c., each fluctuating according to its own law of frequency about its mean value, respectively x'_1, x'_2, ... Suppose that the range within which each element fluctuates is so small that F never differs sensibly from

$$\left[\frac{d\mathrm{F}}{dx_1}\right]_0 x_1 + \left[\frac{d\mathrm{F}}{dx_2}\right]_0 x_2 + \cdots \left[\frac{d\mathrm{F}}{dx_{\mathrm{n}}}\right]_0 x_{\mathrm{n}}, \text{ where } \left[\frac{d\mathrm{F}}{dx_1}\right]_0$$

denotes what the expression within the brackets becomes when 0 is substituted for each of the variables; this condition (together with those referred to in the preceding paragraph) would be sufficient for the generation of the normal law. The *necessary* condition is somewhat less stringent.

[4] *Memoirs of Astronomical Society*, 1878, p. 105.

[5] *Journ. Stat. Soc.*, 1890, p. 462 *et seq.*

[6] *E.g.*, the marking of the same work by different examiners. *Ibid.*

[7] *Lettres sur la Théorie des Probabilités* and *Physique Sociale.*

[8] *E.g.*, the measurements of Italian recruits, adduced in the *Atlante Statistico*, published under the direction of the *Ministero di Agricultura*, Rome, 1882; and Professor Weldon's measurements of crabs, *Proc. Roy. Soc.*, vol. liv. p. 321; discussed by Professor Pearson in the *Trans. Roy. Soc.*, 1894, vol. clxxxv. A.

[9] *Wages in the United Kingdom in the Nineteenth Century*; and art. on "Wages" in the Supplement to the *Ency. Brit.*, 9th ed.

or "fictitious"; the first class nearly corresponding with our (α) and (β) put together, the second class with our (γ). But the division would be neither clear nor useful. On the one hand so-called real means are often only approximately equal to objective quantities. Thus the proportional frequency with which one face of a die—the *six* suppose—turns up is only approximately given by the objective fact that the *six* is one face of a nearly perfect cube. For a set of dice with which Professor Weldon experimented, the average frequency of a throw, presenting either five or six points, proved to be not ·3, but 0·3377.[1] The difference of this result from the regulation 0·3 is as unpredictable from objective data, prior to experiment, as any of the means called subjective or fictitious. So the mean of errors of observation often differs from the thing observed by a so-called "constant error." So shots may be constantly deflected from the bull's eye by a steady wind or "drift."

13. On the other hand, statistics, not purporting to represent a real object, have more or less close relations to magnitudes which cannot be described as fictitious. Where the items averaged are ratios, *e.g.*, the proportion of births or deaths to the total population in several districts or other sections, it sometimes happens that the distribution of the ratios exactly corresponds to that which is obtained in the simplest games of chance—"combinational" distribution in the phrase of Professor Lexis.[2] There is unmistakably suggested a *sortition* of the simplest type, with a real ascertainable relation between the number of "favourable cases" and the total number of cases. The most remarkable example of this property is presented by the proportion of male to female (or to total) births. Some other instances are given by Professor Lexis[3] and Professor Westergaard.[4] A similar correspondence between the actual and the "combinational" distribution has been found by Professor Bortkevitch[5] in the case of very small probabilities (in which case the law of error is no longer "normal"). And it is likely that some ratios—such as general death-rates—not presenting combinational distribution, might be broken up into subdivisions—such as death-rates for different occupations or age-periods—each distributed in that simple fashion.

14. Another sort of averages which it is difficult to class as subjective rather than objective occurs in some social statistics, under the designation of index-numbers. The percentage which represents the change in the value of money between two epochs is seldom regarded as the mere average change in the price of several articles taken at random, but rather as the measure of something, *e.g.*, the variation in the price of a given amount of commodities, or of a unit of commodity.[6] So something substantive appears to be designated by the *volume of trade*, or that of the *consumption of the working classes*, of which the growth is measured by appropriate *index-numbers*,[7] the former due to Mr Bourne and Sir Robert Giffen,[8] the latter to Mr George Wood.[9]

15. But apart from these peculiarities, any set of statistics may be related to a certain *quæsitum*, very much as measurements are related to the object measured. That *quæsitum* is the limiting or ultimate mean to which the series of statistics, if indefinitely prolonged, would converge, the mean of the complete group; this conception of a limit applying to any *frequency-constant*, to "c," for instance, as well as "a" in the case of the normal curve.[10] The given statistics may be treated as samples from which to reason up to the true constant by that principle of the Calculus which determines the comparative probability of different causes from which an observed event may have emanated.[11]

16. Thus it appears that there is a characteristic more essential to the statistician than the existence of an objective *quæsitum*, namely, the use of that method which is primarily, but not exclusively, proper to that sort of *quæsitum—inverse probability*. Without that delicate instrument the doctrine of error can seldom be fully utilized; but some of its uses may be indicated before the introduction of technical difficulties.

Direct applications of the normal law.

17. The mere presumption that wherever three or four independent causes co-operate, the law of error tends to be set up, has a certain speculative interest.[12] The assumption of the law as a hypothesis[13] is legitimate. When the presumption is confirmed by specific experience, this knowledge is apt to be turned to account. It is usefully applied to the practice of gunnery; a use which, so far as it involves inverse probabilities,[14] belongs, with the treatment of errors proper, or fallible observations, to a later section. In many kinds of examination it is found that the total marks given to different candidates for answers to the same set of questions range approximately in conformity with the law of error. It is understood that the Civil Service Commissioners have founded on this fact some practical directions to examiners. Apart from such direct applications, it is a useful addition to our knowledge of a class that the measurable attributes of its members range in conformity with this general law. Something is added to the truth that "the days of a man are threescore and ten," if we may regard that epoch, or more exactly for England 72, as "Nature's aim, the length of life for which she builds a man, the dispersion on each side of this point being . . . nearly normal."[15] So Herschel says: "An [a mere] average gives us no assurance that the future will be like the past. A [normal] mean may be reckoned on with the most complete confidence."[16] The existence of independent causes,[17] inferred from the fulfilment of the normal law, may be some guarantee of stability. In Natural History especially have the conceptions supplied by the law of error been fruitful. Investigators are already on the track of this inquiry: if those members of a species whose size or other measurable attributes are above (or below) the average are preferred —by "natural" or some other kind of selection—as parents, how will the law of frequency as regards that attribute be modified in the next generation?

18. The relations between different generations involve the law of error in two or more dimensions. It was found

[1] *Phil. Mag.*, 1900, p. 168.
[2] Cp. *Journ. Stat. Soc.*, Jubilee No., p. 192.
[3] *Massenerscheinungen.*
[4] *Grundzüge der Statistik.* Cp. Bowley, *Elements of Statistics*, p. 302.
[5] *Das Gesetz der kleinen Zahlen.*
[6] See for other definitions *Report of the British Association*, 1889, pp. 136 and 161, and compare Mr Walsh's exhaustive *Measurement of General Exchange-Value.*
[7] Cp. Bowley, *Elements of Statistics*, chap. ix.
[8] *Journ. Stat. Soc.*, 1874 and later. Parly. Papers [C. 2247] and [C. 3079].
[9] "Working-Class Progress since 1860," *Journ. Stat. Soc.*, 1899, p. 639.
[10] On this conception compare Venn, *Logic of Chance*, chs. iii. and iv., and Sheppard, *Proceedings of the Lond. Mathematical Society*, p. 363 *et seqq.*
[11] Laplace's 6th principle, *Théorie Analytique*, Introduction x.
[12] Cp. Galton's enthusiasm, *Natural Inheritance*, p. 66.
[13] The distribution of velocities according to law of error as the condition of the stability of molecular motion (cp. Clerk Maxwell, *Phil. Trans.*, 1867, p. 63; *Trans. Camb. Phil. Soc.*, 1879) is connected by Mr Burbury (*Phil. Mag.*, 1894, vol. xxxvii. p. 151) with what is here called the law of great numbers (above, § 9).
[14] Employed, for instance, by Didion (*Calcul des Probabilités appliqué au tir*) to determine, from the results of past shooting, the probable accuracy of a future shot.
[15] Venn, *Journ. Stat. Soc.*, 1891, p. 443.
[16] *Ed. Rev.*, 1850. xcii. p. 23.
[17] Cp. Galton, *Phil. Mag.*, 1875, vol. xlix. p. 44.

by Galton that the heights and other measurable attributes of children of the same parents range about a mean which is not that of the parental heights, but nearer the average of the general population. The amount of this "regression" is simply proportional to the distance of the "mid-parent's" height from the general average. This is a case of a very general law which governs the relations not only between members of the same family, but also between members of the same organism, and generally between two (or more) coexistent or in any way co-ordinated observations, each belonging to a normal group. Let x and y be the measurements of a pair thus constituted. Then[1] it may be expected that the conjunction of particular values for x and y will approximately obey the two-dimensioned normal law which has been already exhibited (see § 7).

19. In the expression above given, put $1/\sqrt{km}=r$, and the equation for the frequency of pairs having values of the attribute under measurement becomes

$$z=\frac{1}{2\pi\sqrt{km}\sqrt{1-r^2}}\ \exp-\left[\frac{(x-d)^2}{k}-2r\frac{(x-d)(y-b)}{\sqrt{k}\ \sqrt{m}}+\frac{(y-b)^2}{m}\right]/2(1-r^2).$$

This formula is of very general application.[2] If two sets of measurements were made on the height, or other measurable feature, of the proverbial "Goodwin Sands" and "Tenterden Steeple," and the first measurement of one set was coupled with the first of the other set, the second with the second, and so on, the pairs of magnitudes thus presented would doubtless vary according to the above-written law, only in that case r would presumably be zero; the expression for z would reduce to the product of the two *independent* probabilities that particular values of x and y should concur. But slight interdependences between things supposed to be totally unconnected would often be discovered by this law of error in two or more dimensions.[3] It may be put in a more convenient form by substituting ξ for $(x-d)/\sqrt{k}$ and η for $(y-b)/\sqrt{m}$. The equation of the surface then becomes $z=(1/2\pi\sqrt{1-r^2})\ \exp-[\xi^2-2r\xi\eta+\eta^2]/2(1-r^2)$. If the frequency of observations in the vicinity of a point is represented by the number of dots in a small increment of area, when $r=0$ the dots will be distributed uniformly about the origin, the *curves of equal probability* will be circles. When r is different from zero the dots will be distributed so that the majority will be massed in two quadrants: in those for which ξ and η are both positive or both negative when r is positive, in those for which ξ and η have opposite signs when r is negative. In the limiting case, when $r=1$ the whole host will be massed along the line $\eta=\xi$, every deviation ξ being attended with an equal deviation η. In general, to any deviation of one of the variables ξ' there corresponds a set or "array" (Pearson) of values of the other variable; for which the frequency is given by substituting ξ' for ξ in the general equation. The section thus obtained proves to be a normal probability-curve with standard deviation $\sqrt{1-r^2}$. The most probable value of η corresponding to the assigned value of ξ is $r\xi'$. The equation $\eta=r\xi$, or rather what it becomes when translated back to our original co-ordinates $(d-b)/\sigma_2=r(x-d)\sigma_1$, where σ_1, σ_2 are our $\sqrt{k}$, $\sqrt{m}$ respectively,[4] is often called a *regression-equation.*[5] A verification is to hand in the above-cited statistics, which Professor Weldon obtained by casting batches of dice. If the dice were perfect, $r\ (=1/\sqrt{km})$ would equal $\frac{1}{2}$, and as the dice proved not to be very imperfect, the coefficient is doubtless approximately $=\frac{1}{2}$. Accordingly, we may expect that, if axes x and y are drawn through the point of maximum-frequency at the centre of the compartment containing 244 observations, corresponding to any value of x, say $2\nu i$ (where i is the side of each square compartment), the most probable value of y should be νi, and corresponding to $y=2\nu i$ the most probable value of x should be νi. And in fact these regression-equations are fairly well fulfilled for the *integer* values of ν (more than which could not be expected from *discrete* observations): *e.g.*, when $x=+4i$, the value of y, for which the frequency (25) is a maximum, is as it ought to be $+2i$; when $x=-2i$ the maximum (119) is at $y=-i$; when $x=-4i$ the maximum (16) is at $y=-2i$; when y is $+2i$ the maximum (138) is at $x=+i$; when y is $-2i$, the maximum (117) at $x=-i$, and in the two cases ($x=+2i$, and $y=+4i$), where the fulfilment is not exact, the failure is not very serious.

20. Analogous statements hold good for the case of three or more dimensions of error.[6] The normal law of error for any number of variables, $x_1\ x_2\ x_3$, may be put in the form $z=(1/(2\pi)^{\frac{n}{2}}\sqrt{\triangle})\ \exp-[R_{11}x_1^2+R_{22}x_2^2+\text{etc.}+2R_{12}x_1x_2+\text{etc}]/2\triangle$ where $\triangle$ is the determinant:—

$$\begin{matrix} 1 & r_{12} & r_{13} & \cdots \\ r_{21} & 1 & r_{23} & \cdots \\ r_{31} & r_{32} & 1 & \cdots \\ \vdots & \vdots & \vdots & \end{matrix}$$

each r, *e.g.*, $r_{23}\ (=r_{32})$, is the coefficient of correlation between two of the variables, *e.g.*, x_2, x_3; R_{11} is the first minor of the determinant formed by omitting the first row and first column; R_{22} is the first minor formed by omitting the second row and the second column, and so on; $R_{12}\ (=R_{21})$ is the first minor formed by omitting the first column and second row (or *vice versâ*). The principle of correlation plays an important *rôle* in Natural History. It has replaced the notion that there is a simple proportion between the size of organs by the appropriate conception that there are simple proportions existing between the *deviation* from the average of one organ and the *most probable* value for the coexistent deviation of the other organ from its average.[7] Attributes favoured by "natural" or other selection are found to be *correlated* with other attributes which are not directly selected. The extent to which the attributes of an individual depend upon those of his ancestors is measured by correlation.[8] The principle is instrumental to most of the important "mathematical contributions" which Professor Pearson has made to the theory of Evolution.[9] In social inquiries, also, the principle promises a rich harvest. Where numerous fluctuating causes go to produce a result like pauperism or immunity from small-pox, the ideal method of eliminating chance would be to construct "regression-equations" of the following type:—"Change per cent. in pauperism [in the decade 1871–81] in rural districts $= -27{\cdot}07$ per cent., $+0{\cdot}299$ (change per cent. out-relief ratio), $+0{\cdot}271$ (change per cent. on proportion of old), $+{\cdot}064$ (change per cent. in population)."[10]

21. In order to determine the best values of the coefficients involved in the law of error, and to test the worth of the results obtained by using any values, recourse must be had to *inverse probability*.

Inverse probability.

22. The simplest problem under this head is where the *quæsitum* is a single real object and the data consist of a large number of observations, $x_1, x_2, \ldots x_n$, such that if the number were indefinitely increased, the completed series would form a normal probability-curve with the true point as its centre, and having a given modulus c. It is as if we had observed the position of the dints made by the fragments of an exploding shell so far as to know the distance of each mark measured (from an origin) along a right line, say the line of an extended fortification, and it was known that the shell was fired perpendicular to the fortification from a distant ridge parallel to the fortification, and that the shell was of a kind of which the fragments are scattered according to a normal law[11] with a known coefficient of dispersion; the question is at what position on the distant ridge was the enemy's gun probably placed? By received principles the probability, say P, that the given set of observations should have resulted from measuring (or aiming at) an object of which the real position was between x and $x+\triangle x$ is

$$\triangle x\ J\ \exp-[(x-x_1)^2+(x-x_2)^2+\text{etc.}]/c^2;$$

where J is a constant obtained by equating to unity $\int_{-\infty}^{+\infty}P\,dx$

[1] Where plurality of independent causes is presumable.

[2] Herschel's *à priori* proposition concerning the law of error in two dimensions (above, § 2) might still be defended either as *generally* true, so many phenomena showing no trace of interdependence, or on the principle which justifies our putting $\frac{1}{2}$ for a probability that is unknown (below, § 24), or 5 for a decimal place that is neglected; correlation being equally likely to be positive or negative. The latter sort of explanation may be offered for the less serious contrast between the *à priori* and the empirical proof of the law of error in one dimension (below, § 44).

[3] Cp. above, § 8. [4] Cp. note to § 1, above. [5] Cp. above, § 18.

[6] *Phil. Mag.*, Aug. 1892, p. 200 *et seqq.*; March 1896, p. 211; Pearson, *Trans. Roy. Soc.*, 1896, vol. clxxxvii. p. 302; Burbury, *Phil. Mag.*, 1894, p. 145.

[7] Pearson, "On the Reconstruction of Prehistoric Races," *Trans. Roy. Soc.*, 1898, A, p. 174 *et seqq.*; *Proc. Roy. Soc.*, 1898, p. 418.

[8] "The Law of Ancestral Heredity," Pearson, *Trans. Roy. Soc.*, *Proc. Roy. Soc.*, 1898.

[9] Papers in the Royal Society in progress since 1895.

[10] An example instructively discussed by Mr Yule, *Journ. Stat. Soc.* 1899.

[11] If normally in any direction indifferently according to the two- or three-dimensioned law of error, then normally in one dimension when collected and distributed in *belts* perpendicular to a horizontal right line, as in the example cited below, § 47.

(since the given set of observations must have resulted from some position on the axis of x). The value of x, from which the given set of observations *most probably* resulted, is obtained by making P a *maximum*. Putting $\frac{dP}{dx}=0$, we have for the maximum $\left(\frac{d_2P}{dx_2}\right.$ being negative for this value), the arithmetic mean of the given observations. The accuracy of the determination is measured by a probability-curve with modulus $c/\sqrt{n}$. Thus in the course of a very long siege if every case in which the given group of shell-marks $x_1, x_2 \cdots x_n$ was presented could be investigated, it would be found that the enemy's cannon was fired from the position x', the (point right opposite to the) arithmetic mean of x_1, x_2, &c., x_n, with a frequency assigned by the equation

$$z=(\sqrt{n}/\sqrt{\pi}c)\ \exp.-n(x-x')^2/c^2.$$

23. Simple as this solution is, it is not the one which has most recommended itself to Laplace. He envisages the *quæsitum* not so much as that point which is *most probably* the real one, as that point which may *most advantageously* be put for the real one. In our illustration it is as if it were required to discover from a number of shot-marks not the point[1] which in the course of a long siege would be most frequently the position of the cannon which had scattered the observed fragments, but the point which it would be best to treat as that position—to fire at, say, with a view of silencing the enemy's gun—having regard not so much to the frequency with which the direction adopted is right, as to the extent to which it is wrong in the long run. As the measure of the detriment of error, Laplace[2] takes "la valeur moyenne de l'erreur à craindre," the mean first power of the errors taken positively on each side of the real point. The mean square of errors is proposed by Gauss as the criterion.[3] *Any* mean power indeed, the integral of any function which increases in absolute magnitude with the increase of its variable, taken as the measure of the detriment, will lead to the same conclusion, if the normal law prevails.[4]

24. Yet another speculative difficulty occurs in the simplest, and recurs in the more complicated, inverse problem. In putting P as the probability, deduced from the observations that the real point for which they stand is x (between x and $x+\triangle x$), it is tacitly assumed that prior to observation one value of x is as probable as another. In our illustration it must be assumed that the enemy's gun was as likely to be at one point as another of (a certain tract of) the ridge from which it was fired. If, apart from the evidence of the shell-marks, there was any reason for thinking that the gun was situated at one point rather than another, the formula would require to be modified. This *à priori* probability is sometimes grounded on our *ignorance*; according to another view, the procedure is justified by a rough general knowledge that over a tract of x for which P is sensible one value of x occurs about as often as another.[5]

25. Subject to similar speculative difficulties, the solution which has been obtained may be extended to the analogous problem in which the *quæsitum* is not the real value of an observed magnitude, but the mean to which a series of statistics indefinitely prolonged converges.[6]

26. Next, let the modulus, still supposed given, not be the same for all the observations, but c_1 for x_1, c_2 for x_2, &c. Then P becomes proportional to

$$\exp-[(x-x_1)^2/c_1^2+(x-x_2)^2/_2^2+\&c.].$$

Method of least squares. And the value of x which is both the most probable and the "most advantageous" is $(x_1/c_1^2+x_2/c_2^2+\text{etc.})/(1/c_1^2+1/c_2^2+\&c.)$; each observation being weighted with the inverse mean square of observations made under similar conditions.[7] This is the rule prescribed by the "Method of Least Squares"; but as the rule in this case has been deduced by genuine inverse probability, the problem does not exemplify what is most characteristic in that method, namely, that a rule deducible from the hypothesis that the errors of observations obey the normal law of error is employed in cases where the normal law is not known, or even is known not, to hold good. For example, let the law of error for each observation be of the form of

$$z=(1\sqrt{\pi}c)\ \times\ \exp[-x^2/c^2-2j(x/c-2x^3/3c^3)],$$

where j is a small fraction, so that z may equally well be equated to $(1/\sqrt{\pi}c)[1-2j(x/c-2x^3/3c^3)]\ \exp-x^2/c^2$, a law which is actually very prevalent.[8] Then, according to the genuine inverse method, the most probable value of x is given by the quadratic equation $\frac{d}{dx}\log P=0$, where $\log P=\text{Const.}-\Sigma(x-x_r)^2/c_r^2-\Sigma 2j[(x-x_r)/c_r-2(x-x_r)^3/3c_r^3]$, Σ denoting summation over all the observations. According to the Method of Least Squares, the solution is the weighted arithmetic mean of the observations, the weight of any observation being inversely proportional to the corresponding mean square, *i.e.* $c_r^2/2$ (the terms of the integral which involve j vanishing), which would be the solution if the j's are all zero. We put for the solution of the given case what is known to be the solution of an essentially different case. How can this paradox be justified? Many of the answers which have been given to this question seem to come to this. When the data are unmanageable, it is legitimate to attend to a part thereof, and to determine the most probable (or the "most advantageous") value of the *quæsitum*, and the degree of its accuracy, from the selected portion of the data as if it formed the whole. This throwing overboard of part of the data in order to utilize the remainder has often to be resorted to in the rough course of applied probabilities. Thus an Insurance Office only takes account of the age and some other simple attributes of its customers,[9] though a better bargain might be made in particular cases by taking into account all available details. The nature of the method is particularly clear in the case where the given set of observations consists of several batches, the observations in any batch ranging under the same law of frequency with mean x'_r and mean square of error k_r, the function and the constants different for different batches; then if we confine our attention to those parts of the data which are of the type x'_r and k_r—ignoring what else may be given as to the laws of error—we may treat the x'_r's as so many observations, each ranging under the normal law of error with its coefficient of dispersion; and apply the rules proper to the normal law. Those rules applied to the selected data give, as the most probable (and also the most advantageous) solution, that which is prescribed by the method of least squares, and for the law of error to which the relation is liable, the normal law with modulus $\sqrt{2\ \Sigma k/n}$.

27. This principle might be illustrated by the proposal to make the economy of datum a little less rigid: to utilize not indeed all, but a little more, of our materials—not only the mean square of error for each batch, but also the mean cube of error. To begin with the simple case of a single homogeneous batch; suppose that in our example the fragments of the shell are no longer scattered according to the normal law. By the Method of Least Squares it would still be proper to put the arithmetic mean of the given observations for the true point required, and to measure the accuracy of that determination by a probability-curve of which the modulus is $\sqrt{2k/n}$, where k is the mean square of deviation (of fragments from their mean). If it is thought desirable to utilize more of the data, there is available the proposition that the arithmetic mean of a numerous set of observations, say x_1, $x_2 \cdots x_n$, taken as a sample from an indefinitely large group obeying any the same law of frequency, varies from set to set according to the following law of error (to be established later[10])—

$$z=\sqrt{n/\pi}(1/c)\ \exp-[nx^2/c^2+2nj(x/c-2x^3/3c^3)/c^3]=f(x)\ \text{say};$$

where $\frac{1}{2}c^2=$ the mean square of deviation and $j=$ the mean cube of deviation and j/c^3, say j, is small. Then by abstraction analogous to that which has just been attributed to the Method of Least Squares, we may regard the datum as a single observation, the arithmetic mean subject to the law of error $z=f(x)$. The most probable value of the *quæsitum* is therefore[11] given by the equation $f'(x-x')=0$, where x' is the arithmetic mean of the given observations. From the resulting quadratic equation, putting $x=x'+\xi$, and recollecting that j is small, we have $\xi/c^2=j/c$, $\xi=jc$. That is the correction due to the utilization of the mean cube of error. The *most advantageous* solution cannot now be determined ($f(x)$ being unsymmetrical) without assuming a particular form for the function of detriment. The (additional) degree of accuracy is no longer measured by a normal probability-curve. This method of

---

[1] Or small interval (cp. preceding section).

[2] "Toute erreur soit positive soit negative doit être considerée comme un désavantage ou une perte réelle, à un jeu quelconque," *Théorie analytique*, Art. 20 *et seqq.*, especially Art. 25. As to which it is acutely remarked by Bravais (*op. cit.* p. 258), "Cette règle simple laisse à desirer une demonstration rigoureuse, car l'analogue du cas actuel avec celui des jeux de hasard est loin d'être complète."

[3] *Theoria Combinationis*, part i. s. 6. Among contemporaries Professor Simon Newcomb is conspicuous by walking in the way of Laplace and Gauss in his preference of the *most advantageous* to the *most probable* determinations. With Gauss he postulates that "the evil of an error is proportioned to the square of its magnitude" (*American Journal of Mathematics*, vol. viii. No. 4).

[4] As argued by the present writer, *Camb. Phil. Trans.*, 1885, vol. xiv. part ii. p. 161. Cp. Glaisher, *Mem. Astronom. Soc.* xxxix. p. 108.

[5] The view taken by the present writer on the "Philosophy of Chance," in *Mind*, 1880 (approved by Professor Pearson, *Grammar of Science*, 2nd ed., p. 146). See also "À priori Probabilities," *Phil. Mag.*, Sept. 1884, and *Camb. Phil. Trans.*, 1885, vol. xiv. part ii. p. 147 *et seqq.*

[6] Above, § 15.

[7] The mean square $\int_{-\infty}^{+\infty}(x^2/\sqrt{\pi}c)\ \exp-x^2/c^2=c^2/2dx.$

[8] Below, § 49.

[9] Cp. Venn, *Logic of Chance*, 3rd ed., ch. ix. Arts, 21, 22.

[10] Below, § 49.

[11] Cp. above, § 22.

least squares *plus* cubes may easily be extended[1] to the case of several batches, or even individual observations, having different laws of frequency.

28. This application of the rules of Inverse Probability not to the actual data but to a selected part thereof, this economy of probability, is widely practised in miscellaneous statistics in order to determine the worth of an average: whether the observed difference between two averages is accidental or significant of a real difference.[2] For instance, let the data be ages at death of individuals of two classes (*e.g.*, temperate or drunken, urban or rural, &c.) who have been under observation since the age of, say, 20. Granted that the ages of death conform to Gompertz's law,[3] the determination of the most probable mean of either class and of the probability that the observed means of say n individuals of one class, n' of another, should differ by so much, would most perfectly be effected by the genuine inverse method: dealing with Gompertz's law in the same manner as with the normal law of error in a case where the observations were known to obey the latter law. But it suffices by assumed inversion to proceed *as if* our data consisted of two observations x' and y', the average ages at death of the two classes, each average obeying the normal law of error, with respective moduli $c_1 = \sqrt{[(x'-x_1)^2 + (x'-x_2)^2 + \text{etc.}]2/n}$, $c_2 = \sqrt{[(y'-y_1)^2 + (y'-y_2)^2 + \text{etc.}]2/n}$, where x_1, x_2, &c., y_1 y_2, &c., are the respective sets of observed ages at death; as follows from the *law of great numbers*,[4] whatever the law of distribution of the given observations. According to a well-known property of the normal law, the difference between the averages of n and n' observations respectively will range under a probability-curve with modulus $\sqrt{c_1^2 + c_2^2}$, say c. Whence for the probability that a difference as great as the observed one, say e, should have occurred by chance we have $\frac{1}{2}[1-\theta(\tau)]$, where $\tau = e/c$, and $\theta(x)$ is the integral $(2/\sqrt{\pi}\int_0^x(\exp -x^2)dx$, given in many treatises.[5]

Abridged methods.

29. This principle may be applied to other kinds of means besides the arithmetic, in particular the *median* (that point which has as many of the given observations above as below it). By simple induction we know that the median of a large sample of observations is a probable value for the *true* median; how probable is determined as follows from a selection of our data. First suppose that all the observations are of the same weight. If x' were the true median, the probability that as many as $\frac{1}{2}n + r$ of the observations should fall on either side of that point is given by the normal law for which the exponent is $-2r^2/n$.[6] This probability that the observed median will differ from the true one by a certain number of observations is connected with the probability that they will differ by a certain extent of the abscissa, by the proposition that the number of observations contained between the true and apparent median is equal to the small difference between them multiplied by the density of observations at the median—in the case of normal and generally symmetrical curves the greatest ordinate. This is the second datum we require to select. In the case of the normal curve it may be calculated from the modulus itself, determined by induction from a selection of data. If the observations are not all of the same worth, weight may be assigned by counting one observation as if it occurred oftener than another. This is the essence of Laplace's Method of Situation.[7]

30. In its simplest form, where all the given observations are of equal weight, this method is of wide applicability. Compared with the genuine inverse method, it is always more convenient, seldom much less accurate, sometimes even more accurate. If the given observations obey the normal law, the precision of the median is less than the precision of the arithmetic mean by only some 25 per cent.—a discrepancy not very serious where only a rough estimate of the worth of an average (see § 28) is required. If the observations do not obey the normal law—especially if the extremities are abnormally divergent—the precision of the median may be greater than that of the arithmetic mean.[8]

31. Yet another instance of the contrast between genuine and abridged inversion is afforded by the problem to determine the modulus as well as the mean for a set of observations known to obey the normal law; what the first problem[9] becomes when the coefficient of dispersion is not given. By inverse probability we ought in that case, in addition to the equation $\frac{dP}{dx}=0$, to put $\frac{dP}{dc}=0$. Whence $c^2 = 2[x'-x_1)^{10}$ $+ (x'-x_2)^2 + \text{etc.} + (x'-x_n)^2]/n$, and $x' = (x_1 + x_2 + \text{etc.} + x^n)/n$. This solution differs from that which is often given in the text-books[2] in that there, in the expression for c^2, $(n-1)$ occurs in the denominator instead of n. The difference is explained by the fact that the authorities referred to determine c, not by genuine inversion, but by ordinary induction, by a condition which certainly would be fulfilled in the long run, but does not express the whole of our data; a condition in this respect like the equation of c to $\sqrt{\pi}(\Sigma e)/n$, where e is the difference (taken positively, without regard to its sign) between any observation and the arithmetic mean of all the observations.[11]

Determination of frequency-constants.

32. Of course the determination of the most probable value is subject to the speculative difficulties proper to *à priori* probability; which are particularly striking in this case, as it appears equally natural to take as that constant, of which the values are *à priori* equally probable, $k(=c^2/2)$, or even[12] $h(=1/c^2)$, the measure of weight, as in fact Laplace has done;[13] yet no two of these assumptions can be exactly true.[14]

33. A more convenient determination is obtained from simple induction by equating the modulus to some datum of the observed group to which it would be equal if the group were complete—in particular to the distance from the median of some percentile (or point which marks off a certain percentage, *e.g.*, 25 of the given observations) multiplied by a factor corresponding to the percentile obtainable from a familiar table. Mr Sheppard has given an interesting proof[15] that we cannot by way of percentiles obtain such good[16] results for the frequency-constants as by the use of "the average and average square" [the method prescribed by inverse probability].

34. The same philosophical subtleties, with greater mathematical complications, meet us when we pass on to the case of two or more *quæsita*. The problem under this head which mainly exercised the older writers was to determine a number of unknown quantities, given a larger number, n, of equations involving them.

Entangled measurements.

35. Supposing the true values approximately known, by substituting the approximate values in the given equations and expanding, according to Taylor's theorem, there will be obtained for the *corrections*, say x, y · · · ,n linear equations of the form

$$a_1x + b_1y \cdot\cdot = f_1$$
$$a_2x + b_2y \cdot\cdot = f_2,$$

where each a and b is a known coefficient, and each f is a fallible observation. Suppose that the error to which each is liable obeys the normal law, and that the modulus pertaining to each observation is the same—which latter condition can be secured by multiplying each equation by a proper factor—then if x' and y' are the true values of the *quæsita*, the frequency with which $(a_1x' + b_1y' - f_1)$ assumes different values is given by the equation $z = 1/(\sqrt{\pi}\,c_1)$ $\exp -[a_1x + b_1y - f_1]^2/c_1^2$, where c_1 is a constant which, if not known beforehand, may be inferred, as in the simpler case, from a set of observations. Similar statements holding for the other equations, the probability that the given set of observations f_1, f_2, &c., should have resulted from a particular system of values for $x, y \cdot\cdot$ is $J \exp -[(a_1x + b_1y - f_1)^2/c_1^2 + (a_2x + b_2y - f_2)^2/c_2^2 + \text{\&c.}]$, where J is a constant determined on the same principle as in the analogous simpler cases.[17] The condition that P should be a maximum gives as many linear equations for the determination of x' y' · · · as there are unknown quantities.

36. The solution proper to the case where the observations are

[1] See on the method of least squares, *Proceedings of the Cambridge Philosophical Society*, 1887, vol. vi. part ii., and references there given.

[2] The present writer's *Methods of Statistics* in the Jubilee volume of the *Journ. Stat. Soc.* is designed to illustrate this use of the normal law.

[3] *Text-Book of Institute of Actuaries*, ch. vi.

[4] Above, § 9.

[5] *E.g.*, *Ency. Brit.*, art. "Probability," 8th and 9th ed.

[6] Above, § 4.

[7] *Théorie analytique*, supplement ii. p. 614. *Mécanique Céleste*, book iii. Art. 40; on which see the note in Bowdich's translation. The method may be extended to other percentiles. See Czuber, *Beobachtungsfehler*, § 59. Cp. *Phil. Mag.*, October 1886, p. 375; and Sheppard, *Trans. Roy. Soc.*, 1889, A, vol. cxcii. p. 135, *et ante*, where the error incident to this kind of determination is ascertained with much precision.

[8] Cp. *Phil. Mag.*, 1887, vol. xxiv. p. 269 *et seqq.*

[9] Above, § 22.

[10] *E.g.*, Airy, *Theory of Errors*, Art. 60.

[11] It is a nice point that the expression for c^2, which has $(n-1)$ instead of n for denominator, though not the more *probable*, may yet be the more *advantageous* (supposing that there were any sensible difference between the two). Cp. *Camb. Phil. Trans.*, 1885, vol. xiv. part ii. p. 165.

[12] Above, § 1, note.

[13] *Théorie analytique*, 2nd Supp., ed. 1847, p. 578.

[14] See the matter discussed in *Camb. Phil. Trans.*, *loc. cit.*

[15] *Trans. Roy. Soc.*, 1899, A, vol. cxcii. p. 135.

[16] Good as tested by a comparison of the mean squares of errors in the frequency-constant determined by the compared methods (*loc. cit.*, cp. below, § 41, note).

[17] Above, § 22.

known to range according to the normal law may be extended to numerous observations ranging under any law, on the principles which justify the use of the Method of Least Squares in the case of a single *quæsitum*.

37. As in that simple case, the principle of economy will now justify the use of the *median, e.g.*, in the case of two *quæsita*, putting for the true values of x and y that point for which the sum of the perpendiculars let fall from it on each of a set of lines representing the given equations (properly weighted) is a minimum.[1]

Normal correlation.

38. The older writers have expressed the error in the determination of one of the variables without reference to the error in the other. But the error of one variable may be regarded as *correlated* with that of another; that is, if the system $x', y' \cdots$ forms the solution of the given equations, while $x'+\xi$, $y'+\eta \cdots$ is the real system, the (small) values of $\xi, \eta \cdots$ which will concur in the long run of systems from which the given set of observations result are normally correlated. From this point of view Bravais, in 1846, was led to several theorems which are applicable to the now more important case of correlation in which ξ and η are given (not in general small) deviations from the means of two or more correlated members (organs or attributes) forming a normal group.

39. To determine the frequency-constants of such a group it is proper to proceed on the analogy of the simple case of one-dimensioned error. In the case of two dimensions, for instance, the probability p_1 that a given pair of observations (x_1, y_1) should have resulted from a normal group of which the means are x' y' respectively, the standard deviations σ_1 and σ_2, and the coefficient of correlation r, may be written—

$$\triangle x \triangle y \triangle \sigma_1 \triangle \sigma_2 \triangle r \ (1/2\pi\sqrt{\sigma_1\sigma_2(1-r^2)} \exp - \tfrac{1}{2}E^2,$$

where $E^2 = (x'-x_1)^2/\sigma_1{}^2 - 2r(x'-x_1)(y'-y_1)/\sigma_1\sigma_2 + (y'-y_1)^2/\sigma_2{}^2$.

A similar statement holds for each other pair of observations (x_2y_2), $(x_3y_3)\cdots$; with analogous expressions for $p_2, p_3\cdots$. Whence, as in the simpler case, we have $p_1 \times p_2 \times$ &c. $\times p_n/J$ (a constant) for P, the *à posteriori* probability that the given observations should have resulted from an assigned system of the frequency-constants. The most probable system is determined by making P a maximum, and accordingly equating to zero each of the following expressions—

$$\frac{dP}{dx}, \quad \frac{dP}{dy}, \quad \frac{dP}{d\sigma_1}, \quad \frac{dP}{d\sigma_2}, \quad \frac{dP}{dr}.$$

The values of the arithmetic mean and of the standard deviation for each variable are what have been obtained in the simple case of one dimension. The value of r is $\Sigma(x'-x_r)(y'-y_r)/\sigma_1\sigma_2$.[2] The probable error of the determination is assigned on the assumption that the errors to which it is liable are small.[3] Such coefficients have already been calculated for a great number of interesting cases. For instance, the coefficient of correlation between the human stature and femur is 0·8, between the right and left femur is ·96, between the statures of husbands and wives is 0·28.[4]

40. This application of inverse probability to determine correlation-coefficients and the error to which the determination is liable was first made by Professor Pearson.[5] He has pointed out a circumstance which seems to be of great importance in the theory of evolution: that the errors incident to the determination of different frequency-coefficients are apt to be mutually correlated. Thus if a random selection be made from a certain population, the correlation-coefficient which fits the organs of that set is apt to differ from the coefficient proper to the complete group in the same sense as some other frequency-coefficients.

41. The last remark applies also to the determination of the coefficients, in particular those of correlation, by abridged methods, on principles explained with reference to the simple case; for instance, by the formula $r = \Sigma\eta/\Sigma\xi$, where $\Sigma\xi$ is the sum of (some or all) the positive (or the negative) deviations of the values for one organ or attribute measured by the modulus pertaining to that member, and $\Sigma\eta$ is the sum of the values of the other member, which are associated with the constituents of $\Sigma\xi$.[6] There is a variety of this method which is certainly much less troublesome, and is perhaps not much less accurate, than the method prescribed by genuine inversion.[7]

42. A method of rejecting data analogous to the use of percentiles in one dimension is practised when, given the frequency of observations for each increment of area, *e.g.*, each $\triangle x \triangle y$, we utilize only the frequency for *integral* areas. Mr Sheppard has given an elegant solution of the problem: to find the correlation between two attributes, given the medians L, and M, of a normal group for each attribute and the distribution of the total group, as thus[8]—

	Below L,	*Above L,*
Below M,	*P*	*R*
Above M,	*R*	*P*

If cos D is put for r, the coefficient of correlation, it is found that $D = \pi R/(P+R)$. For example, let the group of statistics relating to dice already[9] cited from Professor Weldon be arranged in four quadrants by a horizontal and a vertical line, each of which separates the total groups into two halves: lines of which the equations prove to be respectively $y = 6·11$ and $x = 6·156$. For R we have 1360·5, and for P 687·5 roughly. Whence $D = \pi \times 0·66$; $r = \cos 0·66 \times \pi = -\tfrac{1}{2}$ nearly, as it ought; the negative sign being required by the circumstance that the lower part of Mr Sheppard's diagram shown here corresponds to the upper part of Professor Weldon's diagram shown in § 8.

43. Necessity rather than convenience is sometimes the motive for resort to percentiles. Professor Pearson has applied the median method to determine the correlation between husbands and wives in respect of the darkness of eye-colour, a character which does not admit of exact graduation: "our numbers merely refer to certain groupings, arranged, it is true, in increasing darkness of colour, but in no way corresponding to equal increases in colour-intensity."[10] From data of this sort, having ascertained the number of husbands with eye-colour above the median tint who marry wives with eye-colour above the median tint, Professor Pearson finds for r the coefficient of correlation +0·1. A general method for determining the frequency-constants when the data are, or are taken to be, of the integral sort has been given by Professor Pearson.[11] Attention should also be called to Mr Yule's treatment of the problem by a sort of logical calculus on the lines of Boole and Jevons.[12]

Abnormal correlation.

44. In the cases of correlation which have been so far considered, it has been presupposed that the things correlated range according to the normal law of error. But now, suppose the law of distribution to be no longer normal: for instance, that the dots on the plane of xy,[13] representing each a pair of members, are no longer grouped in elliptic (or circular) rings of equal frequency, that the locus of the maximum y deviation, corresponding to an assigned x deviation, is no longer a right line. How is the interdependence of these deviations to be formulated? It is submitted that such data may be treated as if they were normal: by an extension of the *Method of Least Squares*, which is justified by the *law of great numbers*, in two or more dimensions.[14] Thus when the amount of pauperism together with the amount of outdoor relief is plotted in several unions, there is obtained a distribution far from normal. Nevertheless if the average pauperism and average outdoor relief are taken for *aggregates*—say quintettes or decades—of unions taken at random, it may be expected that these means will conform to the normal law, with coefficients obtained from the original data, according to the rule which is proper to the case of the normal law. By obtaining averages conforming to the normal law, as by the simple application of the method of least squares, we should not indeed have utilized the whole of our data, but we shall put a part of it in a very useful shape. Although the regression-equations obtained would not accurately fit the original material, yet they would have a certain correspondence thereto. What sort of correspondence may be illustrated by an example in games of chance, which

[1] See *Phil. Mag.*, 1888. "On a New Method of Reducing Observations"; where a comparison in respect of convenience and accuracy with the received method is attempted.

[2] Corresponding to the $1/\sqrt{km}$ of §§ 7, 19.

[3] Pearson, *Trans. Roy. Soc.*, A, vol. cxci. p. 234.

[4] Pearson, *Grammar of Science*, ed. 2, p. 402 and p. 431.

[5] *Trans. Roy. Soc.*, 1898, vol. cxci., A.

[6] *Phil. Mag.*, 1893, July, p. 101.

[7] *Ibid.* p. 103. But it should be observed that here—as in some other comparisons more favourable to genuine inversion—the rival is the judge: the test is prescribed by that abridged or "assumed" inversion (above, § 26, and *Camb. Phil. Trans.* vol. xiv. part ii. p. 153), which falls short of the genuine inversion, not fully utilizing by means of the expression P (above, § 22) what is given as to the form of the required function.

[8] *Trans. Roy. Soc.*, 1899, A, vol. cxcii. p. 141.

[9] Above, § 8.

[10] *Grammar of Science*, p. 432.

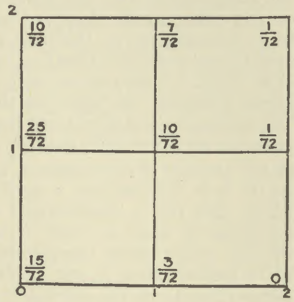
[11] *Trans. Roy. Soc.*, A, vol. cxcv.

[12] *Trans. Roy. Soc.*, 1900, A, vol. cxciv. p. 257; 1901, A, vol. cxcvii. p. 91.

[13] Above, § 19.

[14] Above, § 9.

Professor Weldon has kindly supplied. Three half-dozen of dice having been thrown, the number of dice with more than three points in that dozen which is made up of the first and the second half-dozen, is taken for y, the number of sixes in the dozen made up of the first and the third half-dozen, is taken for x. Thus each twofold observation (xy) is the sum of six twofold elements, each of which is subject to a law of frequency represented by the annexed diagram; where[1] the figures outside denote the number of successes of each kind, for the ordinate the number of dice with more than three points (out of a cast of two dice), for the co-ordinate the number of sixes (out of a cast of two dice, one of which is common to the aforesaid cast); and the figures inside denote the comparative probabilities of each twofold value (*e.g.*, the probability of obtaining in the first cast two dice each with more than three points, and in the second cast two sixes, is 1/72). Treating this law of frequency according to the rule which is proper to the normal law, we have (for the element) if the sides of the compartments each $=i$



$$\sigma_1 = i\sqrt{5/18}\,;\ \sigma_2 = i/\sqrt{2}\,;\ \mathrm{r} = 1/\sqrt{20}.$$

Whence for the regression-equation which gives the value of the ordinate most probably associated with an assigned value of the abscissa we have $y = x \times \mathrm{r}\sigma_2/\sigma_1 = 0{\cdot}3x$; and for the other regression-equation, $x = y/6$. Accordingly, in Professor Weldon's statistics, which are reproduced in the annexed diagram, when

	0	1	2	3	4	5	6	7	8	9	10	11	12
12					1								
11		4	3	3	3	1							
10	3	17	15	13	10	4	3	1					
9	12	51	59	61	36	14	5	3					
8	36	135	154	150	64	21	5	2	1				
7	74	195	260	179	112	35	5	1					
6	90	248	254	170	75	26	3						
5	93	220	230	124	51	8	2						
4	86	162	127	75	19	4	1						
3	37	86	56	17	6	2							
2	14	23	23	4	3								
1	2	4											
0													

$x=3$ the most probable value of y ought to be 1. And in fact this expectation is verified, x and y being measured along lines drawn through the centre of the compartment, which *ought* to have the maximum of content, representing the concurrence of one dozen with *two* sixes and another dozen with *six* dice having each more than three points, the compartment which in fact contains 254 (*almost* the maximum content). In the absence of observations at $x = -3i$ or $y = \pm 6i$, the regression-equations cannot be further verified. At least they have begun to be verified by batches composed of six elements, whereas they are not verifiable at all for the simple elements. The normal formula describes the given statistics as they behave, not when by themselves, but when massed in crowds: the regression-equation does not tell us that, if x' is the magnitude of one member, the most probable magnitude of the other member associated therewith is rx', but that, if x' is the average of several samples of the first member, then rx' is the most probable average for the specimens of the other member associated with those samples. In the view of the present writer this is the rationale of Mr Yule's proposal to construct regression-equations according to the normal rule "without troubling to investigate the normality of the distribution."[2] Mr Yule's own view of the subject is, however, well worthy of attention.

[1] Cp. above, § 8.

[2] *Proc. Roy. Soc.* vol. lx. p. 477.

45. Professor Pearson has given a beautiful application of the theory of correlation to test the empirical evidence that a given group conforms to a proposed formula, *e.g.*, the normal law of error.[3]

Empirical verification.

46. Supposing the constants of the proposed function to be known,—in the case of the normal law the arithmetic mean and modulus—we could determine the position of any percentile, *e.g.*, the median, say a. Now the probability that if any sample numbering n were taken at random from the complete group, the median of the sample, a', would lie at such a distance from a that there should be r observations between a and a' is $\int_{\mathrm{r}}^{\infty} \sqrt{2/\pi n}\,\exp - 2\mathrm{r}^2/n$.[4]

If, then, any observed set has an excess which makes the above-written integral very small, the set has probably not been formed by a random selection from the supposed given complete group. To extend this method to the case of two, or generally n, percentiles, forming $(n+1)$ compartments, it must be observed that the excesses, say e and e′, are not independent but correlated. To measure the probability of obtaining a pair of excesses respectively as large as e and e′, we have now (corresponding to the extremity of the probability-curve in the simple case) the solid content of a certain probability-surface outside the curve of equal probability which passes through the points on the plane xy assigned by e, e′ (and the other data). This double, or in general multiple, integral, say P, is expressed by Professor Pearson with great elegance in terms of the quadratic factor, called by him χ^2, which forms the exponent of the expression for the probability that a particular system of the values of the correlated e, e′, &c., should concur—

$$\mathrm{P} = \sqrt{2/\pi}\int_{\chi}^{\infty} e^{-\frac{1}{2}\chi^2}\,d\chi + \sqrt{\frac{2}{\pi}}\,e^{-\frac{1}{2}\chi^2}\left[\frac{\chi}{1} + \frac{\chi^3}{1\cdot 3} + \cdots + \frac{\chi^{n-2}}{1\cdot 3\cdots(n-2)}\right]$$

when n is odd; with an expression different in form, but nearly coincident in result, when n is even. The practical rule derived from this general theorem may thus be stated. Find from the given observations the probable values of the coefficients pertaining to the formula which is supposed to represent the observations. Calculate from the coefficients a certain number, say n, of percentiles; thereby dividing the given set into $n+1$ sections, any of which, according to calculation, ought to contain say m of the observations, while in fact it contains m'. Put e for $m' - m$; then $\chi^2 = \Sigma e^2/m$. Professor Pearson has given in an appended table the values of P corresponding to values of $n+1$ up to 20, and values of χ^2 up to 70. He does not conceal that there is some laxity involved in the circumstance that the coefficients employed are not known exactly, only inferred with probability.[5]

47. One of Professor Pearson's illustrations is particularly relevant here. The annexed table gives the distribution of 1000 shots fired at a line in a target, the hits being arranged in belts drawn on the target parallel to the line:—

Belt.	Observed Frequency.	Normal Distribution.	e	e^2/m
1 . .	1	1	0	0
2 . .	4	6	−2	0·667
3 . .	10	27	−17	10·704
4 . .	89	67	+22	7·224
5 . .	190	162	+28	4·839
6 . .	212	242	−30	3·719
7 . .	204	240	−36	5·400
8 . .	193	157	+36	8·255
9 . .	79	70	+9	1·157
10 . .	16	26	−10	3·846
11 . .	2	2	0	0
	1000	1000	...	45·811

The "normal distribution" is obtained from a normal curve, of which the coefficients are determined from the observations. From the value of χ^2, viz. 45·8, and of $(n+1)$, viz. 11, we deduce, with sufficient accuracy from Professor Pearson's table, or more exactly from the formula on which the table is based, that P = ·000,001,5 · ·. "In other words, if shots are distributed on a target according to the normal law, then such a distribution as that cited could only be expected to occur on an average some 15 or 16 times in 10,000,000 times."

[3] *Phil. Mag.*, July 1900.

[4] As shown above, § 29.

[5] *Loc. cit.* p. 166.

48. That the normal law of error should not be exactly fulfilled is not disconcerting to those who ground the law upon the plurality of independent causes. On that view the normal law would only be exact when the numbers of elements from which it is generated is very great. In general, when that number is large, but not indefinitely great,[1] there is required a correction, formed by adding to the exponent of the normal function, namely, $-x^2/c^2$, a descending series of terms of the order $1/\sqrt{n}$, $1/n$, &c., respectively, where n is the number of the elements.[2]

Second and further approximations to the law of error.

49. The first term of this series may be written

$$-2(j/c^3)[x/c - 2\,x^3/3c^3];$$

where $c^2/2$ is the mean square of deviation for the compound and also the sum of the mean squares of deviations for the component elements, j is the mean cube of deviations for the compound and the sum of the mean cubes for the components; and the elements are supposed to be such and so numerous that j/c^3 is of the order $1/\sqrt{n}$. The order of the term being such, it is permissible to bring the term down from the exponent by expanding and neglecting higher powers.[3] This second approximation, first given by Poisson, was rediscovered by De Forest.[4] The present writer has obtained it[5] by extending the method of partial differential equations which Mr Morgan Crofton had applied to find the first approximation. By a further extension of this method a *third* and further approximations may be found. The corrected normal law is then of the form[6]

$$z = \frac{1}{\sqrt{\pi c}}\left(\exp - \frac{x^2}{c^2}\right)\left[1 - 2\mathrm{j}\left(\frac{x}{c} - \frac{2}{3}\frac{x^3}{c^3}\right) + \mathrm{j}^2\left(-\frac{5}{3} + 10\frac{x^2}{c^2} - \frac{20}{3}\frac{x^4}{c^4} + \frac{8}{9}\frac{x^6}{c^6}\right) + \mathrm{i}\left(\tfrac{1}{2} - 2\frac{x^2}{c^2} + \frac{2}{3}\frac{x^4}{c^4}\right)\right];$$

where $\mathrm{j} = j/c^3$, $\mathrm{i} = i/c^4$, j and c are defined as above, i is the sum of the respective differences for each element between its mean fourth power of error and thrice its mean square of error,[7] and also the corresponding difference for the compound. The formula may be verified by the case of the *binomial*, considered as a simple case of the law of great numbers. Here

$$c^2 = 2npq,\ j = npq\,(q-p),\ i = npq\,(1-6pq).^{8}$$

These values being substituted for the coefficients in the general formula, there results an expression which may be obtained directly by continuing[9] to expand the expression for a term of the binomial.

50. In virtue of the second approximation a set of observations is not to be excluded from the affinity to the normal curve because, like the curve of barometric heights,[10] it is slightly asymmetrical. In virtue of the third approximation it is not excluded because, like the group of shot-marks above examined, it is, though almost perfectly symmetrical, in other respects apparently somewhat abnormal. If the thus corrected *quasi-normal* curve be submitted to the same criterion as just now the normal curve, to test its capacity to represent a given group of shot-marks, the improbability is reduced from odds of millions to one to odds of hundreds to one.[11] The details of the calculation are given elsewhere,[12] but some points of general interest may be noticed here.

51. Regarding the contents of the *first* "belt" as spread out between 0·5 and 1·5, and so on, we have 6·482 for the arithmetic mean. For the mean square of deviation we have $(\Sigma\epsilon^2)/1000$, where ϵ is the distance of the centre of a belt from 6·482; upon the supposition that the contents of each belt are massed at its centre. But, as Mr Sheppard has pointed out,[13] in order to obtain from this sum, say μ_2, the proper *integral*, say (μ_2), the rough value ought to be corrected thus: $(\mu_2) = \mu_2 - h^2/12$, where h is the breadth of a "belt." Here h is unity, and accordingly, the rough value being 2·485676, we have for the corrected value of μ_2 2·402343. The correction is particularly important, when it is well above the probable error to which the determination of μ_2 is liable on account of the paucity of observations, namely, $\mu_2/\sqrt{n}$ nearly.[14] However, in all such calculations a good margin is to be left for the possibility that the n observations are not perfectly *independent*: the accidents of wind or nerve[15] which affected one shot may have affected other shots immediately before or after. Again, it is to be noticed that in our application of the criterion one or two compartments at the extremity have not been taken into account, since on the hypothesis under consideration it is not to be expected that there should be a close fit at the extremities.[16] The contents of the compartments, connected by the formula with the *integral* and the *ordinate* of the probability-curve, are readily determined from a table of that integral and its differences.[17]

52. A formula much more comprehensive than the corrected normal law is proposed by Professor Pearson under the designation of the "generalized probability-curve." The ground and scope of the new law cannot be better stated than in the words of the author:—

The "generalized probability-curve."

53. "The slope of the normal curve is given by a relation of the form

$$\frac{1}{y}\frac{dy}{dx} = -\frac{x}{c_1}.$$

The slope of the curve correlated to the skew binomial, as the normal curve to the symmetrical binomial, is given by a relation of the form

$$\frac{1}{y}\frac{dy}{dx} = -\frac{x}{c_1 + c_2 x}.$$

Finally, the slope of the curve correlated to the hypergeometrical series (which expresses a probability distribution in which the contributory causes are not independent, and not equally likely to give equal deviations in excess and defect), as the above curves to their respective binomials, is given by a relation of the form

$$\frac{1}{y}\frac{dy}{dx} = -\frac{x}{c_1 + c_2 x + c_3 x^2}.$$

This latter curve comprises the two others as special cases, and, so far as my investigations have yet gone, practically covers all *homogeneous* statistics that I have had to deal with. Something still more general may be conceivable, but I have found no necessity for it."[18]

54. The "hypergeometrical series," it should be explained, had appeared as representative of the distribution of black balls[19] in the following case. "Take n balls in a bag, of which pn are black and qn are white, and let r balls be drawn and the number of black be recorded. If $r > pn$, the range of black balls will lie between 0 and pn; the resulting frequency-polygon is given by a hypergeometrical series." The "generalized probability-curve" presents two forms[20]—

$$y = y_0(1 + x/a_1)^{\nu a_1}(1 - x/a_2)^{\nu a_2},$$

$$\text{and } y = y_0\,\frac{1}{(1 + x^2/a^2)^m}\,e^{-\nu\tan^{-1}x/a}.$$

[1] As probably in Natural History. Cp. Galton, *Phil. Mag.*, 1875.

[2] The elements being supposed independent and of the same order of magnitude; *mutatis mutandis* if there is a superior order. Cp. above, § 9.

[3] The form employed by Todhunter, *History of Probability*, Art. 993, and in the article on "Probability" in the 8th edition of *Ency. Brit.*, § 136.

[4] *The Analyst* (Iowa), vol. ix.

[5] *Phil. Mag.*, February 1896.

[6] The part of the third approximation affected with j^2 may be found by proceeding to another step in the method described (*Phil. Mag.*, 1896 vol., p. 96). The remaining part of the third approximation is found by the same method (or the variant on p. 97) from the new partial differential equation $\frac{dy}{di} = \frac{1}{24}\frac{d_4 y}{dx^4}$, where i is the difference between the actual mean fourth power of deviation and what it would be if the normal law held good. Further approximations may be obtained on the same principle.

[7] $\mu_4 - 3\mu_2^2$ in the notation which Professor Pearson has made familiar.

[8] Cp. Pearson, *Trans. Roy. Soc.*, 1895, vol. clxxxvi., A, p. 347.

[9] Above, § 4, referring to Todhunter, *History*, Art. 993. The third (or second additional term of) approximation for the binomial, given explicitly by Professor Pearson, *Trans. Roy. Soc.*, 1895, A, footnote of 347, will be found to agree with the general formula above given, when it is observed that the correction affecting the *absolute term*, his y_0, disappears in his formula by division.

[10] *Journ. Stat. Soc.*, 1899, p. 550, referring to Pearson, *Trans. Roy. Soc.*, 1898, A.

[11] That the improbability still remains so considerable is perhaps due to the fact that the statistics form a mixture of two types, as suggested by Professor Pearson, *Trans. Roy. Soc.*, 1894, vol. clxxxv., A, p. 91.

[12] *Journ. Stat. Soc.*, 1901.

[13] *Proceedings of London Mathematical Society*, vol. xxix. p. 369, &c.

[14] Todhunter, *History of Probability*, Art. 1006.

[15] Above, § 10.

[16] Cf. *Journ. Stat. Soc.*, 1899.

[17] Such as Table III. appended to De Morgan's article on the "Calculus of Probabilities" in the *Ency.-Metropol.* Mr Burgess's tables in the *Transactions of the Edinburgh Royal Society for 1900*, giving the values of the *ordinate* as well the integral, are most convenient for the present purpose.

[18] *Trans. Roy. Soc.*, 1895, A, p. 381; *et ante.*

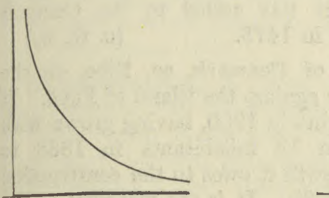
[19] *Ibid.* p. 360.

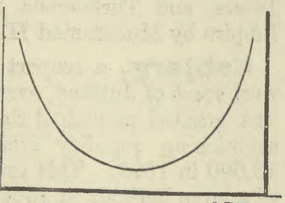
[20] *Ibid.* p. 367.

When a_1, a_2, ν are all finite and positive, the *first* form represents, in general, a skew curve, with limited range in both directions; in the particular case, when $a_1 = a_2$ a symmetrical curve, with range limited in both directions. If $a_2 = \infty$, the curve reduces to

$$y = y_0(1 + x/a_1)^{\nu a_1} e^{-\nu x};$$

representing an asymmetrical binomial with $\nu = 2\mu_2/\mu_3$, and $a_1 = 2\mu_2^2/\mu_3 - \mu_3/2\mu_2$, μ_2, and μ_3, being respectively the mean second and mean third power of deviation measured from the centre of gravity. In the particular case, when μ_3 is small, this form reduces to what is above called the "quasi-normal" curve; and when μ_3 is zero, a_1 becoming infinite, to the simple normal curve. The pregnant general form yields two less familiar shapes apt to represent curves of the character shown in the annexed diagrams—the





one occurring in a good number of instances, such as infant deaths, the values of houses, the number of petals in certain flowers; the other less familiarly illustrated by *Consumptivity* and *Cloudiness*.[1] The *second* solution represents a skew curve with unlimited range in both directions. Professor Pearson has successfully applied these formulæ to a number of beautiful specimens culled in the most diverse fields of statistics. The flexibility with which the generalized probability-curve adapts itself to every variety of existing groups no doubt gives it a great advantage over the normal curve, even in its extended form. It is only in respect of *à priori* evidence that the latter can claim precedence.[2]

55. Any law which has claims to be called *the* law of error may be expected in certain circumstances to give rise to some derivative laws which should be noticed here. First, statistics relating to two (or more) different types are apt to be mixed; for instance, the measurements of human heights in a country comprising two distinct races.[3]

56. If the measurements for each race are grouped according to a normal law of error, the *quæsita* are the constants in the curve

$$y = \alpha(1/\sqrt{\pi}c_1)\exp - (x-a)^2/c_1^2 + \beta(1/\sqrt{\pi}c_2)\exp - (x-b)^2/c_2^2,$$

where α and β are the proportionate sizes of the two groups $(\alpha + \beta = 1)$; a and b are the respective centres of gravity; and c_1 c_2 the respective moduli. The data are measurements each of which relates to *one or other* of these component curves. A splendid solution of this difficult problem has been given by Professor Pearson.[4] The five unknown quantities are connected by him with the centre of gravity of the given observations, and the mean second, third, fourth, and fifth powers of their deviations from that centre of gravity, by certain rational algebraic equations, which reduce to an equation in one variable of the *ninth* dimension. In an example worked by Professor Pearson, this fundamental equation had three possible roots, two of which gave very fair solutions of the problem, while the third suggested that there might be a *negative* solution, importing that the given system would be obtained by *subtracting* one of the normal groups from the other; but the coefficients for the negative solution proved to be imaginary. "In the case of crabs' foreheads, therefore, we cannot represent the frequency curve for their forehead length as the difference of two normal curves." In another case, which *primâ facie* seemed normal, Professor Pearson found that "all nine roots of the fundamental nonic lead to imaginary solutions of the problem. The best and most accurate representation is the normal curve."

57. Another modification may be introduced by an objection which has been made against the normal curve, and might be made, with as much or as little justice, against any other formula claiming to be *the* law. If there is any law applicable to things in general, it must be applicable to functions of things, which also are things. But if a group is transformed by substituting for the size of each member a certain function of that size, the resulting group will not conform to the same law of error as the original one, in general and except when the function is linear. If the diameters of oranges of the same species vary according to the normal, or any other law of error, then the volume of oranges, being proportioned to the cube of the diameter, will not vary according to that law. The answer to this difficulty is that, very generally, the variable part of an organ or attribute is so small relatively to the whole, that the cube or other ordinary function of the whole may be treated as a linear function of the variable part. Thus the cubes of a man's height may be written $M^3(1 + e/M^3)$, where M is the mean, say 67″, and e is the deviation of the individual's height from the mean. The modulus for human heights being about 3·7, it appears that the transformed measure is very nearly $M^3(1 + 3e/M)$, for five-sixths of the group differing by a proportion less than ·01 from the true cube. Occasionally, however, it may be expected that the deformation due to such transformations will be sensible. The case in which the compound magnitude is a function other than linear of a sum of elements is a species of the more general case in which the compound is a function, explicit or implicit, of the elements. If the function admits of expansion in ascending powers of the variables,[5] the second and further approximations to the law of error for the compound have the same form as that which has been given for the case in which the compound is a linear function of the elements (see § 49), the constants c j i, and have the same relation as before to the mean powers of the compound; but not the same relation to the mean powers of the elements. For instance, the mean cube of error for the compound (which, divided by the cube of the modulus, forms the constant j) is now affected not only by the asymmetry of the laws of frequency for the elements but also by the asymmetry of the structure, the function combining the elements. When the function involving the elements does not admit of expansion, being not even approximately linear, then the law of frequency for the compound will be not even approximately normal. For example, if the velocities (in any assigned direction) of molecules of equal, say unit, mass are distributed according to a normal law of which the centre is zero, then the squares of the velocities, the energies, will be distributed according to a quite different law[6] represented by a unilateral curve, in that respect like the statistics of infant mortality (above, § 54).

58. Other deformations of the law of error might be suggested. But the question recurs: How far does the fact that a certain function fits the facts tolerably establish that this, and not another, is the true formula? For instance, the hump in the curve representing the column headed d_x in a life-table, which has been regarded as a probability-curve of the "normal"[7] or of the "generalized"[8] variety, may really be due to those conditions of accelerated mortality which render the Gompertz–Makeham law appropriate to the facts; the expression for the decrement of l_x according to that law having a unique maximum when values of the constants suited to life-tables are substituted in the formula. The statistician must not forget that there are other laws besides the law of error.

An exhaustive list of writings on a nearly related subject, the "Method of Least Squares," was given by Merriman in *Connecticut Trans.* iv. Leading publications up to 1884 are noticed under PROBABILITY, *Ency. Brit.*, 9th edition. Czuber, the latest there mentioned, has referred to, criticized, and improved on many of his predecessors. Since that date a great advance has been made by Pearson in the mathematical papers frequently cited above. See also the references to Burbury, Galton, Lewis, Sheppard, and others. Bowley's *Elements of Statistics*, part ii., forms an introduction which leads the beginner easily, yet far. (F. Y. E.)

Erzerúm.—1. A viláyet of Asiatic Turkey, divided into three sanjaks—Erzerúm, Erzingan, and Bayezid; its area is about 29,600 square miles, and the population numbers 645,500 (Moslems, chiefly Kúrds, 500,500; Christians, 145,000, of whom 135,500 are Armenians). It includes the highest portion of the Armenian plateau (see ARMENIA), and in it the two arms of the Euphrates, the Araxes and the Acampsis, take their rise. It is an agricultural country with few industries. There are large forests; iron, salt, sulphur, and other mineral springs; and unworked salt and coal mines. 2. A fortified town,

[1] Pearson, *loc. cit.* p. 364, and *Proc. Roy. Soc.*

[2] *Journ. Stat. Soc.*, 1895, p. 506.

[3] See references to instances in Professor Pearson's paper cited below.

[4] *Trans. Roy. Soc.*, 1894, vol. clxxxv., A.

[5] The species has been illustrated by the present writer in the *Journ. Stat. Soc.*, Dec. 1898, p. 678 *et seq.*, and Sept. 1899, p. 540; the genus to be discussed in a later paper.

[6] *Journ. Stat. Soc.*, 1898, p. 676, and Sept. 1899, p. 543.

[7] Above, § 17.

[8] Pearson, *Trans. Roy. Soc.*, 1895, A, p. 406, and *Chances of Death.*

capital of the viláyet and sanjak of the same name, residence of a Governor-General, situated at an altitude of 6250 ft., on the lower slopes of the Palentoken Dagh (10,300 ft.), at the south-east corner of a plain (5750 ft.), through which the Western Euphrates runs. North of the town there are large marshes, and to the east is the Deveboyún range (6950 ft.). It is an important military station, with a large garrison, military school, and hospital. It has an enceinte which encloses an area of 3 square miles, only partially covered by the town, and is protected against an attack from the east and south-east by a strong line of defences, 27 miles long. The houses are partly well built and partly underground. There are interesting remains of Seljúk buildings of the 12th century, including tombs and the beautiful Chifte Minareh. The chief Armenian quarter is on the north side. The streets are irregular, badly drained, and dirty, and the town, though well supplied with water, is said to be the most insanitary in Asia Minor. The climate is healthy, and the atmosphere clear and dry except in spring. The winter is very severe, with great cold (–20° to –22° F.), deep snow, and blizzards. The summer heat is moderate (59° to 77° F.). Roads lead to Trebizond and Riza on the Black Sea; westwards to Sivas, Kara-hissar, and Kelkit Chiftlik; southwards to Diarbekr, Músh, and Van; and eastwards to Olti and Kars. The industries, excepting blacksmith's and coppersmith's work and tanning, have died out. The fertile plain north of the town was well cultivated with wheat, barley, millet, and vegetables, but since the Armenian massacres of 1895 much of the land has lain fallow. The exports are wheat, linseed, furs, live-stock, &c. (value in 1896, £148,510; in 1900, £177,750). The imports are Manchester goods, sugar, copper, petroleum, &c. (value in 1896, £188,510; in 1900, £262,355). The Persian trade has almost disappeared since 1890; poverty has been increasing; and, with the Kúrds unsubdued and the Armenians impoverished, there seems little prospect of an early recovery of prosperity. The population is 40,000 (Moslems, 26,500; Armenians, 11,000; Greeks and Protestants, 1500; Persians, Jews, &c., 1000). There are British and other European consulates, and an American mission, with schools. The town was unsuccessfully attacked by the Russians, 9th November 1877; occupied by them, 7th February 1878, during the armistice; and restored to Turkey after the Treaty of Berlin. On the 30th and 31st October 1895 there was a massacre of Armenians, in which officers and men of the Turkish army took part. In November 1901 an earthquake caused serious damage to the town.

See Consular Reports in Parliamentary Papers, *Turkey*, 1878–99; Murray, *Handbook to Asia Minor*, 1895. (C. W. W.)

Erzingan, ERZINJAN, or ERIZA (Arsinga of Middle Ages), the chief town of a sanjak of the Erzerúm viláyet of Asiatic Turkey. It is the headquarters of the 6th Army Corps, and a place of great military importance, and is situated, at an altitude of 3900 feet, on the Sivas–Erzerúm road, near the western extremity of a rich well-watered plain, through which the Frát Su, or Western Euphrates, runs. It is surrounded by orchards and gardens, and stands on nearly level ground, about one mile from the right bank of the Frát, which here runs in two channels crossed by bridges. The main street, which forms part of the military road from west to east, is 30 feet wide; the other streets are narrow, unpaved, and dirty. In the town and its vicinity are large barracks, military stores, school, hospital, Government tanneries, and boot and clothing factories. There are also silk, cotton, and copper industries. The climate is hot in summer and moderate in winter. Roads lead to Sivas, Kerasund, Trebizond, Erzerúm, and Kharpút. The population numbers 23,000 (Moslems 15,500, Armenians 7500). The plain, which is almost surrounded by lofty mountains, is highly productive, and has many villages. Wheat, fruit, vines, &c., are grown, and cattle and sheep are bred. About 11 miles south-west of the town is the celebrated Armenian Monastery of St Gregory, "The Illuminator." It occupies the site of an early town in which there was a temple of Anaitis, and was an important place early in the 4th century, when St Gregory lived in it. The district passed from the Byzantines to the Seljúks after the defeat of Romanus, 1071, and from the latter to the Mongols, in 1243. After having been held by Mongols, Tatars, and Turkomans, it was added to the Osmanli Empire by Muhammad II. in 1473. (C. W. W.)

Esbjerg, a seaport of Denmark, co. Ribe, on the west coast of Jutland, over against the island of Fanö. It was granted municipal rights in 1900, having grown with astonishing rapidity from 13 inhabitants in 1868 to 13,000 in 1899. This growth it owes to the construction of a large harbour in 1868–88. It is the principal outlet westwards for S. Jutland; exports pork and meat, butter, eggs, fish, cattle and sheep, skins, lard, and agricultural seeds. The port was entered by 774 vessels of 257,418 tons in 1899 and cleared by 775 of 259,205 tons. There are very large slaughter-houses.

Escanaba, capital of Delta county, Michigan, U.S.A., on Little Bay de Noquette, an inlet of Green Bay, Lake Michigan, at an altitude of 608 feet. It is regularly laid out, with seven wards. The manufacture of lumber is its principal industry, and it has a large lake commerce in lumber and iron ore. Population (1880), 3026; (1890), 6808; (1900), 9549.

Esher, William Baliol Brett, 1ST VISCOUNT (1817–1899), English lawyer and Master of the Rolls, was a son of the Rev. Joseph G. Brett, of Chelsea, and was born on 13th August 1817. He was educated at Westminster and at Caius College, Cambridge. Called to the Bar in 1840, he went the Northern Circuit, and became a Q.C. in 1861. On the death of Richard Cobden he unsuccessfully contested Rochdale as a Conservative, but in 1866 was returned for Helston in unique circumstances. He and his opponent polled exactly the same number of votes, whereupon the Mayor, as returning officer, gave his casting vote for the Liberal candidate. As this vote was given after four o'clock, however, an appeal was lodged, and the House of Commons allowed both members to take their seats. Brett rapidly made his mark in the House, and in 1868 he was appointed Solicitor-General and received the honour of knighthood. On behalf of the Crown he prosecuted the Fenians charged with having caused the Clerkenwell explosion. In Parliament he took a leading part in the promotion of Bills connected with the administration of law and justice. He was shortly afterwards appointed a Justice in the Court of Common Pleas. Some of his sentences in this capacity excited much criticism, notably so in the case of the gas stokers' strike, when he sentenced the defendants to imprisonment for twelve months, with hard labour, which was afterwards reduced by the Home Secretary to four months. On the reconstitution of the Court of Appeal in 1876, Brett was elevated to the rank of a Lord Justice. After holding this position for seven years, he succeeded Sir George Jessel as Master of the Rolls in 1883. In 1885 he was raised to the House of Lords as Baron Esher. He opposed the Bill proposing that an accused person or his wife might give evidence in their own case, and supported the Bill which empowered Lords of Appeal to sit and vote after their retirement. The Solicitors Act of 1888, which increased the powers of the Incorporated

Law Society, owed much to his influence. In 1880 he delivered a remarkable speech in the House of Lords, deprecating the delay and expense of trials, which he regarded as having been increased by the Judicature Acts. Lord Esher suffered, perhaps, as Master of the Rolls from succeeding a lawyer of such eminence as Jessel. He had a caustic tongue, but also a fund of shrewd common sense, and one of his favourite considerations was whether a certain course was "business" or not. He retired from the Bench at the close of 1897, and a Viscounty was conferred upon him on his retirement, a dignity never given to any judge, Lord Chancellors excepted, "for mere legal conduct since the time of Lord Coke." He died 24th March 1899.

Eskilstuna, a town of Sweden, province of Södermanland, on the navigable river Eskilstuna, which connects Lakes Mälar and Hjelmar, 55 miles west from Stockholm, the chief seat in Sweden of the iron and steel industries, its cutlery being especially noted. There is a technical school for the metal industries. Population (1880), 8161; (1900), 13,663.

Eski-Shehr, a town in Asia Minor, in the Kutaya sanjak, of the Khudavendikiar (Brúsa) viláyet; a station on the Haidar Pasha–Angora Railway, 194½ miles from the former and 164 miles from Angora, and the junction for Konia; situated on the right bank of the Pursak Su (*Tembris*), a tributary of the Sakaría, at the foot of the hills that border the broad treeless valley. The town is divided by a small stream into a commercial quarter on low ground, in which are the bazárs, kháns, and the hot sulphur springs (122° F.); and a residential quarter on the higher ground. The population numbers 20,000 (Moslems 15,000, Christians 5000). The town is noted for its good climate, the Pursak Su for the abundance of its fish, and the plain for its fertility. The annual output of the celebrated meerschaum mines is valued at £272,000.

Eski-Zagra or **Stára-Zagóra,** chief town of a department in Eastern Rumelia, in the principality of Bulgaria, situated on the southern slope of the Balkans, 70 miles north-west of Adrianople. It is surrounded by vineyards, and has also cloth and carpet manufactures, copper foundries, and tanneries. The production of cocoons is also carried on in the district. The town having been almost wholly destroyed during the war of 1877, has been rebuilt on a regular plan, with wide and broad streets radiating from a fine central square, where are situated the principal public buildings. During the rebuilding of the town the foundations and remains of a very old town were discovered, with important Thracian, Roman, Byzantine, and Turkish antiquities. The old town, founded probably by the Macedonians, attained to such prosperity under the Romans that it was known as Augusta Traiana, but afterwards, to distinguish it from a Macedonian town of this name, it was named Beroe or Berrhoea. By the Turks the name was changed in the 17th century to Eski-Zagra or Eski-Zaara, but by the Bulgarians it is known as Stára-Zagóra. Population, 17,457, of whom about four-fifths are Bulgarians.

Esmarch, Johannes Friedrich August von (1823-——), German surgeon, was born at Tönning, in Schleswig-Holstein, on 9th January 1823. He studied at Kiel and Göttingen, and in 1846 became Langenbeck's assistant at the Kiel surgical hospital. He served in the Schleswig-Holstein War of 1848, first as officer and then as junior surgeon, and this directed his mind to the subject of military surgery. He was taken prisoner, but afterwards exchanged, and was then appointed as surgeon to a field hospital. During the truce of 1849 he settled at Kiel, but on the fresh outbreak of war he returned to the troops and was promoted to the rank of senior surgeon. In 1854 he became director of the surgical clinic at Kiel, and in 1857 head of the general hospital and professor at the university. During the Schleswig-Holstein War of 1864 Esmarch rendered good service to the field hospitals of Flensburg, Sundewitt, and Kiel. In 1866 he was called to Berlin as member of an Emergency Hospital Commission, and also to take the superintendence of the surgical work in the hospitals there. When the Franco-German War broke out in 1870 Esmarch was appointed surgeon-general and army consultant, and afterwards consulting surgeon at the great military hospital near Berlin. In 1872 he married Princess Henrietta von Schleswig-Holstein Sonderburg Augustenburg, aunt of the Empress Auguste Victoria. In 1887 a patent of nobility was conferred on him. Esmarch is one of the greatest authorities on hospital management and military surgery. His *Surgeon's Handbook on the Treatment of Wounded in War* was written for a prize offered by the Empress Augusta, on the occasion of the Vienna Exhibition of 1877, for the best handbook for the battlefield of surgical appliances and operations. This book is illustrated by admirable diagrams, showing the different methods of bandaging and dressing, as well as the surgical operations as they occur on the battlefield. Esmarch himself invented an apparatus, which bears his name, for squeezing the blood out of a limb before amputation. No part of Esmarch's work is more widely known than that which deals with "First Aid." *First Aid to the Wounded* and *First Aid to the Injured* are popular manuals on the subject. The latter is the substance of a course of lectures delivered by him in 1881 to a "Samaritan School," the first of the kind in Germany, founded by Esmarch in 1881, in imitation of the St John's Ambulance Classes which had been organized in England in 1878. These lectures were very generally adopted as a manual for First Aid Students, edition after edition has been called for, and they have been translated into twenty-three languages, the English version being the work of H.R.H. Princess Christian. No Ambulance course would be complete without a demonstration of the Esmarch bandage. It is a three-sided piece of linen or cotton, of which the base measures four feet and the sides two feet ten inches. It can be used folded or open, and applied in thirty-two different ways. It answers every purpose for temporary dressing and field-work, while its great recommendation is that the means for making it are always at hand.

Esperance, a town in West Australia, 275 miles north-east from Albany, with a large and safe natural harbour. It is a summer resort, and in the neighbourhood are interesting caves. Being on the high road between the Eastern states and the goldfields, it is likely to become an important seaport. It has a Government jetty 2000 feet long, with 18 feet depth of water alongside, and a new town jetty 600 feet long with 22 feet of water. Population, about 450.

Esperanza.—An old country town of Santa Clara Province, Cuba. It is noted for the quality and quantity of the guava jelly manufactured there. Population, 2177.

Espartero, Baldomero (1792–1879), Duke of Vitoria, Duke of Morella, Prince of Vergara, Count Luchana, Knight of the Toison d'Or, &c. &c., a famous Spanish soldier and statesman, was born at Granatula, a town of the province of Ciudad Real, on 27th February 1792. He was the ninth child of a carter, who wanted to make him a priest, but the lad at fifteen enlisted in a battalion of students to fight against the armies of Napoleon I. In 1811 Espartero was appointed a lieutenant of Engineers in Cadiz, but having failed to pass his examination, he entered a line regiment. In 1815 he went to America as a captain under General Morillo, who had been made commander-in-chief to quell the risings of the colonies on the Spanish Main. For eight years Espartero distinguished himself in the struggle against the colonists. He was several times wounded, and was made major and colonel on the battlefields of Cochabamba and Sapachni. He had to surrender to Sucre at the final battle of Ayacucho, which put an end to Castilian rule. He returned to Spain, and, like most of his companions in arms, remained under a cloud for some time. He was sent to the garrison town of Logroño, where he married the daughter of a rich landowner, Dona Jacinta Santa Cruz, who eventually survived him. Henceforth Logroño became the home of the most prominent of the Spanish political generals of the nineteenth century. Espartero became in 1832, on the death of King Ferdinand VII., one of the most ardent defenders of the rights of his daughter, Isabella II. The Government sent him to the front, directly the Carlist war broke out, as commandant of the province of Biscay, where he severely defeated the Carlists in many encounters. He was quickly promoted to a divisional command, and then made a lieutenant-general. At times he showed qualities as a *guerillero* quite equal to those of the Carlists, like Zumalacarregui and Cabrera, by his daring marches and surprises. When he had to move large forces he was greatly superior to them as an organizer and strategist, and he never disgraced his successes by cruelty or needless severity. Twice he obliged the Carlists to raise the siege of Bilbao before he was appointed commander-in-chief of the northern army on September 17, 1836, when the tide of war seemed to be setting in favour of the Pretender in the Basque provinces and Navarre, though Don Carlos had lost his ablest lieutenant, the Basque Zumalacarregui. His military duties at the head of the principal national army did not prevent Espartero from showing for the first time his political ambition. He displayed such radical and reforming inclinations that he laid the foundations of his popularity among the lower and middle classes, which lasted more than a quarter of a century, during which time the Progressists, Democrats, and advanced Liberals ever looked to him as a leader and adviser. In November 1836 he again forced the Carlists to raise the siege of Bilbao. His troops included the British Legion under Sir de Lacy Evans. This success turned the tide of war against Don Carlos, who vainly attempted a raid towards Madrid. Espartero was soon at his heels, and obliged him to hurry northwards, after several defeats. In 1839 Espartero carefully opened up negotiations with Maroto and the principal Carlist chiefs of the Basque provinces. These ended in their accepting his terms under the famous Convention of Vergara, which secured the recognition of their ranks and titles for nearly 1000 Carlist officers. Twenty thousand Carlist volunteers laid down their arms at Vergara; only the irreconcilables led by Cabrera held out for a while in the central provinces of Spain. Espartero soon, however, in 1840, stamped out the last embers of the rising, which had lasted seven years. He was styled "El pacificador de España," was made a grandee of the first class, and received two dukedoms.

During the last three years of the war Espartero, who had been elected a Deputy, exercised from his distant headquarters such influence over Madrid politics that he twice hastened the fall of the Cabinet, and obtained office for his own friends. At the close of the war the Queen Regent and her Ministers attempted to elbow out Espartero and his followers, but a *pronunciamiento* ensued in Madrid and other large towns which culminated in the Marshal's accepting the post of Prime Minister. He soon became virtually a dictator, as Queen Christina took offence at his popularity and resigned, leaving the kingdom very soon afterwards. Directly the Cortes met they elected Espartero Regent by 179 votes to 103 in favour of Arguelles, who was appointed guardian of the young Queen. For two years Espartero ruled Spain in accordance with his Radical and conciliatory dispositions, giving special attention to the reorganization of the administration, taxation, and finances, declaring all the estates of the church, congregations, and religious orders to be national property, and suppressing the *diezma*, or tenths. He suppressed the Republican risings with as much severity as he did the military *pronunciamientos* of Generals Concha and Diego de Leon. The latter was shot in Madrid. Espartero crushed with much energy a revolutionary rising in Barcelona, but on his return to Madrid was so coldly welcomed that he perceived that his prestige was on the wane. The advanced Progressists coalesced with the partisans of the ex-Regent Christina to promote *pronunciamientos* in Barcelona and many cities. The rebels declared Queen Isabelle of age, and, led by General Narvaez, marched upon Madrid. Espartero, deeming resistance useless, embarked at Cadiz on July 30, 1843, for England, and lived quietly apart from politics until 1848, when a Royal degree restored to him all his honours and his seat in the Senate. He retired to his house in Logroño, which he left six years later, in 1854, when called upon by the Queen to take the lead of the powerful Liberal and Progressist movement which prevailed for two years. The old Marshal vainly endeavoured to keep his own Progressists within bounds in the Cortes of 1854–56, and in the great towns, but their excessive demands for reforms and liberties played into the hands of a Clerical and reactionary Court, and of the equally retrograde governing classes. The growing ambition of General O'Donnell constantly clashed with the views of Espartero, until the latter, in sheer disgust, resigned his Premiership and left for Logroño, after warning the Queen that a conflict was imminent between O'Donnell and the Cortes, backed by the Progressist militia. O'Donnell's *pronunciamiento* in 1856 put an end to the Cortes, and the militia was disarmed, after a sharp struggle in the streets of the capital. After 1856 Espartero resolutely declined to identify himself with active politics, though at every stage in the onward march of Spain towards more liberal and democratic institutions he was asked to take a leading part. He refused to allow his name to be brought forward as a candidate when the Cortes of 1868, after the Revolution, sought for a ruler. Espartero, strangely enough, adopted a laconic phrase when successive Governments on their advent to power invariably addressed themselves to the venerable champion of liberal ideas. To all—to the Revolution of 1868, the Constituent Cortes of 1869, King Amadeus, the Federal Republic of 1873, the nameless Government of Marshal Serrano in 1874, the Bourbon restoration in 1875—he simply said: "Cumplase la voluntad nacional"—"Let the national will be accomplished." King Amadeus made him Prince of Vergara. The Restoration raised a statue to him near the gate of the Retiro Park in Madrid. Spaniards of all shades, except Carlists and Ultramontanes, paid homage to his memory when he passed away at his Logroño residence on January 8, 1879. His tastes were singularly modest, his manners rather reserved, but always kind and considerate for humble folk. He was a typical Spanish soldier-politician, though he had more of the better traits of the soldier born and bred than of the arts of the statesman. His military instincts did not always make it easy for him to accommodate himself to courtiers and professional politicians. (A. E. H.)

Espirito Santo, an Atlantic state of Brazil, between 18° 5′ and 21° 28′ S. lat., and 39° 48′ and 41° 30′ W. long., bounded on the N. by the state of Bahia, on the W. by that of Minas Geraes, on the S. by that of Rio de Janeiro, and on the E. by the Atlantic. Its area is 17,312 square miles, and it had a population in 1870 of 82,137, and in 1890 of 136,000. Its coast-line is about 250 miles long. The capital, Victoria, has 8000 inhabitants. Amongst other towns are Anchieta, S. Matheus, Serra, Guarapary Conceiçao da Barra, Porto do Cachoeiro, but of all of them the population is small. There are short railways at Cachoeiro do Ita, one along the Rio Castello, the other to Alegre.

Essen, a town of Prussia, in the Rhine province, 22 miles by rail north-east from Düsseldorf, the seat of the well-known iron and steel works of Krupp, employing (1900) some 25,150 persons. The buildings cover an area of 150 acres, and the area owned by the firm 870 acres. Here, too, are extensive coal-fields. Essen possesses a mining school and a deaf and dumb asylum. The very interesting minster church was restored in 1881–86. The Roman Catholics have a new church (St Joseph's) built in 1895, and the Evangelicals one (Holyrood) built in 1896. There are monuments to the Emperor William I. (1898), Alfred Krupp, and Bismarck. Population (1885), 65,064; (1895), 96,128; (1900) 118,863.

Essendon, a town in Victoria, Australia, in the county of Bourke, 5 miles north-west of Melbourne, with a station on the North-Eastern Railway. Meat-preserving and rope-making are the principal industries. Population, 15,200.

Essentuki, a watering town of Russia, North Caucasia, province of Terek, 10 miles by rail from Pyatigorsk; altitude, 1980 ft. Its alkaline and sulphur-alkaline mineral waters, similar to those of Ems, Selters, and Vichy, but superior in carbon dioxide and salts, are much visited in summer. The vegetation is poor, and the climate shows great variations in temperature. Population (1897), 9515.

Essex, one of the London home counties, situated on the south-east coast of England, and bounded on the E. and S.E. by the North Sea. On the S. it is separated from Kent by the river Thames, on the W. from Middlesex and Hertfordshire by the Lea and the Stort, and on the N.E. from Suffolk by the Stour, while on the N. it is conterminous with Cambridgeshire.

Area and Population.—The area of the ancient and geographical county is 987,028 acres, or 1542 square miles, with a population in 1881 of 576,434, and in 1891 of 785,445, of whom 390,515 were males and 394,930 females, the number of persons per square mile being 509, and of acres to a person 1·26. The population in 1901 was 1,085,576. Parts of Sudbury and Hawerhill Urban Sanitary Districts are in the administrative county of Suffolk, and must therefore be deducted from the administrative county of Essex, leaving an area of 985,545 acres. The area of the registration county is 904,642 acres, with a population in 1891 of 701,191; in 1901 of 1,062,452, of whom 524,634 were males and 537,818 females. Within this area the increase of population between 1891 and 1901 was 51·52 per cent. Between 1881 and 1891 the excess of births over deaths was 107,152, and the increase in resident population 208,894. The following table gives the number of marriages, births, and deaths, with the number of illegitimate births, for 1880, 1890, and 1899:—

Year	Marriages.	Births.	Deaths.	Illegitimate Births.	
				Males.	Females.
1880 .	3235	18,548	10,165	331	338
1890 .	4699	23,264	12,873	360	331
1899 .	7279	30,097	16,603	413	415

The following table shows the marriage-, birth-, and death-rates per 1000 of the population, with the percentage of illegitimate births, for a series of years:—

	1870–79.	1880.	1880–89.	1890.	1889–98.	1899.
Marriages . .	12·0	11·9	12·1	12·6	13·0	14·7
Births . . .	33·3	34·1	33·9	31·3	31·0	30·5
Deaths . . .	18·3	18·7	17·3	17·3	16·0	16·8
Percentage of Illegitimate Births .	4·1	3·6	3·3	3·0	2·9	2·8

The birth-rate is above the average and the death-rate is below the average. In 1891 there were in the county 8061 natives of Scotland, 7224 natives of Ireland, and 4012 foreigners.

Administration.—The ancient county is divided into eight parliamentary divisions, and it also includes the parliamentary boroughs of Colchester and West Ham, the latter consisting of two divisions. The administrative county includes six municipal boroughs, namely, Chelmsford (12,580), Colchester (38,351), Harwich (10,019), Maldon (5564), Saffron Walden (5896), Southend-on-Sea (28,857), and one county borough, West Ham (267,308). The following are urban districts:—Barking Town (21,547), Braintree (5330), Brentwood (4932), Brightlingsea (4501), Buckhurst Hill (4786), Burnham-on-Crouch (2918), Chingford (4372), Clacton (7453), East Ham (95,989), Epping (3789), Gray's Thurrock (13,831), Halstead (6072), Ilford (41,240), Leigh-on-the-Sea (3663), Leyton (98,899), Loughton (4730), Portslade-by-Sea (5217), Romford (13,656), Shoeburyness (4081), Waltham Holy Cross (6547), Walthamstow (95,125), Walton-on-the-Naze (2014), Wanstead (9179), Witham (3454), Wivenhoe (2560), Woodford (13,806). Essex is in the South-Eastern Circuit, and the assizes are held at Chelmsford. The boroughs of Harwich and West Ham have separate Commissions of the Peace, and the boroughs of Colchester, Maldon, and Saffron Walden have, in addition, separate courts of quarter sessions. The county is ecclesiastically within the diocese of St Albans, and is divided into two archdeaconries. There are 413 civil parishes and parts of three others.

Education.—The number of elementary schools on the 31st of August 1899 was 535, of which 175 were board and 360 were voluntary schools; the latter including 314 national Church of England schools, 5 Wesleyan, 14 Roman Catholic, and 27 "British and other." The average attendance at board schools was 67,026, and at voluntary schools 44,364. The total school board receipts for the year ended 29th September 1899 was over £612,516. The income under the Agricultural Rates Act was over £3604. There are five certified industrial schools in Essex, namely, Chelmsford, Essex Industrial School for Boys (150 boys); Grays, School Board for London Industrial School Ship *Shaftesbury* (350 boys); Halstead, Industrial School for Girls (70 girls); Little Ilford, St Nicholas Industrial School for Roman Catholic Boys (150 boys); Walthamstow, St John's Industrial School for Roman Catholic Boys (150 boys); also the Davenport Hill Industrial School (late of Brentwood, now in temporary premises at the Sanatorium, Margate), 100 boys; and Islington Home for Working Boys, closed for the present.

Agriculture.—About three-fourths of the total area is under cultivation, and of this area about one-third is under permanent pasture. Less than 2200 acres are in hill pasture, and nearly 31,000 acres are under woods. Wheat, barley, and oats are the principal corn crops (in this relative order), and their acreage has within recent years greatly diminished. Beans and peas are each nearly half the produce of oats. Turnips and Swedes and mangold occupy about half the area under green crops.

The following table gives the main divisions of the cultivated area at intervals of ten years from 1880:—

Year.	Total Area under Cultivation.	Corn Crops.	Green Crops.	Clover.	Permanent Pasture.	Fallow.
1880	830,135	386,399	100,310	87,829	195,534	59,531
1890	834,151	353,918	98,677	94,807	236,314	49,630
1899	805,916	310,602	93,990	99,364	266,047	33,895

The following table gives particulars regarding the principal live stock for the same years:—

Year.	Total Horses.	Total Cattle.	Cows or Heifers in Milk or in Calf.	Sheep.	Pigs.
1880 .	43,385	77,332	23,886	356,536	83,245
1890 .	39,570	82,556	29,209	313,787	101,749
1899 .	39,040	90,377	35,766	295,051	88,743

Industries and Trade.—According to the annual report for 1898 of the chief inspector of factories (1900), the total number of persons employed in factories and workshops in 1897 was 53,608, as compared with 50,494 in 1896. Textile factories employed 3288, of whom 1745 were employed in the manufacture of silk, and 757 in that of flax, hemp, jute, and China grass. In non-textile factories 43,912 persons were employed, of whom 6381 were employed in chemical industries and 5761 in the gas industry. Husbandry and stock-feeding are the chief industries of Essex. The manufacture of silk is carried on at Braintree and Halstead, and there is a silk mill at Chelmsford. Government powder works are situated at Waltham Abbey, and powder stores at Purfleet. The Royal Victoria and Albert Docks are in Plaistow Level; Tilbury docks were opened in 1886. The ports of the county are Barking, Bradwell, Brightlingsea, Burnham, Colchester, Grays, Harwich, Leigh, Maldon, Manningtree, Purfleet, Salcott, Southend, Wakering. There is steamer communication between London and Purfleet, Grays, Tilbury, Southend, Walton, Clacton, and Harwich. Steamers on the Orwell run from Harwich to Ipswich. There is a daily service of steamers between Harwich and Antwerp and the Hook of Holland. The oyster-beds of the Colne produce the famous Colchester native. The rivers Crouch, Roach, and Blackwater also produce native oysters.

Essex is supplied with railways by the Great Eastern Company—which has several distinct lines, with various branches.

There is a military station and depôt for recruits at Warley, and a garrison at Tilbury. At Shoeburyness there is an extensive ground for testing Government artillery of the largest calibre.

(H. B. W*.)

Essonnes, a town in the arrondissement of Corbeil, department of Seine-et-Oise, France, about 1 mile south-west of Corbeil, of which it may be regarded as a suburb. The church dates from the 13th century. The principal manufactures are machinery and paper, both conducted on a very extensive scale, the latter employing about 3000 men. Population (1881), 4999; (1896), 6844, (comm.) 8955; (1901), 9405.

Establishment AND **Disestablishment.**—Perhaps the best definition which can be given, and which will cover all cases, is that establishment implies the existence of some definite and distinctive relation between the State and a religious society (or conceivably more than one) other than that which is shared in by other societies of the same general character. Of course, a certain relationship must needs exist between the State and every society, religious or secular, by virtue of the sovereignty of the State over each and all of its members. Every society must possess certain principles or perform certain acts, and the State may make the profession of such principles unlawful, or impose a penalty upon the performance of such acts; and, moreover, every society is liable before the law as to the fulfilment of its obligations towards its members and the due administration of its property should it possess any. With all this establishment has nothing to do. It is not concerned with what pertains to the religious society *quâ* society, or with what is common to all religious societies, but with what is exceptional. It denotes any special connexion with the State, or privileges and responsibilities before the law, possessed by one religious society to the exclusion of others; in a word, establishment is of the nature of a monopoly. But it does not imply merely privilege. The State and the Church have mutual obligations towards one another: each is, to some extent, tied by the existence of this relationship, and each accepts the limitations for the sake of the advantages which accrue to itself. The State does so in view of what it believes to be the good of all its members; for "the true end for which religion is established is not to provide for the true faith, but for civil utility" (Warburton), even if the latter be held to be implied in the former. On the other hand, the Church accepts these relations for the facilities which they involve, *i.e.*, for its own benefit. It will be seen that this definition excludes, and rightly, many current presuppositions. Establishment affirms the *fact*, but does not determine the precise *nature*, of the connexion between the State and the religious society. It does not tell us, for example, when or how it began, whether it is the result of an unconscious growth (as with the Gallican Church previous to the French Revolution), or of a determinate legislative act (as with the same Church re-established by the Concordat of 1801). It does not tell us whether an endowment of the religious society by the State is included; what particular privileges are enjoyed by the religious society; and what limitations are placed upon the free exercise of its life. These things can only be ascertained by actual inquiry; for the conditions are precisely similar in no two cases.

Outside Britain.

To proceed to details. At the present day there is no established religion in the United States, the German Empire as a whole, Holland, Belgium, France (although France still exercises a certain influence in the East by virtue of its ancient relations with the Holy See, and certain provisions with regard to Roman Catholicism still exist by concordat), and Austria-Hungary (saving, indeed, "the rights of the sovereign arising from ecclesiastical dignity"); whereas there are religious establishments in Russia, Greece, Sweden, Norway, Denmark, Prussia, Spain, Portugal, and even in Italy, as well as in England and Scotland. These, however, differ greatly amongst themselves. In Russia the "Orthodox Catholic Eastern" is the State religion. The emperor is, by the fundamental laws of the empire, "the sovereign defender and protector of the dogmas of the dominant faith, who maintains orthodoxy and holy discipline within the Church," although, of course, he cannot modify either its dogmas or its outward order. Further, "the autocratic (*i.e.*, imperial) power acts in the ecclesiastical administration by means of the Most Holy Ruling Synod, created by it"; and all the officers of the Church are appointed by it. The enactments of the Synod do not become law till they have received the emperor's sanction, and are then published, not in its name but in his; and a large part of the revenues of the Church is derived from State subsidies. In Greece "the dominant religion (Ἡ ἐπικρατοῦσα θρησκεία) is that of the Eastern Orthodox Church of Christ"; and although toleration is otherwise complete, no proselytism from the Church of Greece is allowed. The king swears to protect it, but no powers pertain to him with regard to it such as those which the Tsar enjoys; the present king is not a member of it, but his successors must be. In Sweden, Lutheranism was adopted as the State religion by the Synod of Upsala (*Upsala möte*) in 1593, and the king must profess it. The "Lutheran Protestant Church" retains an episcopal order, and is supported out of its own revenues. Archbishops and bishops are chosen by the king out of those names submitted to him, and he also nominates to royal peculiars. The ecclesiastical law (*Kyrkolag*), first constituted in 1686, is part of the law of the State, but may not be modified or abrogated without the consent of a General Synod; and although *ad interim* interpretations of that law may be given by the king on the advice of the Supreme Court, since 1866 these have been subject to review and rejection by the next General Synod. In Norway the "Evangelical-Lutheran" is the "official religion," but the Church is supported by the State, its property having been secularized. It is also more subject to the king, who by the constitution is to "regulate all that concerns divine service and the clergy," and to see that the prescribed order is carried out. It is much the same in Denmark, where, however, the "Evangelical-Lutheran Church" has since 1849 been described as the National Church (*Folkekirche*) instead of the State Church (*Statskirche*) as formerly, and the constitution provides for a new fundamental law for its regulation, which has not yet been passed. For PRUSSIA, see *Ency. Brit.*, 9th edit., vol. xx. p. 17; it need only be added that self-government still tends to increase, but that the present emperor has exercised his office as *summus episcopus* more freely than most of his predecessors. In SPAIN the "Catholic, Apostolic, and Roman" religion is that of the State, "the nation binds itself to maintain its worship and its ministers," and the rites of any other religion are only permitted in private. The patriarch of the Indies and the archbishops are senators by right, and the king may nominate others from amongst the bishops; only laymen may sit in the chamber of deputies. Convents were suppressed, and their property confiscated, in 1835 and 1836; in 1859 the remaining ecclesiastical property was exchanged for untransferable Government securities, and the support of the clergy of the State Church is assured by an unrepealed law previous to the present constitution. In PORTUGAL it is much the same, but all the home bishops sit in the upper chamber as peers (*Pares do Reino*) by right, and there is no restriction on membership of the chamber of deputies. A more important point is that the king confers all ecclesiastical benefices and nominates the bishops, instead of their being chosen, as in Spain, by agreement between the civil power and the Papacy. In ITALY, in spite of the feud between the Papacy and the civil power, the fact remains that, by the *Statuto fondamentale*, "the Catholic, Apostolic, and Roman religion is the sole religion of the State," and the king may nominate "archbishops and bishops of the State" to be senators. The *Legge sulle prerogative del Summo Pontifice*, &c., or "Law of Guarantees," by which the papal prerogatives are secured, has been declared by the Council of State to be a fundamental law; and whilst many civil restrictions upon the activities of the Church are removed by it, outside Rome and the suburbicarian dioceses the royal *exequatur* is still required before a bishop is installed. Moreover, the bulk of Church property having been secularized, the Italian clergy receive a stipend from the State.

Church and State in Britain.

Establishment is, of course, a distinctively English term, but it implies precisely the same thing as "Staatsreligion" or "église dominante" does elsewhere, neither more nor less. It denotes the existence of a special relationship between Church and State without defining its precise nature. The statement that the Church of England or the Scottish Kirk is "established by law" denotes that it has a peculiar status before the law; but that is all. (*a*) There is no basis whatever for the once popular assumption that the word "established" as applied to the Church means "created," or the like; on the contrary, the modern use of the word in this sense is a misleading perversion. To *establish* is to make firm or stable; and a thing cannot be established unless it is already in existence. A few examples will make it clear that this is the true sense of the word, and that in which it is used here. "Stablish the thing, O God, that thou hast wrought in us" (Ps. lxviii. 28, P.B.; A.V. and R.V. "strengthen") implies that the thing is already wrought; it could not be "stablished" else. "Stablish your hearts" (Jas. v. 8) implies that the hearts are already in existence. "Until he had her settled in her raine With safe assuraunce and establishment" (*Faerie Queene*, v. xi. 35) would have been impossible unless the reign had already begun. This is the meaning of the words in many Tudor Acts of Parliament, "be it enacted, ordained, and established," or the like (21 Hen. VIII. c. 1; 27 Hen. VIII. c. 28, s. 9; 28 Hen. VIII. c. 13 [Ireland]; 28 Hen. VIII. c. 18 [Ireland], 33 Hen. VIII. c. 27; 1 Eliz. c. 1, ss. 15, 17; 1 Eliz. c. 4, s. 4); that which is then and there enacted is to be valid for the future. (*b*) Nor is it necessarily implied that establishment is a process completed once for all. Every law touching the Church slightly alters its conditions; everything that affects the relations of Church and State may be regarded as a measure of establishment or the reverse. When the two Houses of Parliament, in an address to William III. after his coronation, spoke of their proposed measures of toleration, the king said in his reply, "I do hope that the ease which you design to Dissenters will contribute very much to the establishment of the Church" (Cobbett, *Parl. Hist.* v. 218). And Defoe (in 1702) published an ironical tract with the title, *The Shortest Way with the Dissenters, or Proposals for the Establishment of the Church.* (*c*) Nor is it necessarily implied that there was any specific time at which establishment took place. Such may indeed be the case, as with the Kirk in Scotland; but it certainly cannot be said that the English Church was established at any particular time, or by any particular legislative act. There were, no doubt, periods when the existing relations between Church and State were modified or re-defined, notably in the 16th and 17th centuries; but the relations themselves are far older. In fact, they existed from the very first: the English Church and State grew up side by side, and from the beginning they were in close relations with one another. But although the state of thing which it represented was there from the first, the term "established" or "established by law" only came into use at a later date. Until there was some other religious society to be compared with it such a distinctive epithet would have had no point. As, however, there arose religious societies which had no status before the law, it became more natural; and yet more so when the formularies of the Church came to be "established" by civil sanctions (the Books of Common Prayer by 5 and 6 Edw. VI. c. 1, s. 4, &c.; the Articles by 13 Eliz. c. 12; the new Ordinal by 13 and 14 Car. II. c. 4, title). Accordingly, the Church itself came to be spoken of as established by law; first, it would seem, in the Canons of 1604, and subsequently in many statutes (12 and 13 Will. III. c. 2; 6 Anne, c. 8 and c. 11, &c.). In all such cases the Church is described as already established, not as being established by the particular canon or statute. In other words, the constitutional status of the Church is affirmed, but nothing is said as to how it arose.

The legislative changes of the 16th and 17th centuries brought "establishment" into greater prominence and greatly modified its conditions, but a moment's thought will show that it did not commence then. If, *e.g.*, all post-Reformation ecclesiastical statutes were non-existent, the relations between Church and State would be very different, but there would still be an "establishment." The bishops would sit in the House of Lords, the clergy would tax themselves in convocation, the Church courts would possess coercive jurisdiction, and so on. The present relations of Church and State in England may be briefly summed up as follows:—1. *The personal relation of the Crown to the Church*, including (*a*) restraints upon the action of convocation (formulated by 25 Hen. VIII. c. 19); (*b*) nomination of bishops, &c. (25 Hen. VIII. c. 20); (*c*) power of supervision as Visitor, long disused (26 Hen. VIII. c. 1; 1 Eliz. c. 1, s. 17); (*d*) power of receiving appeals as the fount of civil justice (25 Hen. VIII. c. 19, &c.). In connexion with these, it must be borne in mind that (*a*) the holder of the Crown receives coronation from the Church and takes an oath having reference to it (1 Will. III. c. 6), and (*b*) the Crown is held on the condition of communion with the Church of England (12 and 13 Will. III. c. 2, s. 3; the conditions of communion are laid down in the Prayer Book, which itself is sanctioned by law). 2. *The relation of the Church to the Crown in Parliament.* No change has been permitted in its doctrine or formularies without the sanction of an Act of Parliament. 3. *Privileges of the*

Church and clergy. Of these may be mentioned (*a*) the coercive jurisdiction of the Church courts; (*b*) the right of bishops to sit in the House of Lords. It need hardly be said that establishment in England does not include an endowment of the Church by the State. Nothing of the kind ever took place on any large scale, and the grants for Church purposes in the 18th century are comparable with the *regium donum* to Nonconformists.

The position of the Church of Ireland until its disestablishment (see below) was not dissimilar. With Scotland the case is different: it cannot with any accuracy be said that the legal status of the unreformed Church of Scotland survived the Reformation, even in a modified form. The establishment of the Kirk was an entirely new process, carried out by a more or less definite series of legislative and administrative Acts. For example, the Scottish Act of 1567, c. 6, declares it to be "the onely true and halie kirk of Jesus Christ within this realme." Again, by the Act of 1690, c. 5, the Crown and estates "ratifie and establish the Confession of Faith, . . . as also they do establish, ratifie, and confirm the Presbyterian government and discipline." The "Act of Security" of 1705, as incorporated in the Act of Union (5 Anne, c. 8, ss. 2–6), speaking of it "as now by law established," says that "Her Majesty . . . doth hereby establish and confirm" it, and finally declares this Act, "with the Establishment therein contained," to be "a fundamental and essential condition of the Union." Nevertheless, the conditions of establishment in the Scottish Kirk are much easier than those of the Church of England. It is bound by the statutes sanctioning its doctrine and order, but within these limits its legislative and judicial freedom is unimpaired. A Royal Commissioner is present at the meetings of the General Assembly, but he need not be a member of the Kirk; and there is no constitutional tie between the Crown and the Kirk such as there is in England. There is what may accurately be described as a State endowment, the bulk of the property of the old Church having been conferred upon the Scottish Kirk.

The Colonies.

Not unnaturally, the organization of Anglican Churches in the Colonies was followed in some cases by their establishment, which included endowment. It was so, for example, in the East and West Indies: and the disestablishment of the West Indian Church in 1868 was followed, in 1873, by a re-establishment of the Church in Barbadoes by the colonial legislature. India is the only other part of the empire (outside Great Britain) in which there is to-day a religious establishment.

Disestablishment.

Disestablishment is in theory the annulling of establishment; but since an established Church is usually rich, disestablishment generally includes disendowment, even where there is no State endowment of religion. It is, in a word, the abrogation of establishment, coupled with such a confiscation of Church property as the State thinks good in the interests of the community. The disestablishment of the West Indian Church in 1868 has already been referred to; in 1869 the Irish Church Disestablishment Bill was passed; and although nothing of the kind has yet taken place in England or Scotland, it is not for want of effort. Private bills relating to Scotland have more than once been brought forward; and in 1893 Mr Gladstone's Government made a determined attempt to disestablish and disendow the Church in Wales. A bill was passed through the House of Commons to suspend the creation of new interests in the four Welsh dioceses with a view to this; but it was thrown out by the House of Lords, and the subsequent general election showed that the feeling of the country was strongly against it.

The case of the Irish Church will illustrate the process of disestablishment, although, of course, the precise details would vary in other cases. The Irish Church Act (32 and 33 Vict. c. 42) was passed in 1869 by Mr Gladstone's first Government, after considerable opposition, and provided that from January 1, 1871, the union created by statute (39 and 40 Geo. III. c. 67) between the Churches of England and Ireland should be dissolved, and the Church of Ireland should "cease to be established by law." Existing ecclesiastical corporations were dissolved, and their rights ceased, compensation being given to all individuals and their personal precedence being secured for life. All rights of patronage, including those of the Crown, were abolished, with compensation in the case of private patrons; and the archbishops and bishops ceased to have the right of summons to the House of Lords. All laws restraining the freedom of action of the Church were repealed; the ecclesiastical law, however, to subsist by way of contract amongst the members of the Church (until altered by a representative body). Provision was made for the incorporation by charter of the representative body of the Church, should such a body be found, with power to hold landed property. All existing ecclesiastical property was vested in a Commission, which was to give compensation for life interests, to transfer to the new representative body the churches, glebe houses, and £500,000 in compensation for endowments by private persons since 1660, and to hold the rest for such purposes as Parliament might thereafter determine. For the subsequent fortunes of the disestablished Church, see IRELAND, CHURCH OF.

AUTHORITIES.—F. R. DARESTE. *Les constitutions modernes.* Paris, 1891.—H. GEFFCKEN. *Church and State.* Trans. by E. F. TAYLOR. London, 1877.—P. SCHAFF. *Church and State in the United States* (Papers of the American Hist. Association, vol. ii. No. 4). New York, 1888.—L. MINGHETTI. *Stato e Chiesa.* Milan, 1878 (French translation, with Introd. by E. DE LAVELEYE. Paris, 1882).—C. CADORNA. *Religione, diritto, libertà.* Milan, 1893.—F. NIPPOLD. *Die Theorie der Trennung von Kirche und Staat.* Bern, 1881.—W. WARBURTON. *Alliance between Church and State.* London, 1741 (*Works*, vol. iv., ed. HURD. London, 1788).—*Church Problems* (ed. by H. H. HENSON). London, 1900. Essays on "Establishment" and "Disendowment."—W. R. ANSON. *Law and Custom of the Constitution*, vol. ii. chap. ix. Oxford, 1892.—PHILLIMORE. *Ecclesiastical Law.* London, 1895.—J. S. BREWER. *Endowments and Establishment of the Church of England* (ed. by L. T. DIBDIN). London, 1885.—A. T. INNES. *Law of Creeds in Scotland.* Edinburgh, 1867.—E. A. FREEMAN. *Disestablishment and Disendowment.* London, 1883.—G. HARWOOD. *Disestablishment.* London, 1876.—*Annales de l'école libre des Sciences politiques*, tom. i. Paris, 1885, art. "La séparation de l'église et de l'état en Angleterre," by L. AYRAL. (W. E. Co.)

Estate Duty.—The Finance Act, 1894, imposed on all property passing by death after 1st August 1894 a duty called estate duty, in lieu of certain other duties previously payable. The objects of the Act were—(1) simplification of the death duties and equalization as between real and personal property, and (2) aggregation of all the property passing on a death, and taxation at rates graduated according to the value of the whole. Before the Act a duty (probate duty) was taken on the free personal property of deceased persons in the hands of the executor or administrator, without regard to the subsequent distribution. The legacy and succession duties were levied on distribution of the property passing on the death, from the persons taking any property under the will or intestacy of the deceased, or under settlement, or by devolution of title on his death. These two latter duties were mutually exclusive, and together covered practically all property passing by death. They were levied at rates graduated according to consanguinity. In 1888 an attempt was made to equalize the rates of the death duties as between property (mainly personalty in the United Kingdom not settled) which paid the probate and legacy duties, and property (mainly realty and settled personalty) which paid succession duty only. But the Finance Act, 1894, replaced the probate duty by a duty extending to all property real or personal passing on or by reference to death, whether by disposition of the deceased or not, without regard to its tenure or destination.

For this purpose all property passing on a death is aggregated to form one estate, on the capital value of which the duty is charged, at rates graduated from 1 to 8 per cent. according to the aggregate value. Besides the property of which the deceased was competent to dispose at his death, the aggregated estate includes property in which he had an interest ceasing on his death, from the cesser of which a benefit accrues, or which was disposed of by him within twelve months of death, or at any time, with reservation of an interest to himself. The extent to which property is deemed to pass on the cesser of a limited interest is measured by the proportion of the income to which the interest extended, without regard to the tenure of the deceased or his successor. Property may therefore be included in the aggregate estate at its capital value owing to the passing of a life-interest only, the property being settled so that the absolute ownership does not pass at all. But when the duty has once been paid on property passing under a settlement, the property does not again become chargeable until it passes on the death of a person who is or has been competent to dispose of it. To compensate for this advantage, when property passing under a settlement made after the Act pays the estate duty, a further duty of 1 per cent. (settlement estate duty) is taken, except where the only subsequent life-interest is that of the wife or husband of the deceased.

The rate of duty being fixed according to the aggregate capital value of the whole estate, the charge is distributed according to the different modes of disposition of the property comprised in the estate. The duty on the personalty which passes to the executor as such is paid by him, as the probate duty was, and comes out of the general estate. For the other property passing, trustees, or any person to whom it passes for a beneficial interest in possession, are made accountable, and are required to bring in an account of the property and pay the duty. The duty is a first charge on such property, and, when it is paid by a person having a life-interest only, he may charge the *corpus* of the property with it. The duty on real property included in an account is payable by eight yearly or sixteen half-yearly instalments, becoming due twelve months after the death, and bearing interest at 3 per cent. from that date. On other property, except in a few special cases, the duty bears interest at 3 per cent. from the date of the death. When the estate duty has been paid no further duty is chargeable on property comprised in the estate which passes to lineal relations of the deceased. But on property passing to collaterals or strangers legacy or succession duty, as the case may be, is payable by the devisees or successors, at a rate (which is the same whichever duty be payable) fixed according to consanguinity.

The total amount raised by death duties for the year 1893–94, the last complete year of the old system, was £9,941,855. For the year 1900–1901 the amount was £16,676,290, to which the estate duty contributed £12,685,211.

For a detailed account of the provisions of the Act of 1894 and subsequent amending Acts, and of the practical working of the new duty, reference is made to CARTMELL, *Finance Acts*, 1894–96—*Death Duties*, London, 1896; SOWARD, *Handbook to the Estate Duty*, 4th edit., London, 1900; and to the Reports of the Commissioners of Inland Revenue for 1894–95 and subsequent years. (P. D.)

United States.—The United States imposed a succession duty, by the War Revenue Act of 1898, on all legacies or distributive shares of personal property exceeding $10,000. It is a tax on the privilege of succession. Devises or distributions of land are not affected by it. The rate of duty runs from 75 cents on the $100 to $5 on the $100, if the legacy or share in question does not exceed $25,000. On those of over that value the rate is multiplied 1½ times on estates up to $100,000, twofold on those from $100,000 to $500,000, 2½ times on those from $500,000 to a million, and threefold for those exceeding a million. This statute has been supported as constitutional by the Supreme Court. Many of the States also impose succession duties, or transfer taxes; generally, however, on collateral and remote successions; sometimes progressive, according to the amount of the succession. The State duties generally touch real estate successions as well as those to personal property. If a citizen of State A. owns registered bonds of a corporation chartered by State B., which he has put for safe keeping in a deposit vault in State C., his estate may thus have to pay four succession taxes, one to State A., to which he belongs and which, by legal fiction, is the seat of all his personal property; one to State B., for permitting the transfer of the bonds to the legatees on the books of the corporation; one to State C., for allowing them to be removed from the deposit vault for that purpose; and one to the United States. (S. E. B.)

Este, a town of Italy (Venetia, prov. Padua), at the south end of the Euganean Hills, 21 miles by rail south-west from Padua. The town possesses a cathedral, an archæological museum, the Euganean Prehistoric Museum, and a technical school. Population, about 6800.

Esthonia (German, *Ehstland*; Esthonian, *Eesti-maa*), a Baltic province of Russia, on the south coast of the Gulf of Finland. An archipelago of islands, of which Dagö is the largest, belongs to it, while Oesel belongs to Livonia. Out of its area of 7818 square miles, 503 belong to the islands. Its surface consists of lowlands, having less than 100 ft. of altitude along the seacoast and in the environs of Lake Peipus, and in the interior of a table-land, having an average height of from 200 to 280 ft., saving a few points in the Wesenberg district, where 550 ft. is reached. It is entirely covered with the bottom moraine of the ice-sheet lying upon Silurian sandstones and limestones. Sands and clays cover in places the glacial deposits. It is watered by the navigable Narova, which flows from Lake Peipus into the Gulf of Finland, and countless small rivers and rivulets, and is dotted with small lakes and marshes. Although severe colds are experienced in winter, the climate is moderated by the moist west winds. The population, which consists chiefly of Ehstes, Germans (about 25,000), Russians (18,000), Swedes (5000), and some Jews, &c., is rapidly increasing: it was 323,960 in 1870, and 413,724 in 1897. Out of these, 210,199 are women, and 76,315 live in towns. In 1878 the nobility owned 52 per cent. of the land, 42 per cent. was farmed by the peasants, and only 3 per cent. was owned by persons not belonging to the nobility. Owing to the organization of credit, nearly 500,000 acres have since been bought by the peasants, one-fourth part of whom now own their farms. Agriculture is the chief occupation, and not only on the landlord's estates, but also on the wealthier peasants' farms, it is carried on more thoroughly than in any part of Russia. Every year more than 750,000 acres are under crops (71 to 75 per cent. of all arable land). The average crop is 787,400 quarters of cereals and 1,370,000 of potatoes, chiefly grown for the distilleries. Notwithstanding the density of population (55 per sq. mile), there is every year a surplus of cereals. Cattle-breeding is also in a good state. Meat and butter are yearly growing items of exports. Fine breeds of cattle and sheep are kept, and local wool is used in the woollen cloth factories of the province. Manufactures are chiefly distilleries (over 150), to which one large cotton mill (at Krenholm), one woollen cloth mill, flour mills, several iron and machinery works, paper mills, matches works, and saw mills must be added. Their aggregate production exceeds £4,000,000 per annum. The province is intersected by a railway running from St Petersburg to

Reval and the Baltic Port, with a branch from Taps to Dorpat. A considerable traffic is carried on along this line, Reval and Baltic Port being important towns, both for import and export. Hapsal and Kunda are next in importance, and Dagö for imports. Esthonia is divided into four districts, the chief towns of which are Reval, capital of the province (64,578 inhabitants in 1897); Hapsal, a lively watering-place (3238); Weissenstein (2509); and Wesenberg (5560). (P. A. K.)

Eston, a township and urban district, partly in the Cleveland parliamentary division of the North Riding of Yorkshire, England, 8 miles east from Stockton by rail. There are extensive blast-furnaces, iron foundries, and steam sawing mills in the district. Population of urban district (area, 2252 acres) (1881), 6297; (1891), 10,695.

Estremadura, a former province of Portugal, now divided into the administrative districts of Leiria, Lisbon, and Santarem (*qq.vv.*). Area, 6710 square miles. Population, 1,083,290; giving 161 inhabitants to the square mile. There are mineral waters and baths at Caldas da Rainha, Cucos (near Torres Vedras), Estoril (Cascaes), and Lisbon. Marble is quarried, and coal is mined at Porto de Moz. In 1892 the vineyards covered 88,560 acres, and their produce amounted to 17,941,850 gallons of wine, valued at £827,800. The fishing employs over 9600 men and 1600 boats, and the average value of the fish caught annually is £311,100. The ports of the province were entered in 1897 by 2615 vessels, of 3,569,589 tons.

Esztergom (Gran), a corporate town of Hungary, the capital of a county of the same name In 1898 it was united with its suburbs, and in 1900 had a population of 17,909.

Etah, a town and district of British India, in the Agra division of the North-West Provinces. The town is situated on the Grand Trunk Road, but with no railway station. Population, about 8000. The municipal income in 1897–98 was Rs.12,577.

The DISTRICT OF ETAH has an area of 1741 square miles. It had a population in 1881 of 756,523; and in 1891 of 702,063, giving an average density of 403 persons per square mile. In 1901 the population was 863,719, showing an increase of 23 per cent., due to the extension of canal irrigation. The land revenue and rates were Rs.13,16,370, the incidence of assessment being just over R.1 per acre; the cultivated area in 1896–97 was 570,194 acres, of which 340,424 were irrigated; the number of police was 2031; the number of vernacular schools in 1896–97 was 89, with 4158 pupils; the registered death-rate in 1897 was 24·25 per 1000. Part of the district is watered by the Ganges Canal. It is also now traversed by a branch of the Rajputana Railway from Agra to Cawnpore, with stations at Kasganj and Soron, which are the two largest towns. It has 5 printing presses; 141 indigo factories, employing 7743 persons, with an outturn valued at Rs.5,70,000; and one factory for pressing cotton.

Étampes, French town, in the department of Seine-et-Oise, 31 miles south of Versailles by rail. In addition to its great trade with Paris in food-stuffs, it supplies large quantities of sandstone for street-paving. Manufacturing industries are of little importance. Population (1881), 7465; (1896), 8094, (comm.) 8390; (1901) 8750.

Etawah, a town and district of British India, in the Agra division of the North-West Provinces. The town is situated on the left bank of the Jumna, and has a railway station, 206 miles from Allahabad. Population, about 38,000. The municipal income in 1897–98 was Rs.39,583; the registered death-rate in 1897 was 49·83 per 1000. Etawah is now only the civil headquarters of the district, the military cantonment having been abandoned in 1861. Considerable trade is carried on by rail and river. It makes specialities of cotton cloth, skin-bottles, combs and horn-ware, and sweetmeats.

The DISTRICT OF ETAWAH has an area of 1691 square miles. It had a population in 1881 of 722,371; and in 1891 of 727,629, giving an average density of 430 persons per square mile. In 1901 the population was 806,625, showing an increase of 11 per cent. The land revenue and rates were Rs.16,05,190, the incidence of assessment being R.1-3-8 per acre; the cultivated area in 1896–97 was 459,395 acres, of which 286,477 were irrigated; the number of police was 2094; the number of vernacular schools in 1896–97 was 84, with 3507 pupils; the registered death-rate in 1897 was 45·36 per 1000. It has six printing-presses, issuing two vernacular periodicals; 216 indigo factories, employing 11,128 persons, with an outturn valued at Rs.11,00,000; and three factories for cleaning and pressing cotton. The district is partly watered by branches of the Ganges Canal, and it is traversed throughout by the main line of the East Indian Railway from Cawnpore to Agra

ETHICS.

THE object of the following article is to describe and estimate the work done in Ethics since 1878, the date of Professor Sidgwick's article in the ninth edition of this *Encyclopædia*. The convenience of the reader will probably be best served if an outline is given of the general position in 1878, with some prefatory remarks on the 'Scope of Ethics,' which may help to indicate the point of view taken in regard to that position, and to the work by which it was modified during the last quarter of the 19th century. Following Professor Sidgwick's example, we practically confine our remarks to English Ethics, only mentioning a few foreign writers in the list of authorities given at the end.

The Scope of Ethics.

Ethics may be defined as the Theory of Conduct. It has two parts, which may be distinguished as the General and the Particular Theory of Conduct. The General Theory of Conduct seeks to embrace, within one architectonic survey, all the functions of human nature—all the modes of conduct by which man, as sentient animal, as moral agent, and as thinker, realizes his Type in an environment, which he 'conquers by obeying.' This Type—the end in relation to which alone all objects of human endeavour have 'reality' and 'value,' and are, and ought to be, desired—the General Theory of Conduct seeks to set forth, with the special view of furnishing principles by means of which the Particular Theory of Conduct may interpret that mode of 'conduct' which bulks most largely in man's life, and seems to be 'practical' in an eminent sense—moral conduct, which may be defined as conduct willed by members of the social system for the sake of that system. Moral conduct, as thus defined, is the central part of the subject-matter of Ethics, but must be exhibited in connexion with what is its necessary setting, conduct other than moral.

From 'Man in the State' our range of view must be extended till we can survey 'Man in the Cosmos.' As setting forth 'Man in the Cosmos,' the General Theory of Conduct will (1) describe him as he now is, and trace the history of the process from animal or even lower beginnings, by which he has become what he now is; and (2) will call attention to the significance of his being what he now is. Ethical schools differ chiefly as they take greater or, it may be, exclusive interest in one or the other of these two inquiries embraced within the scope of the General Theory of Conduct. Corresponding to these two ethical 'interests' or 'tendencies,' we find two ways of setting forth man's Type in relation to the Cosmos,—the positive way, and the way of imaginative representation. The way of imaginative representation recommends itself to—indeed, is forced upon—those whose reflection dwells on the significance of man's being what he is—a self-conscious subject. Man's Type for them is intuitively apprehended, being present in self-consciousness. It is "Eternal Consciousness present in my consciousness." This is the True Self, which constitutes the world—makes it the intelligible system that it is. Plato is the master of those who set forth the Type imaginatively. The reverence which the True Self inspires (it is what Aristotle would call τίμιον) finds, with Plato, expression in a solemn ritual, as it were, of mythic or prophetic representation. The history of the immortal soul (which in itself 'has no history') is unfolded in a vision, or miracle-play, before our eyes, from its 'creation' to the time when, purified by penance and philosophy, it is finally disembodied, and, returning to its own star, there participates in, and understands, the eternal motion of the Cosmos, being made 'like unto God.' This is not the place to discuss the reasons which justify Plato in thinking, as he certainly does, that such 'mythology' is part of 'philosophy.' We would only say that much of what has passed since his day under the name of 'metaphysic'—for example, the main part of the metaphysic which the 'Cambridge Platonists' and their present-day English successors supply as basis for morals—is best regarded as rationalized 'myth,' and owes its attractiveness and, we would add, its value to its 'mythological' character. The other way of setting forth man's Type we have called the positive way. While the way of imaginative representation is essentially 'protreptic,' making a personal appeal to the individual soul as such—'Reverence thyself, for thou art worthy,'—and relying largely on the 'prophetic' genius[1] and personal influence of him who employs it, the positive way merely aims at providing instruction for those who care to receive it. Those who employ this latter way, leaving it to others to say that 'we see all things in God,' and letting it go without saying that 'the world is intelligible by man's intelligence,' turn to the natural history of mankind for data out of which to construct a positive theory of man's Type. This 'theory' may either set forth the genetic process by which the Type has been evolved, or amount to nothing more than a descriptive account of the Type as it now appears; in either case the moral life—the life of conduct willed for the sake of the Public Good—being taken as central, the range of view is enlarged, and other than moral elements are included within the survey. In the difference between the descriptive and the genetic account lies the distinction between the old manner and the new of setting forth the Type positively. The positive method was employed in the descriptive manner by Plato (for he by no means confined himself to the method of imaginative representation) and by Aristotle when they took the civilization achieved by their own race—*the ensemble of all its activities*—as the Type to be described. Fortunately for Ethics, it was a many-sided, well-balanced Type; and the concrete presentation of it by Plato and Aristotle has been worth immeasurably more than any exposition starting from the abstract notion of human nature as such would have been. They present human nature as such in a fine rendering of their own particular Civilization—Ἑλληνὶς ἔσται, says Plato, speaking of his καλλίπολις. The result is a portrait which, like all great portraits, is an ideal, setting forth universal human *traits*, while rendering faithfully the features of an individual. The peculiar charm of the ethical portraiture which we have received from the great Greek masters depends, doubtless, on the circumstance that the Type portrayed was accepted without *arrière pensée* as final. The new biology has taught us that Type is never final—that there is no such thing as completed adjustment of organism to environment. Is portraiture, then, in the classical manner, a thing which Ethics, as General Theory of Conduct, cannot now hope to succeed in, and will not seriously attempt? We hold that Ethics must still attempt it. Provisional (or, if any one prefers the word, ideal) description of Type achieved is necessary to give aim to the genetic account. The only way in which the Type can be set forth positively (*i.e.*, for our guidance, as distinguished from our encouragement) is that which combines the genetic with the descriptive account. And the descriptive account will still take the form of the portraiture of some particular civilization. Some specific National Type must always sit as artist's model. Thus, if the moralist is an Englishman, he will do well to keep his eye on the civilization of England. But the new biology will make a great difference to his work. However tempted, as artist, he may be to follow his masters in setting forth the Type as if it were final, he is bound now to remember that it is not final, and, at the same time, that the relations involved are so complicated that calculation of what it will become even in the comparatively near future is not to be attempted. No biologist thinks of speculating about the form which a given organic type may assume in the future, or of interpreting present structure and function in the light of such hypothetical form. He knows that the calculation is too intricate. The scientific character of his 'teleology' is guaranteed by the definiteness of the already achieved organic whole or result, which is always taken as starting-point for the explanation of parts or stages clearly and distinctly perceived to be parts or stages. The scientific caution observed by the biologist in his employment of 'teleology' is likely to be imitated more and more by moralists in their attitude towards 'ideals.' When it is said that 'Ethics' is not really touched by the new biology, the remark must be taken as true only of 'Ethics' as setting forth the Type in the way of imaginative representation. As setting forth the Type in this way, Ethics is certainly not touched by the new biology, just as the *Divina Commedia* is not touched by it. But positive Ethics (whether its manner be principally that of the descriptive or that of the genetic account) is touched, and very nearly, by it, in the respects indicated.

We pass now to Ethics as Particular Theory of Conduct. It has for its subject-matter that branch of general conduct distinguished as 'moral conduct.' It is not necessary to describe 'moral conduct' here. It is enough to ask the reader to recall the subject-matter of any standard treatise on 'morals,' such as Reid's *Essays on the Active Powers* or Adam Smith's *Theory of Moral Sentiments.* But it is important to say, that, in our view, 'moral conduct' belongs to man not as individual, but only as member of society. Were there only one human being in the universe,

[1] Understood in the sense defined by Spinoza in his account of the nature and function of Prophecy: *Tractatus theologico-politicus*, chaps. 1, 2, 3.

there might conceivably be 'branches of knowledge,' and 'logic' or theory of the ways in which the endeavour after knowledge is made; but there could be no 'Ethics' in the narrower sense we are now considering; for the conduct which is its special subject-matter is the behaviour of persons to one another as members of a common concern in which they are fellow-workers. Aristotle recognizes this when he makes his solitary abstracted God a 'thinker,' but denies 'morality' to him. The distinction between 'politics,' *i.e.*, the science of man as πολιτικὸν ζῷον, and 'morals,' or 'private ethics,' is thus apt to be misleading as a distinction within the bounds of Ethics as Particular Theory of Conduct. 'Private morality' is an abstraction, like a caged bird. It may be convenient for observation to have it caged; but what is observed in the cage must always be interpreted with reference to the natural habitat of the prisoner. It may be convenient, for the moment, to look at moral virtue as simply the quality of an individual; but, after all, the quality is what it is because it puts its possessor in certain relations to others in society—ἡ ἕξις ταῖς ἐνεργείαις ὁρίζεται καὶ ὧν ἐστί. The distinction, however, between 'private ethics' and 'politics' where strongly pressed, has been urged not on the mere ground of its convenience for the methodical study of the individual as πολιτικὸν ζῷον, but because it is thought that, after all, the individual for 'Ethics' is not the πολιτικὸν ζῷον—that 'morality' consists essentially in a man's relations, not to fellow-men, but to himself as made in the image of God. The distinction between 'politics' and 'private ethics,' thus pressed, is really that between the Particular and the General Theory of Conduct, as the latter appears in the eschatological myths of Plato where the doctrine of Κάθαρσις is set forth, and in the metaphysical systems which have been more or less influenced by that doctrine. 'True Self to be realized by conscious participation in the intelligible forms which constitute the Eternal Wisdom and Goodness of God'—this is the main purport of these systems. What is characteristic of them is that they are devotional systems; their object is to make a personal appeal to the individual to be perfect even as God is perfect. This is expressly stated by John Norris, the Platonist, to be the object of his book *Reason and Religion* (1689), in which he sets forth the "Eternal and immutable morality" of his school. He explains in his Preface that devotional works exist in plenty for the use of the unlearned reader; but his design is to supply a devotional book for the learned reader. Like the other writers of his school, he sets forth the Divine Nature as the final object of contemplation and desire—as the Light of the World, the Good, the conscious subject of the eternal ideas in which it is man's prerogative to participate by 'Devotion.' Devotion is an act of the will directed to an object of contemplation,—*i.e.*, it is a rational act of the will. The critic of our present-day English 'idealism' has much to learn, we believe, as to the 'tendency' of the school, from its 17th century 'Platonist' representatives.

To understand the position which 'private ethics' ought to occupy within the Particular Theory of Conduct, we must turn to the work of such moralists as Shaftesbury, Hutcheson, and Adam Smith. The 'moral sentiments' so admirably described and analysed by these writers doubtless belong to the individual; but it is assumed throughout that they are 'designed' to operate for the 'Public Good.' The significance of the passage from Hobbes to the moralists of the 'sentimentalist' school is that the centre of interest is shifted from 'state' or 'sovereign' to 'private citizen.' Hobbes intrusts the 'Public Good' entirely to the sovereign, reducing the character of the subject, or private citizen, to the one quality of obedience. The sentimentalist moralists dwell on the initiative of the 'benevolent' private citizen, as reflectively pursuing the Public Good. The Public Good is thus placed in a new light. It is no longer regarded as identical with the stability of a centralized government armed against anarchy, but as gradually realizing itself in the progress of reforms suggested by the experience of enlightened and public-spirited private citizens. Starting from the principle that the private citizen can and ought to work *as private citizen* for the Public Good, the sentimentalist moralists analyse that character in the private citizen which makes him capable and desirous of working for the Public Good. Their psychology of the moral sentiments, though not very 'scientific,' indicates with sufficient clearness the lines on which the education of the private citizen must be conducted with a view to the establishment of the character in question. Their work may therefore be said appropriately to lie in the field of 'private ethics' or 'morals' as distinguished from 'politics' or 'legislation,' inasmuch as the private citizen, and not the sovereign or state, is the centre of interest. 'Private ethics' as cultivated by these moralists attempts to determine, always in relation to the Public Good, what is 'meritorious' in the private citizen, when acting in the ordinary everyday concerns of his life; not to estimate the 'value,' in relation to the same standard, of general rules proposed by a legislative body. It was fortunate for English Ethics that it passed through the hands of psychologists, who made it their business to furnish a theory of the 'merit' of the individual, before it reached the political and legal reformers, Bentham and his followers. It is the individual, as described in the 'private ethics' of the sentimentalist moralists, who ultimately inspires, and is willing to live under, the legislation outlined in the 'politics' of the later utilitarians. At the same time, it must be admitted that the sentimentalists go as far as it is possible to go safely in insisting on 'personal merit' or the 'moment of good' in the individual. They often come very near the substitution of the subjective standard of 'good intentions' for that of the Public Good. It was time that the centre of ethical interest should begin to be shifted back again to the state from the individual—that 'utilitarianism' should cease to be mainly a theory of 'morality,' and fulfil its end by becoming the theory of 'legislation.'

We have now said enough to explain our view of the nature and position of 'private ethics' as dealt with positively. It is the theory of the moral character of the individual; it is complementary to and, in turn, complemented by 'politics,' the theory of the state in which the individual inheres as citizen. There can properly be no 'private ethics' without 'politics,' or 'politics' without 'private ethics.' Both together make what we have called the Particular Theory of Conduct. This might well be called 'Politics'—πολιτική—in the generic sense; for it deals with man as πολιτικὸν ζῷον—is the theory of that kind of conduct by which individuals are brought and kept together as fellow-workers in and for the state. Regard for this common concern, restraining individualistic tendencies, is the living principle of moral conduct, and differentiates it from other forms of 'conduct.'

Position in 1878.

Ethical systems may be conveniently classified according as the interest which inspires them is political, religious, or scientific. English interest has been political and religious throughout, and only lately scientific. We do not mean, of course, that the 'political' moralists—Hobbes, Locke, Shaftesbury, Hutcheson, Adam Smith, Hume, Bentham, J. S. Mill—had no 'scientific' basis—they certainly had it ἐφ' ὅσον ἱκανῶς ἔχει πρὸς τὰ ζητούμενα; and the 'Cambridge Platonists' were most anxious to press 'modern science' into their service, in this respect resembling some of their present-day representatives. But it was not till the introduction of evolutionary theory into Ethics that the subject began to be studied as one of purely scientific interest—man's manner of life being investigated in the same spirit in which the habits of bees and ants are investigated. Where the chief interest is religious or scientific, the system is mainly a contribution to the General Theory of Conduct; where political, to the Particular Theory of Conduct. We shall best explain the position of Ethics in England when the last quarter of the 19th century opened by showing how the three interests—political, religious and, scientific—were then balanced. The prevailing interest of English Ethics was then no longer political, as it had been in Bentham's time. Bentham's preaching of the doctrine of the Public Good had borne fruit in the reforms, constitutional and legal, with which his name will always be associated: "I do not know," says Maine (*Early Hist. of Inst.* p. 397), "a single law reform effected since Bentham's day which cannot be traced to his influence." But when these reforms had been effected, utilitarianism entered on a long period of academic retirement, or even inactivity. As time went on it became more and more difficult for the young men, who made acquaintance with it at the universities, to appreciate the circumstances and temper of those to whom it had been a living gospel; more and more easy to cavil at the 'handy' psychology which had been good enough for Bentham's practical purpose, especially as that psychology was presented by J. S. Mill and Professor Bain. These later exponents of Bentham's system almost courted the charges (mistaken as they were) of 'hedonism,' and of converting a principle of 'legislation' into a principle of 'morals,' which began to be brought against utilitarianism in the 'sixties, and have been reiterated ever since. Here it is only necessary to say that they came chiefly from those whose paramount interest in Ethics was religious—who were dissatisfied with the merely secular aim of utilitarianism.

While Ethics had lost in the third quarter of the 19th century the inspiration of keen political interest, the other interests—the scientific and the religious—were both making themselves powerfully felt. It was during this period that, for the first time in the history of English Ethics, moral conduct was presented frankly as a subject of purely scientific interest—as part of the great *ensemble* covered by Biology, a science, or rather group of sciences, which had now found its Newton. Darwin had brought light into Biology, and made it a study of absorbing interest; Mr Spencer had definitely, without qualification, placed 'Ethics' within its borders. This he did even in writings published before the *Origin of Species*, although without anticipating the distinctive idea of that work.[1] If Darwin's was the greatest influence of the 19th century, it was chiefly through Mr Spencer's writings that it made itself felt among professional students of Ethics during the 'sixties and early 'seventies, although afterwards it reached them through other channels.

But the same period which saw Ethics thus claimed by the biologists for science, saw also a great awakening of the religious interest among the professional students of Ethics. The introduction of Darwinism into Ethics coincided with a notable revival of idealism in Ethics. Various causes contributed to this result. The spirit of the 'Cambridge Platonists,' which had always been cloistered in England, was powerfully appealed to by the so-called 'Oxford Movement.' Idealism became conscious of itself even in men who seemed to stand aloof from that movement. The newly awakened idealism found itself confronted by the utilitarianism of J. S. Mill, and the biological ethics of Mr Spencer, just as, two centuries before, it had been confronted by Hobbism and 'materialism.' At first it was merely with utilitarianism that idealism came into action. With arguments similar to those used by the Cambridge Platonists against 'materialism,' and in a similar spirit, their modern successors attacked the *end* of the popular utilitarianism. Utilitarianism seemed to them to acquiesce in the material welfare of masses, whereas the true end lies beyond in the perfection of persons. The good effected by utilitarian legislation in England was too great to be overlooked, and T. H. Green (whom we take in this article as representative of the idealist school) was not the man to underrate it—but the true end lies beyond in the perfection of persons. If the devotees of this ideal go forth from the cloister, as they often, in our day, feel it to be their duty to do, in order to take an active part in 'social work,' we must still distinguish them from the utilitarians. The ideal of the utilitarians, or political moralists, is a secular one—that of public prosperity. The ideal of the modern Platonist is a religious one—it is (to use a phrase which we hope will not be misunderstood as we use it) the ideal of 'souls to be saved'—of individuals to be made more perfect by personal care, in a social system which is the life of each one of them writ large. Another influence which contributed (though perhaps not so largely as might be supposed) to the revival of idealism in England was, of course, the study now beginning to be given to German philosophy. German philosophy, elaborated in universities, without the distraction of political interest, has always dwelt more on Self than on Citizen; and its influence, as felt by the English idealists twenty-five years ago, was entirely in favour of substituting the ideal of personal perfection, or self-realization, for the utilitarian standard. At the same time Hegel had insisted on the progressive realization of Self in Society. Here the English idealists readily followed Hegel's lead, for he seemed to indicate how they might, without sacrifice of philosophical principle, retain much with which they were in sympathy in the national utilitarianism. It is in social life, then, that personality must realize itself—in the Family, in the State, and, it is important to add, in the visible Church. The idea of 'visible church' had of late years become very vivid and attractive in England. A philosophical reason for its attractiveness seemed to many minds to be added by the teaching of the idealist school. The historian of religious opinion in England during the latter half of the 19th century will have to take serious account of the influence of that teaching within the Church.

The polemic of the new idealism was mainly, at first directed against utilitarianism—against J. S. Mill and his philosophical predecessors Locke and Hume. In time, however, it was turned against the biological ethics, with which it is now chiefly engaged. This conflict is more interesting to the critic than that with utilitarianism, inasmuch as it serves to show more clearly the 'tendency' of English idealism, by bringing out two connected doctrines as of cardinal importance to its whole teaching—(*a*) that man, as self-conscious, is absolutely distinct from the animals, and (*b*) that, in his self-consciousness the eternal self-consciousness is present. The position, it is contended, which biological ethics gives to man, is inconsistent with the ultimate fact that self-consciousness exists, presenting him to himself, in respect of his intelligence and moral freedom, not as product but as principle—as 'reproduction' of the eternal self-conscious principle which is the cause to all 'products' of their coming into existence and being intelligible. This epistemological Theism of the modern idealists, it is to be noted, is essentially that of Cudworth and the other 'Cambridge Platonists,' who argue that through the eternal and immutable truths of which reflection

[1] See the interesting note *Princ. of Biol.* ii. 500.

(Plato would say ἀνάμνησις) makes man aware as constitutive of his understanding and as conditioning his experience, he comes into communion with the Eternal Wisdom of God, Whose νοήματα they are, Who created the world after their pattern. To put this into the language of to-day:—in man's consciousness of self, the Eternal Consciousness is present. Judging from their recent writings, we take it that the modern representatives of Cudworth's school find Theistic Theory the most interesting part of their system; and we may expect that the chief developments of English idealism will be towards the elaboration of such theory.

Henry Sidgwick.

We must not close this general review of the position at the date of Professor Sidgwick's article without referring to his own *Methods of Ethics*, which appeared in 1874. The *Methods of Ethics* is important as being a critical restatement of utilitarianism by one who was intimately acquainted with the history of that doctrine, from Hobbes downwards, as a chapter in the History of the English People, and saw very clearly that that side of it, which received so much—perhaps too much—attention from the sentimentalist moralists, had been too little regarded by utilitarians since Bentham's time. It was, accordingly, to a re-examination of the problems of 'private ethics' (considered always as the other side of 'politics') that Professor Sidgwick mainly devoted his remarkable powers of insight and analysis. The *Methods of Ethics*, we believe, will stand as a landmark in the history of our national utilitarianism. It marks the shifting back of the centre of ethical interest from State or Government to private citizen. For Hobbes, as we have seen, the Public Good was secured entirely by the efficiency of the Government; for Shaftesbury and his school, mainly by the benevolent initiative of private citizens; for Bentham, again, mainly by the legislative action of the State; while the new utilitarianism represented by Professor Sidgwick comes back again to the importance of investigating the moral sentiments of the individual, in order to grasp the lines on which his education for citizenship may be conducted. The lead given by Professor Sidgwick has been followed by other adherents of utilitarianism. This development of utilitarianism in the direction of an exact positive psychology of the moral sentiments is likely to be an important one. The talent for such inquiry is native in England; and, aided by the scientific methods now employed in psychology, ought to produce valuable results. Political, as distinguished from scientific and religious, interest will doubtless again resume its normal influence in English Ethics. New social conditions have arisen which demand, and will undoubtedly create, a new utilitarianism, in which a theory of the moral and political education of the individual citizen based on an exact positive psychology of his moral sentiments will hold a prominent place.

Development since 1878.

Since the publication of Professor Sidgwick's article in the ninth edition of this *Encyclopædia*, important works have been published by English representatives of the evolutionary school—especially *Principles of Ethics* by Mr Spencer, *The Science of Ethics* by Mr Leslie Stephen, and *Moral Order and Progress* by Professor Alexander.

Spencer.

Mr Spencer defines Conduct as 'acts adjusted to ends,' and proceeds to lay down the principle that the part of conduct with which Ethics deals cannot be understood without the study of human conduct as a whole, or the latter without the study of conduct as belonging to animate beings in general. This means that Ethics must begin with the study of the 'evolution of conduct' out of that which cannot be called 'conduct.' The 'evolution of conduct' is marked by improvement in the adjustment of means to ends, so that life gains in 'length' and 'breadth'—life being at once that of the individual, and that of the species maintained by the rearing of offspring. Conduct subserving the life of the individual and conduct subserving the life of the species are mutually dependent. Each reaches its highest form simultaneously with the other; but not until the highest form of a third kind of conduct—social conduct—is reached. When this is reached, the ends of the two lower kinds of conduct are achieved without 'struggle for existence.' 'The limit of evolution can be reached by conduct only in permanently peaceful societies.' That conduct is best which simultaneously achieves the greatest totality of life in self, in offspring, and in fellow-men; the postulate involved in this judgment being that 'life is worth living'—which means that it brings a surplus of 'pleasure' or 'happiness.' Evolutionary theory enables us to substitute a scientific for an empirical utilitarianism, by exhibiting certain fundamental truths common to ethics with physics, biology, psychology, and sociology. In physics we see evolution always tending towards the better maintenance of a 'moving equilibrium.' This appears in biology as 'balance of functions'; the notion of 'balance of functions' yielding, on examination, the truth that "sentient existence can evolve only on condition that pleasure-giving acts are life-sustaining acts." Passing from the biological to the psychological view of ethics, we pass from presented pleasures and pains to represented pleasures and pains as constituting deliberate *motives*, and arrive at the conclusion that evolution is marked by the increasing subordination of simple presentative feelings to compound representative feelings. Thus the 'moral consciousness'—the 'feeling of obligation,' or 'sentiment of duty'—begins to emerge, as a balanced complex of representative feelings, an internal control gradually emancipating itself from three preparatory external controls, the political, religious, and social. Standing, as it does, for the experience of the individual and his progenitors, the 'moral consciousness' is a feeling "at once massive and vague." It is the "abstract consciousness" of the superior "authority" of the guidance supplied by the complex representative (and re-representative) feelings occupied with the future rather than the present. But "the sense of duty or moral obligation is transitory, and will diminish as fast as moralization increases." Passing to the sociological view of ethics, we find that what here corresponds to the 'equilibrium' of the physical view is realized under conditions which, formulated, make a 'code' that confers on Ethics the rank of a 'science': namely, The associated individuals shall (1) inflict no injury (*a*) directly or (*b*) indirectly on one another; and (2) shall help one another (*a*) under agreement and (*b*) beyond agreement. 'Happiness,' special and general, is the ultimately supreme end. Although 'Happiness' itself is not a thing that can be cut up and distributed at all; and although the concrete means to it cannot be distributed equally; yet each man may have like liberty to pursue 'happiness,' and like security in the possession of it. The 'greatest Happiness principle' is meaningless except as asserting the necessity of this. Although egoism, biologically considered, comes before altruism, yet "from the dawn of life altruism has been no less essential than egoism." "Self-sacrifice is no less primordial than self-preservation." Its primordial form is the "physical altruism" of reproduction by fissure. Scientific ethics has to recognize the fact (ignored by the "transformed utilitarianism" which assumes "pure altruism") that egoism *and* altruism coexist. Provisionally we must reconcile their respective claims by compromise. But the opposition between them tends to disappear. 'Sympathy' tends to become stronger; men tend more and more to make each others' pleasures, 'egoistic' and 'altruistic,' their own. This is the ideal of 'perfect conduct,' the subject-matter of 'absolute ethics,' which stands to 'relative ethics' (concerned with conduct which, as involving pain, is only relatively right, *i.e.*, partially wrong) as rational stands to experimental mechanics.

Leslie Stephen.

Mr Leslie Stephen summarizes his system in one sentence (*op. cit.* p. 454):—"Morality is a product of the social factor; the individual is moralized through his identification with the social organism; the conditions, therefore, of the security of morality are the conditions of the persistence of society; and if we ask from the scientific point of view what these conditions are, we can only reply by stating that the race is dependent upon the environment; by tracing so far as we are able the conditions under which it has been developed, and trying to foresee the future from the past." The ethical problem—to discover the general characteristic of the moral sentiments—Mr Stephen attacks from the position that human beings are the product of a long series of processes of adaptation acting either on the individual or the social organism in which he inheres as a member. The social organism (or better, 'social tissue') is a growth the laws of which can be studied apart from those of the individual atom. The 'social tissue' develops without a corresponding change of individual organism. We are born with brains very like those of remote progenitors; but we use them in an environment of laws, institutions, literature, tangible products of labour, scientific knowledge, logical and mathematical formulæ—a 'social tissue' very different from that in which these progenitors lived. It is on the social tissue, as primary unit, that the process of evolution impinges; and consequently it is in relation to the vitality of the social tissue that we speak of the individual's conduct as 'useful.' "That form of bee will flourish which forms the most efficient hives. The hive . . . will be the unit which must be taken into account in considering the general problem of survival." The social tissue—the all-pervading substance from which the various 'organs' or subordinate associations (governmental, religious, industrial, &c.) are constructed—is its own end. Society being an organic growth, certain instincts or customs are formed corresponding to a given state of the social tissue. What is the nature of those social instincts which give rise to 'morality'? Morality, gradually developed out of Law and Custom by natural process, is distinguished from them by substituting 'Be this' for 'Do this.' Rules of conduct are seen to be rules of character. "The individual must, so far as moral, be capable of aiming at the social welfare before his own." But is such 'self-sacrifice' possible? Yes. The reduction of altruism to egoism involves a confusion of thought. Altruistic does not differ from non-altruistic conduct in any sense which would imply that my conduct can spring from anything but my own feelings. Moreover, 'sympathy' is implied from the first in the very structure of knowledge (see pp. 230 ff.), and, as a matter of fact, is a stronger feeling than egoistic feeling. "The sympathetic being becomes, in virtue of his sympathies, a constituent part of a larger organization," apart from which he is unintelligible. "Altruism is the faculty essentially necessary to moral conduct." "The moral code is a statement of the conditions of social vitality." It is in relation to social vitality, as end, that we must explain merit, obligation, virtuous character, conscience, responsibility. Merit belongs only to voluntary actions, which are actions put forth by character in environment. Responsibility is the dependence of actions on character; conscience is not an instinct co-ordinate with other instincts, but "implies a judgment of the whole character." So far as I identify myself with the social organism I feel a sense of obligation to conform to the conditions of its welfare. While 'happiness' is the criterion of the old utilitarianism, the 'health of society' is that of evolutionary ethics. These two criteria are not really divergent, but the former is unscientific, the latter scientific. Can we modify the utilitarian sanction (that which supplies the motive to virtue) correspondingly with its criterion? Yes: we can show that the acquisition of virtuous character is conducive to 'happiness'—although we must admit that "there is no absolute coincidence between virtue and happiness."

In the first part of his work, dealing with 'moral statics,' Professor Alexander arrives at results similar to those reached by Mr Leslie Stephen. "Conduct and character are the same thing facing different ways." Biology has brought this truth to the front, and, with it, the conception (of course not a new one) of character and conduct as relative to society—'social organism,' or 'social tissue.' In respect of the individual, the goodness of an act depends upon its occupying a definite position in an equilibriated order of action. The good character in relation to which any act is judged good or bad is "an order or systematic arrangement of volitions"—an equilibrium of functions, and of structure. "The conception of a man's character is represented under the name of an *ideal*—a plan of conduct or way of life upon which he acts." "The good man's life is the good or moral ideal." In respect of society, a good act is one "by which the agent seeks to perform the function required of him by his position in society." 'Efficiency' is what is required by the moral judgment of every act. "Conduct is good, not because it leads to some further result, such as pleasure, or because it is determined by some inexplicable idea of good, but in virtue of the equilibrium it establishes between the various parts of conduct itself." "Good conduct (defined as a system or order), as it is the complete statement of the object of morality, is the complete form of the criterion or standard." There is no need to refer to the abstract standard of 'perfection' or of 'pleasure'; good conduct is 'perfect'; and 'pleasure' is part of the standard—for "without the pleasure the standard would be something divorced from our experience." The individual's good, then, "is *ipso facto* an element of the general welfare, and it is a common good because it binds him with others in the moral system." The common good is a medium of communication like language. Egoism and altruism are equally fundamental and original. Having dealt, as above, with 'moral statics,' Professor Alexander goes on to discuss 'moral dynamics,' of which there are two main problems: (1) to show how the moral equilibrium is produced and maintained, and (2) to examine the meaning and law of moral progress. Dealing with the first problem, he explains that the moral ideal, as a system or order, is "a species under which the various ideals as they exist in the minds of good men, are the different individuals"; and that "the course of morality represents the struggle between moral ideals, and the phenomena of the maintenance and growth of morality offer parallels to the history of natural forms." Professor Alexander claims great importance for this theory. It is a question, he thinks, "whether as much light may not be reflected on the natural problem by the ethical, as the reverse." Dealing with the problem of 'progress,' he explains that "the good is always ultimate, but, owing to the development of human nature, it is always in motion"; and that, therefore, there can be no contrast of a 'good' and a 'best,' but only of a 'good' and a 'better'—that adaptation, wherever, and so far as, it exists, is perfect adaptation. This amounts to saying that "goodness means progress," for "in changing from one form to another morality changes from what is right under one set of conditions to what is right under another set, and such change from good to good is what we mean by becoming better." The law of moral progress is stated as the 'law of comprehension'—*i.e.*, the tendency of evolution is towards one dominant ideal, such as that of Christian civilization.

Alexander.

What strikes one most on looking back over the last quarter of the 19th century is that evolutionary ethics in England becomes more and more Darwinian. To Mr Spencer is due the credit of having given vogue to the evolutionary point of view; but he has never shown himself, we venture to think, sufficiently alive to the importance of the distinctively Darwinian ideas of 'struggle for existence' and 'natural selection.' To the younger members of the school these ideas are all-important. The writings of Darwin himself and of the biologists who, on all sides, raise crop from the seed he gave them, have taught these younger moralists better to realize the meaning of 'correspondence of organism with environment'—indeed, to appreciate the complexity and delicacy of biological adaptation in a way which, once for all, gives a new aspect to the moral life. Some little variation which the complexity of the phenomena puts it beyond the power of science to explain, except as involved δυνάμει in an original germ, occurs and makes all the difference in the 'struggle for existence'; for not only does it enable the organism manifesting it to adjust itself to a pressing need in its present environment, but creates a new environment with fresh needs to be met, and so on indefinitely. The complexity and mobility of the relations between organism and environment, as understood by Darwinism, are such as to preclude entirely the idea of 'final correspondence.' Deeply impressed, then, with this, the younger moralists referred to decline to follow Mr Spencer in his doctrine of 'Absolute Ethics,' and 'perfect conduct.'[1] Ethics is only 'relative'; moral conduct, like all other conduct, is always realized in 'struggle.' Ἀεὶ πονεῖ τὸ ζῷον. This is the greatest lesson which Ethics, in our day, has taken home to itself from biology. Of course, 'moral struggle' has been recognized since the dawn of Ethics, but never before has the *necessity* of it been clearly seen. Again, the endless complexity of the relations between organism and environment, which makes perpetual struggle inevitable, also prescribes the method of that struggle as a little-by-little movement of adjustment to new circumstances as they arise. A 'leap in the dark,' or 'shot' aimed at the ideal as some far-off future condition, is out of the question. The balance of the innumerable forces involved is so precarious that any intervention other than slight would overturn it. Those who have learnt the lesson which the new biology teaches are content to think of a succession of 'ideals' which are always being realized—

Evolutionary Ethics criticized.

[1] That Mr Spencer himself has come to realize more fully than he once did the complexity of the relations which evolutionary theory obliges us to take account of, is shown by a noteworthy statement made in the Preface to vol. ii. of *Principles of Ethics* (1893):—"The Doctrine of Evolution has not furnished guidance to the extent I had hoped. . . . Some such result might have been foreseen. Right regulation of the actions of so complex a being as Man, living under conditions so complex as those presented by a society, evidently forms a subject-matter unlikely to admit of definite conclusions throughout its entire range." That Moral Science does not admit of τὸ ἀκριβές is indeed as true now as it was in Aristotle's day, and more evidently true. Whether recent attempts to introduce ἀκριβολογία μαθηματική into Biology (see K. Pearson, *The Grammar of Science*, chaps. x. and xi.) are likely to give results of appreciable value for Moral Science remains to be seen.

and *perfectly* realized—and then superseded—a succession of short views of betterment to be effected on customary lines, each one of these views being naturally suggested by the situation which the realization of its immediate predecessor has created.

It is because they favour the theory of one distant ideal (the aiming at which shall make the great difference between man and brute) that the English opponents of evolutionary ethics are not satisfied with the reasonable positive 'teleology' of the Darwinian moralists (identical with Aristotle's method in biology and ethics, which always has some definite organic whole before it in relation to which the parts are explained), and accuse them of 'explaining the higher by the lower.' This hackneyed phrase entirely misrepresents the method of the Darwinian moralists. They 'explain the higher by the lower' in explaining the lower by the higher. They know well, as biologists, that the parts or stages (the lower) cannot be understood in abstraction from the whole or result (the higher), any more than the whole or result can be understood in abstraction from the parts or stages. The fault which their critics have to find with them is really that they confine themselves to this sober Aristotelian or Darwinian teleology—that they take an achieved organic result, open to our observation (in this case 'Human Nature'), as a many-in-one to be positively set forth in the way of descriptive or genetic account, and do not allow themselves to interpret facts in the light of some theory of what *ought to be.* Thus it is objected that the 'historical method' cannot decide between various ethical ends and determine which *ought* to be followed—that an ethical theory from the standpoint of science is impossible—that it is the 'ideal' that explains the evolution, not *vice versâ* — that the Darwinian moralist does not tell us *why* we desire that society should be in equilibrium with itself—that it is necessary to show (which 'natural history' cannot do) that equilibrium is a *good*—conduces to the realization of the absolute good towards which, as *terminus ad quem*, 'the stream of development is leading.' The Darwinian moralist denies that such an objective is before us. It is always man's Type, as developed 'up to date,' that expresses itself in the successive ideals of slight betterment by which the moral life is maintained and transformed. This current Type must not be pushed forward into the unknown future, and set up there as an Absolute towards which 'the stream of development is leading.' The contention that this "Absolute" is ever present in my self-consciousness cannot be allowed to mean more than that, as a matter of fact, I am a being capable of knowledge and action in the world in which I find myself. From this truism no criterion of what ethical ends *ought* to be followed can be derived; for that we must go to the experience supplied by the 'natural history' which traces the actual development of my knowledge and action. Moreover, the idealist's admission that there is a history of the process by which the animal organism has become the 'vehicle' of consciousness concedes all that the Darwinian moralist contends for. What the idealist contends for, after this admission, is that consciousness *itself* 'has no history.' This is explained[1] to mean that "Existence, as a whole, contained within itself prior to its manifestation as consciousness, all that so manifested itself . . . What is posterior in time is prior in nature: the first is last, and the last first." 'Teleology' here falls back on an original δύναμις, which it rehabilitates as ἐνέργεια: arguing that, inasmuch as consciousness has actually manifested itself, the universe must always have contained the possibility of it—*that is*, the actuality of it. Here it is instructive to observe that 'mechanism,' in our day, seems inclined to take up with a similar employment of logical terms. Professor Weismann (*Romanes Lecture*, 1894) seems to argue that variations (some of which 'catch on' in the struggle for existence) are all *actually* provided for in the microcosm of the original germ-plasm, since that microcosm contains the *possibility* of all that manifests itself afterwards in the secular history of the species.

The polemic of the idealist against the evolutionist appears to us, then, to leave the position of the latter unaffected. The evolutionist never professed to do more than trace the process by which the animal nature has become 'organic' to knowledge and morality, and to supply reasons why, man's Type having a certain known constitution and history, certain actions *ought* to be preferred to others, if (as must be assumed) that Type is to be maintained. There is nothing beyond the competence of the evolutionary moralist in the determination of this *ought*, for the question is always about some immediate step to which he can see his way in the light of past experience. What the distant steps ought to be he cannot foresee; nor, indeed, does the idealist profess to tell him. The idealist merely supplies a 'protreptic.' He appeals to us in the language of 'prophecy,' and thereby helps to make more vivid and effectual in us that γλυκεῖα ἐλπίς[2] which is the very principle of life itself—the belief that 'life is worth living,' in the strength of which man struggles on and on, always seeking after a fuller and fuller 'comprehension of conditions' — a wider and wider 'correspondence with environment,' finding himself, after every successful act of adjustment to a given environment, confronted by a new environment, which does not appal him, but, as being of his own making, interests him and calls forth renewed efforts.

The social organism.

As evolutionary ethics in England becomes more and more Darwinian, greater prominence is given to the idea of 'social organism.' Mr Spencer's use of the idea—interesting as it undoubtedly is—is marred by his individualism and *laisser faire* theory of the functions of the State, inherited from the utilitarian politicians; but the younger evolutionist moralists, coming more directly under the influence of Darwin, use the idea in a way which promises results of great scientific and practical value. Some of them too, like some of their idealist rivals, owe much, in this connexion, to the political ethics of Plato and Aristotle, who still fortunately hold an important place in English philosophical study—perhaps a more important place than in the philosophical study of any foreign nation. When we say that our evolutionist moralists make great and increasing use of the idea of social organism, it must not be understood that they are constantly finding more and more points of close analogy between the body and the 'body politic'; on the contrary, it would seem that the more they know of each 'organism,' the less inclined they are to press into detail the analogy between them. What they do rather is to look at the social system in the light of the general conceptions of heredity, variability, struggle for existence, natural selection, and, above all, with a deep sense of the endless complexity and mobility of the relations involved. The result of this way of looking at society is that several truths of the first importance are brought home to us. It is made clear that moral and political reform is a slow process, and never can be 'radical'—that the general disturbance produced even by a little change may be a good reason for avoiding the latter, if possible; but, that since it is impossible to do so always, the most valuable quality a man or nation can have (always together with

[1] Watson, *An Outline of Philosophy*, p. 182.

[2] Plato, *Rep.* 331 A.

love of routine) is fortitude, wherewith to face the dangerous situations which may be produced by the most trifling constitutional interferences with the *status quo*; that, in any case, however, the unexpected is likely to happen—some quite inexplicable 'variation' will occur—a great man, for example, coinciding with his opportunity, will appear and alter the course of history; and, most important thing of all, it is made clear that 'War' can never cease, for, since development means the continuous differentiation of species, there will always be competing national types of life. Moralists who confine their view to *morals* strictly so called—whose Ethics is merely a Particular Theory of Conduct—are apt to lose sight of this, and to figure 'progress' as towards a cosmopolitan life of 'industrial prosperity' and civilized manners, under a *Pax Œcumenica*. Within each nation, as such, the art of political 'horticulture' may keep in abeyance the fierce physical struggle for existence characteristic of the 'cosmic process,' or 'state of nature'; but its place is taken by another struggle, as fierce—the ethical struggle between persons and parties representing 'ideals' of social life; while between different nations the struggle is always bound to be largely physical. It is easy to misread Huxley when he says (*Romanes Lecture*, 1893): "Let us understand, once for all, that the ethical progress of society depends not on imitating the cosmic process, still less in running away from it, but in combating it." The best commentary on the above is in his own words (*Collected Essays*, vol. ix. p. 11—*Prolegomena to Romanes Lecture*): "Man, physical, intellectual, and moral, is as much a part of nature, as purely a product of the cosmic process, as the humblest weed."

Idealistic Ethics.

Idealism in England received a great stimulus from the posthumous publication of Green's *Prolegomena to Ethics*, and *Works* (with R. L. Nettleship's *Memoir*), and from the comment which these books called forth.

Green.

Green's ethical doctrine is, briefly, that in the consciousness of a moral ideal—'the ideal of a best'—and the determination of human conduct thereby, a principle 'which is not natural' is involved. We are prepared for this result by a metaphysic of knowledge, the gist of which is contained in the following sentences. "The knowledge of nature is not itself a part or product of nature in the sense in which it is said to be an object of knowledge." "It is only because we are consciously objects to ourselves, that we can conceive the world as an object to a single mind, and thus as a connected whole. It is the irreducibility of this self-objectifying consciousness to anything else, the impossibility of accounting for it as an effect, that compels us to regard it as the presence in us of the mind for which the world exists." "The concrete whole which may be described indifferently as an eternal intelligence realized in the related facts of the world, or as a system of related facts rendered possible by such an intelligence, partially and gradually reproduces itself in us, communicating piece-meal, but in inseparable correlation, understanding and the facts understood, experience and the experienced world." "In the growth of our experience an animal organism, which has its history in time, gradually becomes the vehicle of an eternally complete consciousness." From the metaphysic of knowledge Green passes to the metaphysic of morality. "The transition from mere want to consciousness of wanted object, from impulse to satisfy the want to effort for the realization of the wanted objects, implies the presence of the want to a subject which distinguishes itself from it." Thus the want becomes a *motive*. Man is a 'free cause' in conduct, as in knowledge, because he is a 'reproduction' of the eternal self-conscious subject of the world, "carrying with it under all its limitations and qualifications the characteristic of being an object to itself." But how are we to distinguish between virtuous and vicious action? In either case the motive is the achievement of what the self-conscious subject presents to himself as his greatest good. Green's answer is that the true good is an end in which the effort of a moral agent "can really find rest"—"the Ideal of a Best." The distinction between the good and the bad man is that the former is 'conscientious,' wills what is in accordance with the system constituted by the eternal consciousness reproduced in him; while the latter is he whose "will does not answer to his reason," who habitually—knowing that he *should not*—acquiesces in 'self-satisfaction' inconsistent with man's betterment—his progressive ὁμοίωσις τῷ θεῷ in 'the Rational Life.' The ultimate standard of worth is an ideal of personal worth. The spiritual progress of mankind is "*of* personal character *to* personal character." As to man's future, the best conclusion we can draw is that "the end of human development is not one in which persons are extinguished." Meanwhile it is in society that, as a matter of fact, the human person realizes himself—his goodness appearing under the categories given in the Greek classification of the 'virtues.' The 'unconditional good' to which the 'good will' is directed—the 'ideal of humanity,' 'the perfection of man' (in principle identical with God), is thus a Common Good. This ideal of 'human perfection' is more definite, Green contends, than the 'pleasant life' of the utilitarians.

Modern idealism criticized.

We take Green as standing for the whole idealist school, with a few exceptions to be mentioned afterwards. He set his mark on English idealism; and its representatives are distinguished by a remarkable unanimity of opinion, the chief difference between them being, perhaps, with regard to the Theistic inference, in which the interest of the bulk of the school seems always to become stronger.

1. As regards the constructive part of the system, one asks why the primacy of self-consciousness is dwelt upon with such insistence. It seems unnecessary to say that without knower there can be no knowledge, without agent no action—that knowledge and action are relative to the nature and needs of the being that knows and acts. At any rate, this is just what the new biology teaches us—that organism and environment must not be abstracted from each other—that organism moulds environment no less than it is moulded by it. It is rather for the sake of the theistic inference that self-consciousness is made so prominent. The inference is (*a*) the fact that I know the world at all, involves the perfect knowability or rationality of the world; and (*b*) its perfect knowability involves an Eternal Knower, of whom I am an imperfect 'reproduction.' I know the world imperfectly, therefore there is One who knows it perfectly. If I were not conscious of knowing imperfectly, it would be unnecessary to represent me as 'reproduction' of a Perfect Knower. My imperfection must be sustained by a Perfect—an *actual* Perfect, not an ideal. Holding as we do that the ethical system to which this argument belongs is best regarded as 'prophetic' or 'protreptic,' we are not concerned to examine the logic of the argument; if it were fair (which it is not) to bring it to logical test, we should say that it neglects Kant's distinction of the Determinant and the Reflective Judgment, and concludes 'I cannot explain the world without the supposition of a God; therefore He exists.' We should also agree with Professor A. Seth (*Hegelianism and Personality*) and Mr Balfour (*Mind*, Oct. 1893) when they describe the God of this epistemological Theism as a *focus imaginarius*—a 'bare principle of unity,' without personality—or perhaps we should prefer to say that He has a personality which is inconsistent with human personality, putting Green's position thus:—On the one hand there is a 'personal' God, and on the other there is an indefinite number of human spirits, 'reproductions' of Him, the ideal of each one of which is to become indistinguishable from Him. This seems to us not to differ from the pantheistic ideal of the absorption of finite spirits in the Infinite Spirit. Such an ideal has never satisfied the 'religious consciousness'—at least, in the West—which demands 'personal relations' between man and God or gods, and 'personal immortality.' We venture to think that wherever the ground for an effectual Theism is to be sought, it is not in epistemology.[1]

[1] Bradley (*App. and Reality*, pp. 445 ff.) sets forth the difficulties under which theistic theory labours.

2. As regards the critical attitude taken up by the English idealists towards other ethical systems, we have already said enough about their attitude towards evolutionary ethics; but a few additional remarks on their criticism of English utilitarianism may be offered here. The English utilitarians from Hobbes to J. S. Mill are condemned for neglecting to recognize, in moral action, the agency of the self-conscious principle which presents to itself objects of desire—converts wants into motives, and is accordingly self-determined or free. Thus, speaking of Hobbes and Locke, Green says (*Hume*, *Treat.* vol. ii. p. 22): "Each started from the position that the ultimate motive to any action can only be the imagination of one's own pleasure or pain, and neither properly left room for the determination of desire by a conceived object, as distinct from remembered pleasure"; and again he says (*op. cit.* p. 11) that utilitarianism "excludes any test of pleasure but pleasure itself." We venture to think that the charge of 'hedonism'—whether 'ethical' or 'psychological"—brought against the English utilitarians is not reasonable. The English utilitarians were men of affairs in close touch with the actualities of English life. The national history is a testimony to the extraordinary influence which the conception of the 'Public Good' as 'Life of virtuous action sufficiently furnished with external good things' has had in England. The national character may be defined as 'Tendency to make organized social work, not ease and pleasure of separate individuals, the end.' It therefore seems to us to be paradoxical to say that English utilitarian moralists—men of affairs, in whose writings the national ἦθος is reflected with remarkable clearness—are 'hedonists' and 'individualists.' Indeed, one has only to reflect how largely the growth of the English Constitution and the progress of English legislation have been affected by the writings of those chiefly accused of 'hedonism'—Hobbes, Locke, and Bentham—to see how groundless the accusation really is. 'Hedonists' and 'individualists,' as described by the critics, could not have contributed anything effective towards the development of such embodiments of the 'Public Good.' *Laisser faire*, as it appears in Bentham's system, does not justify the charge of 'individualism.' It was forced upon Bentham and his associates by the political circumstances of which their utilitarianism took such careful account. Let us remember always that their utilitarianism was the theory which inspired the reforms of which 1832 is the central date. In order to break up the oligarchical régime, it was necessary to insist on the claim of obscure individuals to be left alone, under equal laws and a system of popular representation, to look after their own interests. The time had not yet come to think of *organizing* the life of these emancipated individuals on lines to be suggested by their own *communis sensus*. That 'individualism' is inseparable from utilitarianism it is quite incorrect to maintain. Benevolence, not self-interest, is its motto. The doctrine that society is an 'organism' (as we now say), of which the individual is conscious in 'Benevolence,' or 'Good Will' (see *Introd. to Princ. of Mor. and Leg.* ch. x., *Princ. of Pen. Code*, part iv. ch. xvi.), is essential to Bentham's system. It may, indeed, rank beside the doctrine of his critics that 'the end is realization as member of the community' (Bradley, *Eth. Stud.* p. 157). Bentham's social ideal is not that of a loose collection of individuals to be separately pleased, but of a body of fellow-workers to be organized under a system of equal laws—a prosperous industrial community the members of which are animated by the spirit of self-help and mutual help. The 'General Happiness' is not an 'abstraction' (Green, *Hume*, *Tr.* vol. ii. p. 7), but the most concrete 'object' which man, as rational being, sets before himself—a certain condition of social life, like the Greek εὐδαιμονία. In bringing the formal charge of 'hedonism' the critics seem to us to put too much into the language used by moralists who were writing for the large public, not for schoolmen. In the first place, it ought to be recognized that the utilitarians speak of pleasures in the plural, rather than of Pleasure; and, in the second place, that by 'pleasures' Bentham means *things* which men, constituted as they are, *like*—desire, and make their *ends or objects of pursuit*, it being often possible to measure the desirability of an object—described as 'mass or portion of happiness'—very accurately in terms of wealth (see *Principles of the Civil Code*, part i. ch. vi.). Among objects desired, the welfare of fellow-workmen, and the success of the common work, must be included. Bentham's view of the legislator's aim does not differ from that of Plato and Aristotle, who are not commonly accused of 'hedonism,' namely, that it is to get people χαίρειν τε καὶ λυπεῖσθαι οἷς δεῖ, the οἷς δεῖ being determined by the test of τὸ κοινῇ συμφέρον in his system as in their systems. By means of this test τὰ φύσει ἡδέα are distinguished from τὰ μὴ φύσει τοιαῦτα—pursuits which take their place in the harmonious rhythm of the public life are distinguished from those which jar. It is incorrect, then, to say that 'utilitarianism excludes any test of pleasure but pleasure itself'; and J. S. Mill is fully entitled, *as a utilitarian*, to recognize a qualitative difference between pleasures, and bring pleasure to a test which is not pleasure, namely, to the judgment of the connoisseur—the man who has been educated to correspond as accurately as may be with the best social conditions. His judgment is not based on mere 'feeling,' but on 'consciousness of adaptation.' It does not prefer certain 'feelings,' but certain 'objects' of pursuit suitable to human life as understood and valued by the good man. Of course, no system of morals can get out of the circle—'Those are good things which the good man likes.'

The charge, then, of 'ethical hedonism'—of holding that pleasure *ought* to be our end—is disposed of, we think, by a broad view of what utilitarianism is as a phase of the national life. But, it is said, utilitarianism is tainted by 'psychological hedonism,' defined by the critics as the theory that 'the ultimate motive of every action can only be the imagination of one's own pleasure or pain.' The utilitarians, it is admitted, are good men, and have done good, but they do not see how inconsistent their theory is with their practice. "The heart is in the right place, but the brain is wanting." It seems to us that what is stigmatized as 'psychological hedonism' is really nothing more than the Aristotelian theory of voluntary action. According to this theory (adopted without qualification by Hobbes and Locke), voluntary actions are those which proceed from, or are caused immediately by, a principle *within* the man. Just as a man can only see with his own eyes, or walk with his own legs, so he can only act from his own likes and dislikes. But this does not mean that his motives are always 'selfish,' or that even when they are he is seeking the abstraction 'Pleasure,' and not 'the pleasant thing.' We think, then, that the charge of 'psychological hedonism' is founded on a mistake, and that the charge of 'ethical hedonism' is misplaced as laid to the account of the English utilitarians. It is indeed to the English utilitarians, along with Plato and Aristotle, that the idealists are chiefly indebted for their conception of 'self-realization in society.' By this conception Green balances what, unbalanced, would be a more thoroughgoing individualism or 'solipsism' than that with which Bentham is charged. As we have said, the true objection of the idealists to utilitarianism is that it is a merely secular system. It must not be forgotten, however, that Green's writings, while they derive their interest from their religious character, have given a considerable impetus to utilitarianism—no longer that of *laisser faire*, but of social endeavour.

Besides the idealists who belong to the group of which Green is the central figure, there are others, more or less in sympathy with them, who stand somewhat apart; of whom we may mention the following:—The late Dr Martineau, whose *Types of Ethical Theory* has done much to popularize the idealist point of view; Professor Campbell Fraser, whose long sympathetic study of Berkeley, as man and philosopher, has helped him to the doctrine, which he sets forth in his *Gifford Lectures* (*Philosophy of Theism*), and elsewhere, that Faith underlies Knowledge; the late Professor Wallace, whose luminous *Lectures and Essays on Natural Theology and Ethics*,—notably the Essay on *Hedonism*,—neglecting the commonplaces of current controversy, reach conclusions which idealist and utilitarian might well agree to accept; and Professor Andrew Seth (A. S. Pringle-Pattison), whose criticism (*Hegelianism and Personality*) of Green's Theism has been alluded to. Mr Bradley's ethical position, so far as one may judge from *Appearance and Reality*, also seems to differ from Green's.

Utilitarianism.

While English Ethics has thus been chiefly represented, during the last twenty-five years, by idealists and evolutionists,—by moralists whose main interest is religious and scientific respectively, political interest (interest in the Public Good as served by legislation, and by education of the private citizen),—the animating principle of utilitarianism, has shown distinct signs of revival. We have already mentioned Sidgwick's *Methods of Ethics* as a landmark in the history of English utilitarianism. The utilitarian revival has since been marked by the appearance of two important works, *Progressive Morality* by Dr Fowler, and *The Principles of Morals* by the late J. M. Wilson and Dr Fowler—the latter having had by far the larger share in the work. These books are notable for the skill with which the moral experience of the individual is probed and analysed, always with the view of suggesting lines on which character may be educated for the duties of life. The world changes, and a re-examination of the 'moral sentiments' has to be undertaken periodically in the history of communities. The time for such re-examination has come, and the work begun afresh by Sidgwick and Dr Fowler is likely to occupy more and more the attention of *moralists* as distinguished from anthropologists and religious teachers. We must add here, to prevent possible misunderstanding, that Green incidentally makes some valuable contributions to a practical psychology of the 'moral sentiments' in his discussion of the Greek and Christian 'virtues.' It may be further added that economists, in taking, as they now do, greater account of moral and political considerations, are contributing to the revised 'utilitarianism' of the day. The vogue which the economic term 'value' has lately obtained in Ethics is chiefly interesting as showing that professed moralists are now feeling themselves in some sort of touch with economists. Of course, the idea of 'value' is no novelty in Ethics; and we do not think that the elaboration lately given to it has added anything to what was, though somewhat differently expressed, already familiar to all students. The reader, however, can form his own judgment on this point after perusing such a work as Meinong's *Psychologisch-ethische Untersuchungen zur Werththeorie*.

We have confined ourselves entirely to English Ethics; and will only say, in conclusion, that foreign influences have not been noticeable during the last twenty-five years. English utilitarianism rests on its own bottom; evolutionary ethics is the outcome of the work of Darwin and Mr Spencer, and of such anthropologists as Professor Tylor; and idealism, though Kant and Hegel stimulated it at first, has, since Green set his mark on it, become practically independent of outside influence—indeed, appears now as a product peculiar to ourselves. It does not seem to have influenced foreign thought except in America. On the other hand, the influence of Darwin and Mr Spencer, as well as of the English anthropologists, has been felt throughout the world.

In addition to the works referred to in the article, a few others, published since 1878, may be mentioned as bearing directly or indirectly on the subject of Ethics:—W. Wundt. *Ethik*, 1886 (Eng. trans. by Titchener, Gulliver, and Washburn, 1897).—F. Paulsen. *Ethik*, 1889, 1893 (Eng. trans. by Thilly, 1899).—H. Höffding. *Psychologie*, 1882, 1892 (Eng. trans. by Lowndes, 1892).—G. Simmel. *Einleitung in die Moralwissenschaft*, 1892, 1893.—A. Fouillée. *Le mouvement idéaliste et la réaction contre la science positive*, 1896; *La Liberté et le déterminisme*, 3rd ed., 1890; *L'enseignement au point de vue national* (Eng. trans. by Greenstreet, 1892).—J. M. Guyau. *La morale Anglaise contemporaine* (*morale de l'utilité et de l'évolution*), 1879; *Education et hérédité*, 1889 (Eng. trans. by Greenstreet, with introduction by Stout, 1891); *Esquisse d'une morale sans obligation ni sanction*, 1885 (Engl. trans. by Kapteyn, 1898).—Leslie Stephen. *The English Utilitarians*, 1900.—W. James. *Principles of Psychology*, 1891; *The Will to Believe*, 1897.—J. Martineau. *A Study of Religion*, 1887.—A. J. Balfour. *The Foundations of Belief*, 1895.—E. Caird. *Gifford Lectures* (*The Evolution of Religion*), 1893.—J. Ward. *Gifford Lectures* (*Naturalism and Agnosticism*), 1899.—J. Royce. *Gifford Lectures* (*The World and the Individual*), 1900.—T. B. Strong. *Bampton Lectures* (*Christian Ethics*), 1896.—H. Sidgwick. The "Philosophy of T. H. Green," *Mind*, Jan. 1901.—In Ueberweg's *Gesch. der Phil.* part iii. vol. ii. (*Nach-Kantische Systeme u. Phil. der Gegenwart*), edited by M. Heinze (1897), exhaustive lists of books and review articles up to date will be found. (J. A. St.)

Etna, a borough of Allegheny county, Pa., U.S.A., on the Allegheny river, opposite Pittsburg, and on the Pennsylvania and the Pittsburg and Western Railways. Population (1890), 3767; (1900), 5384.

Eton, a parish and town in the Wycombe parliamentary division of Buckinghamshire, England, on the Thames opposite Windsor. The town is under an Urban District Council, the public offices connected with which were erected in 1891. Area of town, 147 acres. Population, exclusive of Eton College (1901), 3293. Area of parish, 783 acres. Population, 2955. Two new boarding-houses have been erected by the governing body of Eton College, and the portion of land between Slough and Eton, known as Agar's Plough, has been converted into playing fields. The teaching staff has been greatly increased, and new laboratories have been built for the teaching of science. The average number of pupils at the college in 1900 was 1027.

Eugénie, Empress.—Marie-Eugénie-Ignace-Augustine, daughter of Don Cipriano Guzman y Porto Carrero, Count of Teba, subsequently Count of Montijo, and Grandee of Spain, was born at Grenada on 5th May 1826. Her mother was a daughter of William Kirkpatrick, United States Consul at Malaga, a Scotsman by birth and an American by nationality. Her childhood was spent in Madrid, but after 1834 she lived with her mother and sister chiefly in Paris, where she was educated, like so many French girls of good family, in the Convent of the Sacré Cœur. When Louis Napoleon became President of the Republic she appeared frequently with her mother at the balls given by the Prince President at the Elysée, and it was here that she made the acquaintance of her future husband. In November 1852 mother and daughter were invited to Fontainebleau, and in the picturesque hunting parties the beautiful young Spaniard, who showed herself an expert horsewoman, was greatly admired by all present, and by the host in particular. Three weeks later, on 2nd December, the Empire was formally proclaimed, and during a series of fêtes at Compiègne, which lasted eleven days (19th to 30th December) the Emperor became more and more fascinated. On New Year's Eve, at a ball at the Tuileries, Mdlle de Montijo, who had necessarily excited much jealousy and hostility in the female world, had reason to complain that she had been insulted by the wife of an official personage. On hearing of it the Emperor said to her, "*Je vous vengerai*"; and within three days he made a formal proposal of marriage. In a speech from the Throne on 22nd January he formally announced his engagement, and justified what some people considered a mésalliance. "I have preferred," he said, "a woman whom I love and respect to a woman unknown to me, with whom an alliance would have had advantages mixed with sacrifices." Of her whom he had chosen he ventured to make a prediction: "Endowed with all the qualities of the soul, she will be the ornament of the throne, and in the day of danger she will become one of its courageous supports." The marriage was celebrated with great pomp at Notre Dame on 30th January 1853, and on 16th March 1856 the Empress gave birth to a son, who received the title of Prince Imperial. The Emperor's prediction regarding her was not belied by events. By her beauty, elegance, and charm of manner she contributed largely to the brilliancy of the Imperial régime, and when the end came, she was, as the official *Enquête* made by her enemies proved, one of the very few who showed calmness and courage in face of the rising tide of revolution. The Empress acted three times as Regent during the absence of the Emperor,—in 1859, 1865, and 1870,—and she was generally consulted on important questions, but the materials for estimating her political influence are not yet available. What can be said with tolerable certainty is that when the Emperor vacillated between two lines of policy, she generally urged on him the bolder course, that she deprecated everything tending to diminish the temporal power of the Papacy, and that she disapproved of the Emperor's liberal policy at the close of his reign. On the collapse of the Empire she fled to England, and settled with the Emperor and her son at Chislehurst. After the Emperor's death she removed to Farnborough, where she built a mausoleum to his memory. In 1879 her son was killed in the Zulu War, and in the following year she visited the spot and brought back the body, to be interred beside that of his father at Farnborough. Here, and in a villa she built at Cap Martin on the Riviera, she continued to live in retirement, following closely the course of events, but abstaining from all interference in French politics.

Euphrates (Greek, Εὐφράτης, from the Old Persian, *Ufrátu*; Babylonian, *Purat*, from the Sumerian, *Pura*, "the water"; Hebrew, *Prath*; Arab, *Frát* or *Furát*), the largest and most notable river of Western Asia. It may be divided into the upper, middle, and lower Euphrates, each division being distinguished by special physical features. The Upper Euphrates consists of two arms, which, rising on the Armenian plateau, and flowing west in long shallow valleys parallel to Mount Taurus, eventually unite and force their way southwards through that range to the lower level of Mesopotamia. The northern, and shorter arm, Frát or Kara Su (Armenian, *Ephrát* or *Yephrát*; Arab, *Nahr el-Furát*), so well known as the Euphrates in the West, from its having been the boundary of the Roman Empire, is regarded by Orientals as the main stream. It rises in the Domlu Dagh, north-north-east of Erzerúm, in a large circular pool (altitude, 8625 ft.), which is venerated by Armenians and Moslems, and flows south-west to the plain of Erzerúm (5750 ft.). Thence it continues through a narrow valley west-south-west to Erzingan (3900 ft.), receiving on its way the Ovajik Su (right), the Tuzla Su (left), and the Merjan and Chanduklu (right). Below Erzingan, the Frát flows south-west through a rocky gorge to Kemakh (*Kamacha*; Armenian, *Gamukh*), where it is crossed by a bridge and receives the Kumur Su (right). At Avshin it enters a cañon, with walls over 1000 ft. high, which extends to the bridge at Pingan, and lower down it is joined from the west by the Chalta Irmak (*Lycus*; Arab, *Lúkíya*), on which stands Divrik (*Tephrike*). Then, entering a deep gorge, with lofty rock-walls and magnificent scenery, it runs south-east to its junction with the Murad Su. The Frát, separated by the easy pass of Deve-boyún from the valley of the Araxes, marks the natural line of communication between Northern Persia and the West,—a route followed by the nomad Turks, Mongols, and Tatars on their way to the rich lands of Asia Minor. It is a rapid river of considerable volume, and below Erzingan is navigable, down stream, for rafts. The southern and longer arm, Murad Su (*Arsanias Fl.*; Armenian, *Aradzani*; Arab, *Nahr Arsanás*), rises south-west of Diadin, in the northern flank of the Ala Dagh (11,500 ft.), and flows west to the Alashgerd plain. Here it is joined by the Sharian Su from the west, and the two valleys form a great trough through which the caravan road from Erzerúm to Persia runs. The united stream breaks through the mountains to the south, and, receiving on its way the Patnotz Su (left) and the Khinis Su (right), flows south-west, west, and south, through the rich plain of Bulanik, to the plain of Músh. Here it is joined by the Kara Su (*Teleboas*), which, rising near Lake Van, runs past Músh and waters the plain. The river now runs west-south-west through a deep rocky gorge, in which it receives the Gunig Su (right), to Palu (cuneiform inscriptions); and continues through more open country to its junction with the Frát Su. About 10 miles east-north-east of Kharpút the Murad is joined by its principal tributary, the Peri Su, which drains the wild mountain district, Dersim, that lies in the loop between the two arms. The Murad Su is of greater volume than the Frát, but its valley below Músh is contracted and followed by no great road. Below the junction of the two arms the Euphrates flows south-west past the lead mines of Keban Maden, where it is 120 yards wide, and is crossed by a ferry (altitude, 2425 ft.), on the Sivas-Kharpút road. It then runs west, south, and east round the rock-mass of Musher Dagh, and receives (right) the Kuru Chai, down which the Sivas-Malatia road runs, and the Tokhma Su, from Gurun (*Gauraina*) and Derendeh. At the ferry on the Malatia-Kharpút road (cuneiform inscription) it flows eastwards in a valley about a quarter of a mile wide, but soon afterwards enters a remarkable gorge, and forces its way through Mount Taurus in a succession of rapids and cataracts. After running south-east through the grandest scenery, and closely approaching the source of the western Tigris, it turns south-west, and leaves the mountains a few miles above Samsát (*Samosata*, altitude 1500 ft.). At Samosata, the capital of the Seleucid Kings of Commagene, the Persian Royal Road, from Sardis to Susa, probably crossed the river. The general direction of the great gorges of the Euphrates, Pyramus, and Sarus seems to indicate that their formation was primarily due to the same terrestrial movements that produced the Jordan-Âraba depression to the south. The length of the Frát is about 275 miles; of the Murad, 415 miles; and of the Euphrates from the junction to Samsát, 115 miles.

In the middle division, which extends from Samsát to Hit, the Euphrates runs through an open, treeless, and sparsely peopled country, in a valley a few miles wide, which it has eroded in the rocky surface. The valley bed is more or less covered with alluvial soil, and cultivated in places by artificial irrigation. Its rocky sides, which sometimes closely approach the river, as at Helebí-Jelebí, are composed of gypsum, sandstone, and conglomerates; and beyond them, on both banks, is the steppe-like desert, covered in spring with verdure. The right bank, or esh-Shám, is occupied by the ʿAnazeh Arabs, and the left, or el-Jezíre, by the great Shammar tribe. Below Samsát the river runs south-west to Rúm Kaleh (Armenian, *Hrhomgla*), and then south past Khalfat (ferry) to Birejik, where it is only 110 miles from the Mediterranean. From Birejik (*Apamea-Zeugma*, altitude 1170 ft.), where the high road from east to west crossed it, the river runs sluggishly southwards, over a sandy or pebbly bed, past Jerablús (*Europus, Carchemish*), and the confluence of the Sajúr (right), to Meskine, the highest point reached by steamers. At old Meskine, now some distance from the river, was Barbalissus (Arab, *Balis*), once the port of Syria on the Euphrates. Eight miles below Meskine, near Kalát Dibse, was Thapsacus (Tiphsah of 1 Kings iv. 24), the most important passage of the Middle *Euphrates*, and here the river turns east. Lower down is Rakka (*Nicephorium*), at the junction of the Belikh (*Bilechas*), which flows south through the Biblical Aram Naharaim from Urfa (*Edessa*) and Harrán (*Carrhae*). The direction is now south-east between banks green with willow and tamarisk, and before reaching Deir ez-Zor the river meets the first groves of date palms, lemons, and oranges, and encloses several islands. Below Deir the bed is rocky, and the river is joined near Kirkisíeh (*Circisium*; Assyrian, *Sirki*) by the Khabúr (*Chaboras*), which rises in the Karaja Dagh, and with its tributary the Jaghjagh (*Mygdonius*; Arab, *Hirmás*) flows south through the land of Gozan. In early Arab times a canal or river, eth-Tharthar, is said to have run from the Hirmás, through Jebel Sinjar, and past el-Hadhr (*Hatrae*), to the Tigris at Tekrít. Below the Khabúr the river has no affluents. From Werdi to Ana (*Anatho*) it runs east over a rocky bed, passing Deír el-Kaim (Gordian's Tomb (?) and the Perso-Roman boundary); and then south-east to Hit. Between Ana and Hit it is thickly studded with islands, on which are the ruins of several castles. The Middle Euphrates was important as a boundary in early times. It separated Assyria from the Khíta or Hittites; was the limit of the Jewish kingdom in its widest extent; divided the eastern from the western satrapies of Persia (Ezra iv. 17; Neh. ii. 7); and was at several periods the boundary of the Roman Empire. Until the advent of the nomads from Central Asia, there were many flourishing cities on its banks; but the riverain population is now sparse, and the only towns are Samsát, Birejik, Deir, Ana, and Hit. From Samsát to Hit the river is about 720 miles.

Hit (*Is* or *Ihi*), noted for its bitumen springs, stands at the head of the alluvial deposit, and marks the commencement of the Lower Euphrates. Thence the river flows south-east and south-south-east, to its junction with the Tigris at Korna, through an unbroken plain with no natural hill, and, except at el-Haswa, above Hillah, with no trace of rock. In the latitude of Baghdad the Euphrates and Tigris closely approach each other, and then, widening out, enclose the plain of Babylonia (Arab, *Sawád*). In early times great irrigating canals distributed the waters over the plain, and made it one of the richest countries of the East. The river then formed, as it does now, large salt marshes (*Paludes Chaldaici*; Arab, *el-Batiha*), before meeting the Tigris in the tidal estuary, Shatt el-Arab, which, in the time of the Khalifate, reached the open sea about 20 miles above the present shore-line. The distance from Hit to the Persian Gulf is about 550 miles. The ancient system of canalization described by Sir Henry Rawlinson in the 9th edition of this work (viii. 670) was inherited, from the Persians, by the Arabs, who long maintained it in working order (Ibn Serapion, translated by Guy le Strange in *Journal Royal Asiatic Society*, 1895, 1897). Its remote origin may be inferred from the excavations at Abu Habba, Tello, Niffer, &c., which have shown that those sites were occupied by towns 5000–4000 B.C. The astonishing fertility, and consequent prosperity, of the country watered by the Euphrates, its tributaries, and its canals is noticed by ancient writers. Its decline dates from the appearance of the Turkish nomads in the 11th century; its ruin was completed by the Shammar Arabs in the 17th century. If the ancient system of irrigation were restored, sufficient grain could be grown to alter the conditions of the wheat supply of the world.

The length of the Euphrates from its source near Diadin to the sea is about 1800 miles, and its fall during the last 1200 miles is about 10 inches per mile. The river begins to rise in the end of March, and attains its greatest height between the 21st and 28th May. It is lowest in November, and rocks, shallows, and the remains of old dams then render it unnavigable. During high water small steamers ascend to Meskine, but most of the navigation is by native rafts (*Kelek*). Boats, built in Syrian ports, were placed on the Euphrates by Sennacherib and Alexander; and the river was formerly a frequented route followed by merchants on their way from the Mediterranean to Babylon (*Herodotus* i. 185). In its present state it is unsuitable for continuous steam navigation, but the advantageous geographical position of its valley has originated schemes for connecting the Mediterranean and the Persian Gulf by railway as an alternative means of communication with India. All these schemes have fallen through, hitherto, on the money question, or on the unwillingness of the Turkish Government to sanction any line that was not connected directly with Constantinople. In 1872 and 1882 a line from Suedia, near the mouth of the Orontes, by Aleppo, to Meskine, and thence by the Euphrates to Basra, found favour with Committees of the House of Commons. Other schemes were for a line from Tripolis, on the Syrian coast, across the desert to Tekrít on the Tigris, and thence to Baghdad and Basra; from Alexandretta, by Aleppo, to Meskine; and an extension of the Mersina–Tarsus–Adana Railway to Aintab and Birejik. In 1898 Count Kapnist, a Russian subject, applied for a concession to construct a line from Tripolis to Hit, and thence along the Euphrates valley to Basra, and Koweit on the Persian Gulf, with branches to Baghdad and Kerbela. In the same year the scheme of a British syndicate to extend the Anatolian Railway from Konia, by Adana, Aleppo (with a branch to Alexandretta), and the valley of the Euphrates, to Hit, and thence by Baghdad and Basra to the Persian Gulf between Fao and Koweit, failed through the opposition of the Anatolian Railway Company, which is in German hands. This company has under consideration an extension of its Anatolian lines to Baghdad and Basra, either from Angora, by Kaisaríeh, Diarbekr, and Mosul, or from Konia by Marash, Aleppo, and Hit, but the preliminary surveys had not been completed in 1901.

CHESNEY. *Euphrates Expedition.*—AINSWORTH. *Personal Narrative of the Euphrates Expedition.*—LAYARD. *Nineveh and Babylon.*—LOFTUS. *Chaldæa and Susiana.*—RAWLINSON. *Herodotus* i. essay ix.—BLUNT. *Bedouin Tribes of the Euphrates.*—PETERS. *Nippur*, 1897.—SACHAU. *Am Euphrat und Tigris*, 1900.—VON OPPENHEIM. *Vom Mittelmeer zum Persischen Golf*, 1900.—MURRAY. *Handbook to Asia Minor, &c.*, section iii.—GUY LE STRANGE. *Bagdad under the Abbasid Caliphate*, 1901.

(C. W. W.)

Eure, a department in Northern France, watered by the Seine and the Eure.

Area, 2331 square miles. The population had dropped to 358,829 in 1886, and in 1901 counted only 331,181. Births in 1899, 6598, of which 697 illegitimate; deaths, 8108; marriages, 2477. The schools in 1896 numbered 855, with 42,000 pupils, and the illiterate formed 7 per cent. of the population. Evreux, the capital, has 17,000 inhabitants. The area under cultivation in 1896 amounted to 1,383,840 acres, 872,313 acres of which were plough-land. The wheat crop of 1899 returned a value of £1,231,000; mangold-wurzel, £140,000; the grass lands, including the natural pastures, £780,000; cider-apples, £245,000. Of live-stock, Eure had, in 1899, 48,060 horses, 6450 asses, 133,250 cattle, 286,880 sheep, and 42,820 pigs. Though without either coal or iron, the industry in metals produced in 1898 nearly £45,000 in value. Louviers manufactures cloth of esteemed quality; Evreux and Gisors, yarn and cotton stuffs.

Eure-et-Loir, a department in Northern France, watered by the Eure.

Area, 2293 square miles. The population has decreased from 283,719 in 1886 to 274,862 in 1901. Births in 1899, 5742, of which 444 illegitimate; deaths, 6311; marriages, 2100. There were in 1896 731 primary schools, with 40,000 pupils; 2 per cent. of the population is illiterate. Out of 1,388,782 acres of cultivated land in 1896, 1,146,609 acres were arable, 69,190 acres were natural pastures, and 49,420 acres were woods and forests. The wheat crop of 1899 amounted to the value of £1,903,000; rye, £80,000; barley, £227,000; oats, £1,170,000; mangold-wurzel, £153,000; the natural pastures and grass lands, £650,000; beetroot, £275,000. The live-stock of 1899 included 44,330 horses, 102,990 cattle, 577,260 sheep, and 28,180 pigs. Agriculture is the only forward industry in this department, which forms one of the granaries of the basin of the Seine. The production of alcohol in 1898 exceeded 70,000 gallons. Chartres, the capital, counts 23,000 inhabitants.

Eureka, capital of Humboldt county, California, U.S.A., on the south shore of Humboldt Bay, and connected with San Francisco and Portland by steamship lines. Its site is level and the plan of its streets regular. It is in the celebrated coast redwood belt, and is the principal point for the manufacture and shipment of redwood lumber. Several short lumber railways run from this city and from Arcata, across the bay, into the forests, and bring lumber to the mills, most of which are in or near Eureka. The operations, both of lumbering and of milling the timber, are carried on here on a scale nowhere else to be seen. Population (1880), 2639; (1900), 7327.

Eureka Springs, capital of Carroll county, Arkansas, U.S.A., in the Ozark Hills, at an altitude of 1800 feet. It is chiefly noted for its medicinal springs, which attract a large summer population. Population (1880), 3984; (1900), 3572.

EUROPE.

I. Geography and Statistics.

On the subject of the boundaries of Europe there is still divergence of opinion. While some authorities take the line of the Caucasus as the boundary in the south-east, others take the line of the Manich depression, between the upper end of the Sea of Azov and the Caspian Sea, nearly parallel to the Caucasus. Various limits are assigned to the continent on the east. Officially the crest of the Caucasus and that of the Urals are regarded in Russia as the boundaries between Europe and Asia on the south-east and east respectively,[1] although in neither case does the boundary correspond with the great administrative divisions, and in the Urals it is impossible to mark out any continuous crest. Reclus, without attempting to assign any precise position to the boundary-line between the two continents, makes it run through the relatively low and partly depressed area north of the Caucasus and east of the Urals. The Manich depression, marking the lowest line of this area to the north of the Caucasus, has been taken as the boundary of Europe on the south-east by Wagner in his edition of Guthe's *Lehrbuch der Geographie*,[2] and the same limit is adopted in Kirchhoff's *Länderkunde des Erdteils Europa*[3] and Stanford's *Compendium of Geography and Travel*. In favour of this limit much weight ought, we think, to be given to the consideration put forward by Wagner, that from time immemorial the valleys on both sides of the Caucasus have formed a refuge for Asiatic peoples, especially when it is borne in mind that this contention is reinforced by the circumstance that the steppes to the north of the Caucasus must interpose a belt of almost unpeopled territory between the more condensed populations belonging undoubtedly to Asia and Europe respectively. Continuity of population would be an argument in favour of assigning the whole of the Urals to Europe, but here the absence of any break in such continuity on the east side makes it more difficult to fix any boundary-line outside of that system. Hence on this side it is perhaps reasonable to attach greater importance to the fact that the Urals form a boundary not only orographically, but to some extent also in respect of climate and vegetation,[4] and hence to take a line following the crest of the different sections of that system as the eastern limit between the two continents.[5] Obviously, however, any eventual agreement among geographers on this head must be more or less arbitrary and conventional, and provisionally it is advisable to give the area of the continent within different limits.

Boundaries.

The following calculations in English square miles (round numbers) of the area of Europe, within different limits, are given in Behm and Wagner's *Bevölkerung der Erde*, No. viii. (Gotha, Justus Perthes, 1891), p. 53:—

Extent.

Europe, within the narrowest physical limits (to the crest of the Urals and the Manich depression, and including the Sea of Azov, but excluding the Caspian Steppe, Iceland, Novaya Zemlya, Spitsbergen, and Bear Island, 3,570,000 square miles. The same, with the addition of the Caspian Steppe up to the Ural River and the Caspian Sea, 3,687,750 square miles. The same, with the addition of the area between the Manich depression and the Caucasus, 3,790,500 square miles. The same, with the addition of territories east of the Ural Mountains, the portion of the Caspian Steppe east of the Ural River as far as the Emba, and the southern slopes of the Caucasus, 3,988,500 square miles. The same, with Iceland, Novaya Zemlya, Spitsbergen, and Bear Island, 4,093,000 square miles.

In all these calculations the Marmora Islands, Canary Islands, Madeira, and even the Azores, are left out of account.

The estimate of the length of the coast-line in the 9th edition of the *Ency. Brit.*, 19,820 miles (Reuschle, 1869),

---

[1] At the summit of each of the Trans-Ural railways (Perm–Tyumen and Ufa–Chelyabinsk) and that of the road across the Caucasus from Vladikavkaz to Tiflis, sign-posts, with the name Europe on one side, Asia on the other, mark this boundary.

[2] Fifth edition, vol. ii. pp. 24–25.

[3] Pt. i. pp. 11–12.

[4] Griesbach, on the strength of Middendorff's observations, remarks that, in addition to European fruit trees, oak, maples, elms, ashes, and the black alder do not cross the Urals, while the lime tree is reduced to the size of a shrub (*La Végétation du Globe*, translated by Tchihatchef, i. p. 181).

[5] On the history of the boundary between Asia and Europe, see F. G. Hahn in the *Mitteilungen des Vereins für Erdkunde zu Leipzig*, 1881, pp. 83–104. Hahn, on the ground that true mountain systems must be regarded as forming geographical units, pronounces against the practice of making "natural boundaries" run along mountain crests, and assigns the whole of the Caucasus region to Europe as all belonging to such a system, but orographically quite different from the Armenian plateau (p. 103). But surely it is no less different from the European plain.

is one that does not take into account minor indentations. Reclus' estimate, including the more important indentations, brings the coast-line up to 26,700 miles, and that of Strelbitsky up to 47,790 miles (smaller islands not included), or 1 mile of coast for about 75 square miles of area. It may be pointed out, however, that the commercial value of this relation is diminished not merely by the absence in many parts of natural harbours, but in many other parts by the absence of natural facilities for communication between such harbours and a productive interior—in other words, by the absence of a hinterland.

Coast-line.

Several new estimates have been made of the mean elevation of the continent. The following list gives the results of all the estimates that have hitherto been made:—Humboldt, 675 ft.; Leipoldt,[1] 975 ft.; De Lapparent,[2] 960 ft.; Murray,[3] 939 ft.; Supan,[4] 950 ft.; v. Tillo,[5] 1040 ft.; Heiderich,[6] 1230 ft.; Penck,[7] 1085 ft. The exceptionally high estimate of Heiderich is due to the fact that by him Transcaucasia and the islands of Novaya Zemlya, Spitsbergen, and Iceland are reckoned as included in Europe.

Relief.

Since the publication of the ninth edition an estimate has been made by Strelbitsky of the length and of the area of the basins of all the principal rivers of Europe. In the following table all the estimates given without any special authority are based on Strelbitsky's figures, but it should be mentioned that the estimates of length made by him evidently do not take into account minor windings, and are therefore generally less than those given by others. The authorities are separately cited for the originals of all other figures given in the table.

Rivers.

Name of River.	Length in English Miles.		Area of Basin in Square Miles.
	Strelbitsky.	Other Authorities.	Strelbitsky.
Volga	1977*	2107†	563,300
Danube	1644	...	315,435
Ural	1446	1477†	96,350
Dnieper (Dnyepr)	1064	1328†	203,460
Kama	984	1115†	202,615
Don (Russia)	980	1123†	166,125
Pechora	915	1024†	127,225
Rhine	709	...	63,265
Oka	706	914†	93,205
Dniester (Dnyestr)	646	835†	29,675
Elbe	612	...	55,340
Vistula	596	646†	73,905
Vyatka	596	680†	50,555
Tagus	566	...	31,865‡
Theiss (Tisza)	550	...	59,350
Loire	543	...	46,755
Save	535	...	37,595
Meuse	530	...	12,740
Mezen	496	507†	30,410
Donets	487	613†	37,890
Douro	485	...	36,705
Düna (W. Dvina)	470	576†	32,975
Ebro	470	...	38,580‡
Rhone	447	...	38,180
Desna	438	590†	33,535
Niemen (Nyeman)	437	537†	34,965
Drave	434	...	15,745
Bug (Southern)	428	477†	26,225
Seine	425	...	30,030
Oder	424	...	17,150
Kuban	405	509†	21,490
Khoper	387	563†	23,120
Maros	390	...	16,975
Pripet	378	404†	46,805
Guadalquivir	374	...	21,580‡
Pruth (Prutŭ)	368	503†	10,330
Northern Dvina	358	447†	141,075
Weser-Werra	355	...	19,925
Po	354	...	28,920‡
Garonne-Gironde	342	...	32,745
Vetluga	328	464†	14,325
Pinega	328	407†	17,425
Glommen	326	352§	15,930
Bug (Western)	318	450†	22,460
Guadiana	316	...	25,300‡
Aluta (Alt, Oltŭ)	308	...	9,095
Mosel	300	...	10,950
Main	300	...	10,600
Maritsa	272	...	20,790
Jucar	270	...	7,620‡
Mologa	268	338†	15,005
Torneå	268	...	13,045
Inn	268	...	9,825
Saône	268	...	8,295
Moldau	255	267§	10,860
Moksha	249	371†	19,090
Ljusna-elf	243	...	7,700
Mur	242	...	5,200
Morava, Servian	235	...	15,715
Klar-elf	224	...	4,520
Voronezh	218	305†	7,760
Berezina	218	285†	9,295
Saale	215	...	8,970
Onega	212	245†	22,910
Vág (Waag)	212	...	6,245
Dema	209	275†	4,830
San	203	444†	6,135
Moskva	189	305†	5,910
Western Manich	176	295†	37,820
Klyezma	159	394†	15,200

* The equivalent of the figures given in *Superficie de l'Europe*. A later measurement by Strelbitsky yielded a result equal to 2215 English miles.

† General v. Tillo, in *Transactions* (*Izvestiya*) *Imp. Rus. Geog. Soc.* vol. xix. (1883), pp. 160-161.

‡ Dr Al. Bludau in *Petermanns Mitteilungen*, 1898, pp. 185-187, has given new calculations of the areas of the basins of certain European rivers, namely, the Tagus, 31,250 sq. m.; Ebro, 32,810 sq. m.; Guadalquivir, 21,620 sq. m.; Po, 28,800 sq. m.; Guadiana, 25,810 sq. m.; and Jucar, 8245 sq. m.

§ St Martin, *Dict. de Géog. Univ.*

The observations on the temperature of European rivers have been collected and discussed by Dr Adolf E. Forster.[8] He finds that the dominant factor in determining that temperature is the temperature of the air above, but that rivers are divisible into four groups with respect to the relation between these temperatures at different seasons of the year. These groups are rivers flowing from glaciers, in which the temperature is warmer than the air in winter, colder in summer; rivers flowing from lakes, characterized by peculiarly high winter temperatures, in consequence of which the mean temperature for the year is always above that of the air; rivers flowing from springs, which, at least near their source, are more rapidly cooled by low than warmed by high air temperatures; and rivers of the plains, which have a higher mean temperature than the air in all months of the year.

River temperatures.

[1] *Die mittlere Höhe Europas.* Plauen, 1874.
[2] *Traité de Géologie*, Paris, 1883. [3] *Scot. Geog. Mag.*, 1888, p. 23.
[4] *Petermanns Mitteilungen*, 1889, p. 17.
[5] *Trans.* (*Izvestiya*) *Imp. Rus. Geog. Soc.*, 1889, p. 113.
[6] *Die mittleren Erhebungsverhältnisse der Erdoberfläche*, pt. i., in Penck's *Geographische Abhandlungen*, vol. v., Vienna, 1891.
[7] *Morphologie der Erdoberfläche*, vol. i.

[8] Penck's *Geographische Abhandlungen*, vol. v. pt. iv., Vienna, 1894; noticed in *Geog. Journ.* vol. vi. p. 264.

Lakes.

Great attention has recently been given to limnology. For many European lakes, especially the smaller ones, estimates have been made of the mean depth and the volume. A list of all the European lakes for which the altitude, extent, and greatest depth could be ascertained, compiled by Dr K. Peucker, is published in the *Geog. Zeitschrift*, 1896, pp. 606–16, where estimates of the mean depth and the volume are also given where procurable. The following table, comprising only the larger lakes, is mainly based on this list, where the original authorities are mentioned. The figures entered in the following table not taken from this list are after Strelbitsky or the *Géog. Universelle* of V. de St Martin:—

Name of Lake and Country.	Height above Sea.	Area.	Greatest Depth.	Mean Depth.	Volume. Millions of Cubic Feet.
	Feet.	Sq. miles.	Feet.	Feet.	
Ladoga, Russia	15	7004	730	...	...
Onega, ,,	115	3765	About 1200	...	...
Wener, Sweden	145	2409	280	...	...
Chudskoye or Peipus, Russia	100	1357*	90	...	...
Wetter, Sweden	290	758	415	...	...
Saima, Russia	255	680*	185	...	...
Päjäne, ,,	255	608*	...	...	...
Enare, ,,	490	549	...	...	...
Segozero, ,,	...	481	140	...	...
Byeloye Ozero, Russia	400	434	35	...	...
Pielis, Russia	305	422	...	...	...
Topozero ,,	...	411	...	...	...
Uleå, ,,	375	380	60	...	...
Ilmen, ,,	107	358	...	...	...
Vigozero, ,,	...	332	...	...	...
Imandra, ,,	...	329	...	...	...
Balaton, Hungary	350	266	13	...	...
Geneva, France and Switzerland	1220	225	1015	500	3,140,000
Kovdozero, Russia	...	225	...	...	...
Star Sjö, Sweden	290-305	216	...	...	...
Constance, Germany and Switzerland	1295	208	825	295	1,711,000
Hjelmar, Sweden	...	...	...	...	...
Luleå-Vattnen, Sweden	...	178	...	...	...
Neagh, Ireland	48	153	113	...	...
Kubinskoye, Russia	...	152	...	...	...
Mjösen, Norway	395	152	1485	...	...
Garda, Italy and Austria	215	143	1135	445	1,757,000
Torneå, Sweden	1140	139	...	...	...
Neusiedler-see, Hungary	370	137	13	...	...
Scutari, Turkey	20	About 130	33	12½	45,900
Siljan, Russia	...	123	...	...	...
Virzjärvi, ,,	115	107	24	...	...
Seliger, ,,	825	100	105	...	...
Stor Afvan, Sweden	1370	92	925	...	...
Yalpukh, Russia	...	89	...	...	...
Neuchâtel, Switzerland	1415	85	500	210	500,000
Ylikitkakarvi, Russia	680	85	30	...	...
Maggiore, Italy and Switzerland	645	82	1220	575	1,316,000
Corrib, Ireland	30	71	152	...	...
Como, Italy	655	56	1360	...	...

* Including L. Pskov as well as the connecting arm known as Teploye.

Of engineering works carried out on European lakes since the publication of the article on Europe in the ninth edition, the most important are those for the draining of Lake Copais in Bœotia, completed in 1893, by means of which nearly 100 square miles have been added to the cultivable area of Greece; those by which Lake Fucino or Celano, in the Abruzzi, was completely drained in 1876, about 60 square miles having thus been reclaimed since the beginning of the operations in 1854; and those by which Lake Trasimeno, in Umbria, was reduced in size, and an area of about 8 square miles of land (including malarial swamp) reclaimed in 1898.

Geology.

The most important event in connexion with the geology of Europe as a whole in recent years has been the commencement of the publication of *The International Geological Map of Europe* on the scale of 1 : 1,500,000. It is to be completed in forty-nine sheets, of which eighteen had in October 1901 been published.

In the way of geological research and theoretical investigation an immense amount of detailed work has of course been done in every part of the continent, but the most extensive work has been in connexion with the Ice Age. It is enough to mention here that the chief questions now under discussion are the number of times that glacial phenomena were repeated in Europe, and the origin of the boulder-clay. While most glacialists appear to consider that there were three periods of ice expansion over parts of Europe, Professor Geikie believes that as many as six periods of glacial expansion and five inter-glacial periods can be distinguished.[1] With regard to boulder-clay, while the great majority of glacialists adhere to the belief that it was formed and transported under land-ice, there are still upholders of the theory that it is of subaqueous origin, and some adherents of the former view admit that in places it must have been finally deposited in a glacial lake.

Minerals.

With regard to the mineral production of Europe, the most notable fact to record is the relatively lower place taken by the United Kingdom in the production of the two minerals of the greatest industrial importance—coal and iron. Here it is enough to state the main results. In the production of coal the United Kingdom is indeed still far ahead of all other European countries, but notwithstanding the fact that the British export of coal has been increasing much more rapidly than the production, it has not been able to keep pace with Germany and Russia in the rate of increase of production. In 1878 the production of coal in the German Empire was only about 34 per cent. of that of the United Kingdom, but in 1900 it had grown to about 49 per cent. This, too, was exclusive of lignite, the production of which in Germany is increasing still more rapidly. It was equal to little more than one-fourth of the coal production in 1878, but more than one-third in 1900. The Russian coal production is still small, but it is increasing more rapidly than that of any other European country. While in 1878 it was little more than 2 per cent. of that of the United Kingdom, in 1900 the corresponding ratio was slightly above 7 per cent. In the production of iron ores the decline in the position of the United Kingdom is much more marked. The production reached a maximum in 1882 (18,032,000 tons), and since then it has sunk in one year (1893) as low as 11,200,000 tons, while, on the other hand, there has been a rapid increase in the production of such ores in the German Zollverein (including Luxemburg), Spain, Sweden, Russia, and Greece. In the total amount of production the United Kingdom now takes the second place. While in 1878 the production of iron ores in the German Zollverein was little more than a third of that in the United Kingdom, it has since 1892 regularly exceeded the British production.

The changes that have taken place in the production of the minor minerals may be seen by comparing the following table,[2] relating to the year 1898, with the corresponding table in the ninth edition:—

	Gold.	Silver.	Quicksilver Ore.	Tin Ore.
Austria	71 kilos.	40,305 kilos.	88,519 m. t.	13 m. t.
German Empire	2847 ,,	480,578 ,,	...	51
Hungary	2768 ,,	18,799 ,,	55 ,,	...
Norway (1897)	...	5,372 ,,	...	...
Portugal	6·8 ,,	119·5 ,,	...	102 ,
Spain	...	...	31,361 ,,	...
United Kingdom	395 oz.	211,403 oz.	...	7,498 ,,

Kilos. = kilograms. M. t. = metric tons.

[1] J. Geikie, *The Great Ice Age*, 3rd ed., London, 1894.

[2] Based on *Mines and Quarries: General Report and Statistics for* 1898, pt. iv. (Cd. 112), 1900.

	Copper Ore.	Lead Ore.	Zinc Ore.	Manganese Ore.
Austria . . .	6,791 m. t.	14,362 m. t.	27,395 m. t.	6,132 m. t.
Belgium . . .	...	133 ,,	11,475 ,,	16,440 ,,
Bosnia-Herzegovina	4,323 ,,	...	10 ,,	5,319 ,,
France . . .	332 ,,	23,342 ,,	85,550 ,,	31,935 ,,
German Empire .	702,781 ,,	151,601 ,,	641,706 ,,	43,354 ,,
Greece . . .	...	...	32,520 ,,	14,097 ,,
Hungary . . .	428 ,,	4,721 ,,	55 ,,	8,055 ,,
Italy	95,128 ,,	34,180 ,,	132,099 ,,	3,002 ,,
Norway (1897) . .	27,606 ,,	...	908 ,,	...
Portugal . . .	290 ,,	3,242 ,,	...	907 ,,
Spain . . .	2,973 ,,	394,540 ,,	99,836 ,,	102,228 ,,
Sweden . . .	23,335 ,,	6,743 ,,	61,627 ,,	2,721 ,,
United Kingdom .	9,145 ,,	33,514 ,,	23,930 ,,	...

M. t. = metric tons.

Climate.

The period since 1878 has been peculiarly rich in important papers on the subject of the climate of the continent. It must suffice to state here compendiously the nature of their subjects, and to refer the reader for their titles to the bibliography at the end of this article, where they are enumerated together. It may be added that the maps illustrating the more important of these papers are all either reproduced in the *Atlas of Meteorology* by Bartholomew and Herbertson (Westminster, 1899), or represented there by new maps based on a wider range of material. The temperature of the continent has been illustrated by Dr Supan in an interesting series of maps based on actual observations not reduced to sea-level, and showing the duration in months of the periods within which the mean daily temperature lies within certain ranges (at or below 32° F.; 50°–68° F.; above 68° F.).[1] Under this head may be mentioned also Mr Dickson's paper on the sea temperatures round the British Isles,[2] inasmuch as it is of wider interest than its immediate subject indicates, throwing new light on the nature of the influence of the Gulf Stream and the Gulf Stream Drift.

The map accompanying König's paper on the duration of sunshine[3] shows on the whole, outside of the Mediterranean peninsulas, an increase from north-west to south-east (Orkney Is., 1145 hours = 26 per cent. of the total possible; Sulina, 2411 h. = 55 per cent.). In the Mediterranean peninsulas the duration is everywhere great—greatest, so far as the records go, at Madrid, 2908 h. = 66 per cent. Dr P. Elfert's[4] map illustrating cloud-distribution in Central Europe embraces the region from Denmark to the basin of the Arno, and from the confluence of the Loire and Allier to the mouths of the Danube.

The seasonal distribution of rainfall in Europe has been illustrated by Dr Supan in four maps[5] showing the percentage of the total rainfall of the year occurring in spring, summer, autumn, and winter respectively.

Since 1893 M. Alf. Angot has been publishing in the *Annales du Bureau Central Météor. de France* a series of memoirs in which the rainfall observations of Europe for the thirty years 1861–90 are recorded and discussed. The first paper (1893, B, pp. 157–194) deals with the Iberian Peninsula, the second (1895, B, pp. 155–192) with Western Europe (from about 43° to 58° N. and as far east as about 19°–21° E.). Both papers are accompanied by maps showing by six tints the mean rainfall for each month as well as for the entire year; and that on Western Europe, by maps extending in the west as far south as Avila, the proportion of the rainfall occurring during the winter, spring, autumn, and summer months respectively.

Mention should here be made also of Brückner's remarkable treatise on the variations of climate in time. Though it deals with such variations over the entire land-surface of the globe, a large proportion of the data are derived from Europe, for which continent, accordingly, it furnishes a great number of particulars with regard to secular variations in temperature, rainfall, the date of the vintage, the frequency of cold winters, the level of rivers and lakes, the duration of the ice-free period of rivers (in this case all Russian), and other matters. Those relating to the date of the vintage are of peculiar interest. They apply to 29 stations in France, South-West Germany, and Switzerland, and for one station (Dijon) go back with few breaks to the year 1391; and as the variations of climate of which they give an indication correspond precisely to the indications derived from temperature and rainfall in those periods in which we have corresponding data for these meteorological elements, they may be taken as warranting conclusions with regard to these points even for periods for which direct data are wanting. A period of early vintages corresponds to one of comparatively scanty rains and high temperatures. It is accordingly interesting to note that the data referred to indicate, on the whole, for Dijon an earlier vintage for the average of all periods of five years down to 1435 than for the average of the periods of the same length from 1816–80; but that the figures generally show no regular retardation from period to period, but more or less regular oscillations, differing in their higher and lower limits in different periods of long duration. (See particularly pp. 261–267 and the chart at the end of the treatise cited.)

Races.

An enormous amount of investigation with regard to this subject has been carried on in recent years. These labours have chiefly consisted in the study of the physical type of different countries or districts, but it is not necessary to consider in detail the results arrived at. It should, however, be pointed out that the idea of an Aryan race may be regarded as definitely abandoned. One cannot even speak with assurance of the diffusion of an Aryan civilization. It is at least not certain that the civilization that was spread by the migration of peoples speaking Aryan tongues originated amongst and remained for a time peculiar to such peoples. The utmost that can be said is that the Aryan languages must in their earliest forms have spread from some geographical centre. That centre, however, is no longer sought for in Asia, but in some part of Europe, so that we can no longer speak of any detachment of Aryan-speaking peoples entering Europe.

The most important works, summarizing the labours of a host of specialists on the races of Europe, are those of Ripley[6] and Deniker.[6] Founding upon a great multitude of data that have been collected with regard to the form of the head, face, and nose, height, and colour of the hair and eyes, most of the leading anthropologists seem to have come to the conclusion that there are three great racial types variously and intricately intermingled in Europe. As described and named by Ripley, these are: (1) the Teutonic, characterized by long head and face and narrow aquiline nose, high stature, very light hair, and blue eyes; (2) the Alpine, characterized by round head, broad face, variable rather broad heavy nose, medium height and "stocky" frame, light chestnut hair, and hazel grey eyes; and (3) the Mediterranean, characterized by long head and face, rather broad nose, medium stature and slender build, dark brown or black hair, and dark eyes. The Teutonic race is entirely confined to North-Western Europe, and embraces some groups speaking Celtic languages. It is believed by Ripley to have been differentiated in this continent, and to have originally been one with the other

[1] *Petermanns Mitteilungen*, 1887, Pl. 10 (text, pp. 165–172).
[2] *Quart. Jour. of the Roy. Meteor. Soc.* vol. xxv. No. 112.
[3] *Nova Acta Leop. Karol. d. Deutschen Akad. d. Naturforscher*, vol. lxvii. No. 3 (Halle, 1896).
[4] *Petermanns Mitteil.* 1890, Pl. 11 (text, pp. 137–145).
[5] *Petermanns Mitteil.*, 1890, Pl. 21 (text, pp. 296–297).

[6] See Bibliography at the end of the article.

long-headed race, sometimes known as the Iberian, and to the Italians as the Ligurian race, which "prevails everywhere south of the Pyrenees, along the southern coast of France, and in Southern Italy, including Sicily and Sardinia," and which extends beyond the confines of Europe into Africa. The Alpine race is geographically intermediate between these two, having its centre in the Alps, while in Western Europe it is spread most widely over the more elevated regions, and in Eastern Europe "becomes less pure in proportion as we go east from the Carpathians across the great plains of European Russia." This last race, which is most persistently characterized by the shape of the head, is regarded by Ripley as an intrusive Asiatic element which once advanced as a wedge amongst the earlier long-headed population as far as Brittany, where it still survives in relative purity, and even into Great Britain, though not Ireland, but afterwards retired and contracted its area before an advance of the long-headed races. Deniker, basing his classification on essentially the same data as Ripley and others, while agreeing with them almost entirely with regard to the distribution of the three main traits (cephalic index, colour of hair and eyes, and stature) on which anthropologists rely, yet proceeds further in the subdivision of the races of Europe. He recognizes six principal and four secondary races. The six principal races are the Nordic, answering approximately to the Teutonic of Ripley, the Littoral or Atlanto-Mediterranean, the Ibero-Insular, the Oriental, the Adriatic or Dinaric, and the Occidental or Cevenole.

Population. The following table shows the area of the countries of Europe, with their estimated or enumerated populations at different dates :—

Countries.	Area.	Population in Thous. (000 omit.).			Pop. per Sq.m.
	Eng. Sq. miles.	About 1880.	About 1890.	Latest Census or Estimate.	
Austria-Hungary .	241,466	37,884	41,358	43,800[11]	181
Bosnia-Herzegovina .	19,735	1 336[1]	...	1,591[12]	81
Liechtenstein	61	...	9[7]	...	147
Belgium . .	11,373	5,520	6,069	6,587[13]	597
Denmark[a] .	15,431	1,980	2,185	2,465[14]	160
France . .	207,206	...	38,343[7]	38,596[14]	186
Monaco .	8	...	...	15[13]	...
German Empire	208,760	45,234	49,428	56,345[16]	270
Luxemburg .	1,003	...	...	218[12]	218
Greece . .	24,974	...	2,187[8]	2,434[15]	97
Italy . .	110,676	28,460[2]	...	32,450[14]	293
San Marino .	23	...	...	9 ?	391
Montenegro .	3,500	...	...	228[15]	65
Netherlands .	12,741	4,013[3]	4,511[8]	5,103[17]	400
Portugal . .	34,347[b]	4,160[4]	4,660	...	136
Rumania . .	50,588	...	...	5,913[17]	117
Russia . .	1,951,249	89,685[1]	...	103,671[18]	53
Finland .	144,255	2,176[1]	...	2,555[11]	18
Servia . .	18,762	1,908[5]	...	2,494[16]	133
Spain[c] . .	191,994	16,432[6]	17,262[9]	17,744[18]	92
Andorra .	175	...	5	...	29
Sweden . .	173,968	4,566	4,785	5,136[16]	30
Norway . .	126,053	...	2,001[7]	2,231[16]	18
Switzerland .	15,976	2,846	2,933[10]	3,314[16]	207
Turkey(Europ.)[d]	66,840	...	...	5,892 ?	90
Bulgaria .	37,323	2,008[2]	3,154[10]	3,733[14]	100
Crete . .	3,328	...	302[9]	...	88
Thasos. .	152	...	...	12 ?	79
United Kingdom .	121,742	35,026[2]	37,881[7]	41,455[14]	341

[a] Including Faroe Islands.
[b] Area exclusive of Tagus and Sado inlets (together 161 sq. miles).
[c] Excluding Canary Islands. [d] With Novi-bazar.
[1] 1885. [2] 1881. [3] 1879. [4] 1878. [5] 1884.
[6] 1877. [7] 1891. [8] 1889. [9] Census 1900. [10] 1888.
[11] Estimate 1896. [12] Census 1895. [13] Estimate 1897.
[14] Census 1901. [15] Census 1896. [16] Census 1900.
[17] Census 1899. [18] Census 1897.

The following table shows that the process of aggregation of the people in large towns referred to in the ninth edition is still going on rapidly :—

comm. = commune. est. = estimate. w. subs. = with suburbs.	Population in Thous. (000 omitted).
London (Greater, 1901) .	6581
London (Registration, 1901)	4536
*Paris (w. subs.) . .	2877
,, (City, 1901) . .	2661
Berlin (w. subs.) . .	2073
,, (1900) . . .	1884
Vienna (1900) . . .	1662
*St Petersburg (w. subs., 1897)	1267
*Constantinople (w. subs.)	1200
Moscow (w. subs., 1897) .	1036
Glasgow (w. subs., 1901) .	910
Hamburg-Altona (1900) .	867
Liverpool (w. subs., 1901).	767
Manchester-Salford (1901)	765
Warsaw (1897). . .	638
Budapest (1896) . .	618
Birmingham (w. subs.,† 1901)	599
*Naples (comm., est. 1898)	540
Brussels (w. subs., est. 1897)	532
*Madrid (1897) . .	512
Amsterdam (comm., 1899)	511
*Barcelona (1897) . .	510
*Rome (comm., est. 1898)	500
Munich (1900) . .	500
Marseilles (1901) . .	495
*Milan (comm., est. 1898)	481
Copenhagen (w. subs., 1901)	477
Leipzig (1900) . . .	455
*Lyons (w. subs., 1896) .	452
Leeds (w. subs., 1901) .	444
Breslau (1900) . .	423
Odessa (1897) . . .	405
Dresden (1900) . .	395
Edinburgh-Leith (1901) .	393
Sheffield (1901) . .	381
Dublin (w. subs., 1901) .	373
Cologne (1900) . .	372
Turin (comm., 1898) .	356
Belfast (1901) . . .	349
Bristol (1901) . . .	329
Newcastle-Gateshead (1901)	325
Rotterdam (comm., 1899)	318
Prague (w. subs., 1900) .	317
Lódz (1897) . . .	315
*Lisbon (1890) . .	301
Stockholm (est. 1901) .	301
Elberfeld-Barmen (1901).	299
*Palermo (comm., 1898) .	291
Bordeaux (w. subs., 1896)	289
Frankfurt a/M (1900) .	288
Riga (w. subs., 1897) .	283
Bucarest (1899) . .	282
Bradford (1901) . .	280
Antwerp (comm., 1897) .	271
West Ham ‡ (1901) . .	267
Nuremberg (1900) . .	261
Kiev (1897) . . .	247
Hull (1901) . . .	241
Nottingham (1901) . .	240
Hanover (1900) . .	237
Genoa (comm., est. 1898)	233
Magdeburg (1900) . .	230
Christiania (1900) . .	226
Düsseldorf (1900) . .	214
Florence (comm., est. 1898)	213
Leicester (1901) . .	212
Chemnitz (1900) . .	207
Roubaix - Tourcoing (w. subs., 1896) . .	205
*Valencia (1897) . .	205

comm. = commune. est. = estimate. w. subs. = with suburbs.	Population in Thous. (000 omitted).
Lille, (w. subs., 1896) .	202
Hague, The (comm., est. 1897)	196
Portsmouth (1901) . .	189
Charlottenburg (1900) .	189
Königsberg (1900) . .	188
Trieste (1900) . .	179
Plymouth, Devonport (1901)	177
Stuttgart (1900) . .	176
Kharkov (1897) . .	174
Bolton (1901) . .	168
Liége (comm., 1897) .	167
Cardiff (1901) . . .	164
Bremen (1900) . .	163
Dundee (1901) . .	161
Ghent (comm., 1897) .	161
Rouen (w. subs , 1896) .	161
Vilna (1897) . . .	160
Brighton-Hove (1901) .	160
Lemberg (1900) . .	160
*Venice (comm., est. 1898)	157
Halle a/S. (1900) . .	157
Bologna (comm., est. 1898)	156
Messina (comm., est. 1898)	154
Aberdeen (1901) . .	153
Salonica	150
Strassburg (1900) . .	150
Zürich (comm., 1900) .	150
Sunderland (1901) . .	147
Seville (1897) . . .	146
Dortmund (1900) . .	142
Danzig (1900) . . .	141
Mannheim (1900) . .	140
Stettin (1895) . .	140
Oporto (1890) . .	139
Croydon (1901) . .	139
Graz (1900) . . .	138
Oldham (1901) . .	137
Saratov (1897) . .	137
Aachen (1900) . .	135
Toulouse (1896) . .	134
Catania (comm., est. 1898)	132
Kazan (1897) . . .	132
Nantes (w. subs., 1896) .	131
Havre (w. subs., 1896) .	129
Blackburn (1901) . .	128
Brunswick (1900) . .	128
St Etienne (1896) . .	127
Malaga (1897) . . .	126
Göteborg (est. 1898) .	123
Ekaterinoslav (1897) .	121
Rostov-on-Don (1897) .	120
Essen (1900) . . .	119
Posen (1900) . . .	117
Preston (1901) . .	113
Astrakhan (1897) . .	113
Norwich (1901) . .	112
Birkenhead (1901) . .	111
Athens (1896) . . .	111
Tula (1897) . . .	111
Brünn (1900) . . .	110
Kishinev (1897) . .	109
Basel (comm., 1900) .	109
Kiel (1900) . . .	108
Murcia (1897) . . .	108
Krefeld (1900) . .	107
Reims (1896) . . .	107
Derby (1901) . . .	106
Kassel (1900) . . .	106
Halifax (1901) . .	105
Southampton (1901) .	105
Leghorn (comm., est. 1898)	105
Utrecht (1899) . .	102

* For explanation see top of next column.
† The contiguous parliamentary boroughs of Birmingham and Aston Manor.
‡ Part of Greater London.

It is estimated that to-day more than 10 per cent. of Europeans live in great cities.[1] In 1800 only those to which an asterisk is prefixed rose above 100,000. Thirty-four out of the 140 towns enumerated in the list above belong to the British Isles.

The following tables must be allowed to speak for themselves :—

*Land Forces.**

Countries.	Total Strength in Round Numbers.		Notes.
	Peace Footing.	War Footing.	
Austria-Hungary .	361,700	1,872,000	[1] Estimated total available force.
Belgium .	51,500	163,000	[2] Number permanently under arms.
Bulgaria .	Abt. 40,000	...	[3] Exclusive of territorial militia of nearly 2,000,000.
Denmark .	9,800	61,600	[4] Whole empire.
France . .	540,000	2,500,000[1]	[5] Full mobilized strength of regular army and reserve.
German Empire .	585,000	Abv. 3,000,000[1]	[6] Strength of *elite*.
Greece . .	25,300	82,000	[7] Regular forces, home, colonial, and Indian.
Italy . .	325,000[2]	1,305,000[3]	[8] The same, with the addition of the first-class army reserve, militia, and volunteers.
Netherlands	27,700	68,000	
Portugal .	Abt. 40,000	149,000	
Rumania .	,, 63,000	172,000	
Russia . .	,, 900,000[4]	3,500,000[4]	
Servia . .	161,000[5]	353,000[1]	
Spain . .	98,000	184,000	
Sweden .	39,000	500,000[1]	
Norway .	18,000	...	
Switzerland .	148,000[6]	510,000[1]	
Turkey .	...	900,000[1 4]	
United Kingdom .	232,000[7]	670,000[8]	

* Based on *The Statesman's Year-Book*, 1900.

*Naval Strength.**

Countries.	Battle-ships.		Cruisers.		Coast Defence Vessels.		Torpedo-Boats.[1]		Torpedo Destroyers.	
	Afl.	Bdg.	Afl.	Bdg.	Afl.	Bdg.	Afl.	Bdg.	Afl.	Bdg.
Austria-Hungary .	5	3	10	3	7	...	83	...	...	...
Bulgaria .	...	...	...	...	3	2	1	...	...	...
Denmark .	...	...	6	...	5	...	34	...	...	...
France [2] .	25	2	51	8	21	...	195	...	18	14
German Empire .	17	7	16	4	11	...	153	...	27	16
Greece . .	5	...	...	...	...	...	7	...	...	...
Italy . .	9	2	14	1	5[3]	...	201	...	9	...
Netherlands	1	1	8	1	5	2	40	17	...	...
Norway .	...	...	...	...	6[4]	...	25	6	..	...
Sweden .	...	...	...	...	11[5]	3[3]	...	...	...	...
Portugal .	1	...	4	3	...	2	45	...	...	...
Rumania .	...	...	1	...	...	...	...	...	...	...
Russia .	19	5	15	4	8	1	201	10(?)	20	10
Spain . .	1	...	13	3	2	...	27	4	...	...
Turkey .	...	...	6	...	12	...	16	...	..	...
United Kingdom .	53	8	125	18	13	...	233	2	100	10

* Based on *The Statesman's Year-Book*, 1900.

[1] Including torpedo gunboats.
[2] While the United Kingdom had one submarine afloat and four building, and one ram-ship of special construction, France had eleven submarines afloat and twenty-eight building.
[3] Old battleships.
[4] Armoured or protected.
[5] All turret-ships.

[1] A. F. Weber, *The Growth of Cities in the Nineteenth Century* (1899), p. 451.

*Finance.**

Countries.	Year.	Revenue.	Expenditure.	Public Debt.
		Thous. £	Thous. £	Thous. £
Austria . .	Est. 1900	66,075	66,100	135,650
Austria-Hungary[1]	,, 1899	13,988	13,071	...
Belgium . .	,, 1900	18,090	18,037	104,152
Bosnia-Herzeg. .	,, 1900	1,736	1,730	...
Bulgaria . .	,, 1899	3,364	3,361	10,400
Denmark . .	,, 1900–01	4,045	4,006	11,555
Finland . .	...	...	...	...
France . .	,, 1899	138,019	136,182	1,197,933
German Empire .	,, 1900–01	98,957	102,916	115,112
Greece . .	,, 1900	4,453	4,409	27,985[2]
Hungary . .	,, 1900	43,938	43,863	203,737
Italy . .	,, 1899–1900	68,026	68,072	490,838
Luxemburg	,, 1900	491	456	480
Netherlands .	,, 1900	12,060	12,605	96,687
Norway . .	,, 1899–1900	4,394	4,394	10,090
Portugal . .	,, 1900–01	11,534	12,122	128,000[3]
Rumania . .	,, 1900–01	8,904	8,904	51,228
Russia . .	,, 1900	186,283	186,283	541,375
Servia . .	,, 1900	3,087	3,028	16,676
Spain . .	,, 1899–1900	37,517	37,487	358,133
Sweden . .	,, 1900	7,689	7,689	15,890
Switzerland .	,, 1900	4,090	4,120	3,376
Turkey . .	,, 1897–98	16,660	16 586	126,833
United Kingdom	,, 1898–99	108,336	108,150	627,563
,, ,, [4]	,, 1901–02	132,255	187,612	705,724

* Based mainly on *The Statesman's Year-Book*, 1900.

[1] Common revenue and expenditure.
[2] Gold debt, in addition to which there is a paper debt of about 174,000,000 drachmai.
[3] Exclusive of a debt of about £30,000,000 stated to be "partly in the hands of the Government."
[4] The actual revenue for 1900–01 was £130,385,000, and the expenditure £183,592,000.

Agricultural products and live-stock.

Though agricultural statistics are not obtainable for all European countries, and where obtainable not in every case for the same years, still the analysis of such as can be got brings out some very striking and interesting results. Since 1880 there has been a rise in the area under wheat in Hungary, the German Empire, Austria, and France, that in Hungary being the largest (more than 25 per cent.), while in the German Empire it has been about 8½ ; in Austria, about 7 per cent. ; and in France, slight. Between 1890 and 1899 there was a rise in the wheat area of Rumania of about 10 per cent., and in Italy one of 4 per cent. between 1890 and 1896. On the other hand, there has been a great decline in the wheat area in Denmark, Belgium, the Netherlands, and the United Kingdom ; that in the United Kingdom nearly reaching to, and in the other countries mentioned exceeding, 30 per cent. The area under rye has been extended in the Netherlands by more than 8 per cent. ; slightly also in Denmark ; while in Austria, Germany, and Hungary it has been practically stationary, and in France it has declined by nearly 20 per cent. Only two countries, Belgium and Ireland, show a decline in the area under potatoes ; that in Ireland amounting to more than 11 per cent. In Great Britain and Sweden the area under this crop has been practically stationary ; while Hungary, France, Austria, Denmark, the German Empire, and the Netherlands have added to the area under this crop by an amount varying from nearly 40 per cent. in Hungary to 8 per cent. in the Netherlands. All European countries for which statistics are available show a decline in the flax area, but these countries do not include Russia. In Ireland the decline between 1880 and 1899 amounted to nearly 80 per cent. Under maize, Hungary has increased its area by 25 per cent. since 1880, and Rumania in the same proportion since 1890. The area under the vine has declined in France since 1880 by more than 25, and in Hungary by more than 30 per cent. ; while in Italy there has been an extension of the vineyards since 1890, and in the German Empire their area has remained almost constant. In most European countries for which statistics are available the numbers of the main kinds of live-stock, except sheep, have been stationary or advancing (mostly advancing), but, except in Ireland and Poland, there has been a decline, generally a considerable decline, in the numbers of sheep and lambs. In Belgium, France, Ireland, the Netherlands, and Norway, the number of horses has remained nearly the same since 1880 ; but in Germany Russia, Great Britain, Austria, and Sweden there has been an increase in numbers, amounting in Germany to as much as 14 per cent. between 1883 and 1897 (since 1873 more than 20 per cent.). The number of cattle increased in all countries publishing statistics except Russia and Norway, the increase amounting to as much as 20 per cent. in Denmark (1881 to 1898), 17 per cent. in the German Empire (1885 to 1897), 16 per cent. in Great Britain, and 15 per cent. in Ireland (both from 1880 to 1899), and 14 per cent. in France and Sweden (both from 1880 to 1898). In Russia the decline amounted to 10 per cent. between 1877 and 1888. The increase was in a much higher ratio in the case of swine, Russia in this case being the only country showing a decline (amounting to 15 per cent. between 1877 and 1888). The increase varied from 20 per cent. in Norway (1875 to 1890) to nearly 100 per cent. in the Netherlands (1880 to 1895). In Belgium it was nearly 80 per cent. (1880 to 1895); in the German Empire, 55 per cent., between 1883 and 1897, and over 100 per cent. between 1873 and 1897; in Sweden, over 90 per cent. (1880 to 1898); in Ireland, over 60 per cent. (1880 to 1899); and in Great Britain, above 25 per cent. (same period). The decline in the number of sheep and lambs amounted in the German Empire to over 50 per cent. between 1873 and 1897, over 40 per cent. between 1883 and 1897; in Belgium, between 1880 and 1895, it was more than 35 per cent.; in Denmark and Italy it was nearly 20 per cent., in the first case between 1881 and 1893, in the second between 1881 and 1890. In most other countries it varied from 6½ to 16 per cent. In Great Britain it was as low as about 3 per cent. (1880 to 1899), and, on the other hand, there was a rise in the number of sheep in Ireland in the same period of nearly 23 per cent. In the United Kingdom, as a whole, the number was nearly the same at both dates. In Poland there was a rise of nearly 37 per cent. between 1890 and 1897.

Commerce, industries, and railways.

With regard to commerce, industries, and railways, as a whole, Europe may be said to be characterized by the rapid development of manufacturing at the expense of agricultural industry. With few exceptions the countries of Europe that export agricultural products are able to spare a diminishing proportion of the aggregate of such produce for export. Other countries are becoming more and more dependent on imported agricultural products. Most European countries, even if not able to export a large proportion of manufactured articles, are at least securing a greater and greater command of the home market for such products.[1] Inland centres of manufacturing industry are extending the range of their markets. All these changes have been largely, if not chiefly, promoted by the improvements in the means of communication, and the methods of transport by sea and land. Larger ships more economically propelled have brought grain at a cheaper and cheaper rate from all parts of the world, and since the date of the ninth edition improved methods of refrigeration have made fresh meat, butter, and other perishable commodities even from the southern hemisphere articles of rapidly growing importance in European markets. Improvements in shipping have likewise tended to cheapen British coal in many parts of the mainland of Europe. On the other hand, the extension of the railway network of the Continent has brought a wider area within the domain of the manufacturing regions associated with the coal-fields occurring at intervals in central Europe from the upper Oder to the basin of the Ruhr, as well as some of the more detached coal-fields of Russia. Among the more important railways that have been opened since the date of the ninth edition (mentioned roughly in the order from west to east in the trunk of Europe, and those in the peninsulas separately) are the line connecting Besançon with the watch-making region of the Swiss Jura; one from Zweibrücken by the valley of the Mosel to the Rhine, thus bringing the great iron-mining district on the borders of Luxemburg and Alsace-Lorraine into the most direct connexion with that river and its valley; three important trans-Alpine lines,—that through the St Gothard tunnel (opened in 1882), that connecting Venice with Vienna by way of Udine, Pontebba, and Klagenfurt, and that through the Arlberg tunnel (opened in 1884) connecting Zürich and the Rhine valley above the Lake of Constance with the valley of the Inn; lines connecting Breslau directly with Bohemia; the lines connecting Constantinople (since August 1888) and Salonica with Belgrade,

Railways in European Countries.

	Date of Opening of First Line.	Miles open.					
		1875.	1880.	1885.	1890.	1895.	1898.
Austria	Nov. 17, 1837	6,402	7,083	8,270	9,506	10,180	10,822[2]
Belgium	May 5, 1835	2,171	2,399	2,740	2,810	2,839	2,867
Bosnia-Herzeg	...	...	...	...	342	471	545
Bulgaria	...	...	...	...	...	...	835[3]
Denmark	June 26, 1847	689	975	1,195	1,217	1,371	1,568
France	Aug. 1, 1828	13,529	16,275	20,177	20,666	22,505	23,324
German Empire	Dec. 7, 1835	17,376	20,693	22,640	25,411	27,392	30,093[2]
Great Britain	Dec. 27, 1825	14,510	15,563	16,594	17,281	18,001	18,483
Greece	1869	7	7	278	452	?	591
Hungary	Sep. 15, 1846	3,992	4,421	5,605	6,984	8,651	10,137
Ireland	...	2,148	2,370	2,575	2,792	3,173	3,176
Italy	Oct. 4, 1836	4,771	5,340	6,408	7,983	9,579	9,381[4]
Luxemburg	...	110	...	...	...	270	276
Netherlands	Sep. 20, 1839	1,006	1,143	1,496	1,653	1,869	1,722
Norway	Sep. 1, 1854	345	652	970	970	1,071	1,213
Portugal	Oct. 30, 1856	643	710	949	1,316	1,336	1,464
Rumania	Nov. 1, 1869	766	859	1,100	1,590	1,617	1,895
Russia[5]	April 4, 1838	12,166	14,026	15,934	18,059	21,948	29,855
Servia	Sep. 15, 1884	...	..	155	335	335	584
Spain	Oct. 28, 1848	3,801	4,550	5,547	6,211	7,483	8,020
Sweden	March 5, 1856	2,171	3,654	4,279	4,980	6,058	6,350
Switzerland	June 15, 1844	1,257	1,596	1,795	2,014	2,233	2,316
Turkey	...	...	727	657	657	935	1,240

[1] Probably the most complete synopsis of the evidence on this point is to be found in Prince Kropotkin's *Fields, Factories, and Workshops*. London, 1899.
[2] 1897. [3] 1899. [4] 1896. [5] Excluding Finland.

Telegraphic Communication in Europe.

	1880.		1897 or 1898.			
	Lines. Miles.	Wires. Miles.	Lines. Miles.	Wires. Miles.	Stations.	Thous. Telegrams.
Austria (1898)	21,770	56,953	32,363	96,580	5,172	14,158
Belgium (1898)	3,451	15,148	3,960	45,944	1,058	10,505
Bosnia-Herzegovina	...	...	1,530	4,380	...	422
Bulgaria	...	...	2,259	6,728	...	1,343
Denmark (1898)	2,194	5,813	3,029[1]	8,733[1]	171[1]	2,106
France (1898)	41,079	122,100	62,952	218,684	...	44,515
German Empire (1898)	43,984	158,888	76,418	278,411	...	42,127
Greece	...	...	560	6,090	218	1,020
Hungary (1898)	9,047	32,433	13,675	66,689	3,026	13,584
Italy (1897)	16,217	53,240	25,715	99,821	6,023	9,705
Luxemburg (1898)	...	...	594	1,162	151	...
Netherlands (1898)	2,373	8,582	3,671[2]	13,017[2]	587[2]	4,958[2]
Norway (1898)	4,668	8,486	8,665	19,793	546	4,172
Portugal (1897)	2,713	6,762	4,584	9,475	425	2,337
Rumania (1898)	...	...	4,290	10,920	539	2,587
Russia	58,801	133,815	...	...	...	...
Servia (1898)	...	...	2,526	5,041	140	996
Spain (1897)	10,013	25,092	19,672	45,224	1,428	5,150
Sweden (end 1897)	5,147	12,628	8,594	26,026	...	2,370
Switzerland (1898)	4,071	9,947	4,435	13,092	2,039	3,820
United Kingdom	...	...	43,803	309,629	10,816	87,044

[1] State. There were also 258 railway and private telegraphic offices.
[2] State telegraph only. There are several private lines.

Elementary Education in Europe.[1]

	Year.	Primary Schools.	Scholars. Round Numbers.	Scholars to every 1000 Inhabitants.
Austria	1897	19,565	3,424,000	136
Belgium	1897	8,513	840,000	127
Bulgaria	1898	4,686	349,000	105
Denmark	(?)	2,940	308,000	115
Finland	1897	1,475	88,000	...
France	1897–8	83,915	5,535,000	34
Great Britain	1898	23,004[2]	6,295,000[2]	177
Greece	1892	2,745	139,000	61
Hungary	1897–8	18,486	2,428,000	129
Ireland	1898	8,651	808,000	184
Italy	1895–6	67,026	3,058,000	98
Netherlands	1897–8	5,568[3]	831,000[3]	166
Norway	1895	(?)	320,000	156
Portugal	1899	4,483	...	...
Prussia	1896	36,138	5,237,000	164
Rumania	1895–7	3,618[4]	298,000[4]	53
Russia	1896	78,724[5]	3,780,000	29
Servia	1893–4	914	77,000	32
Spain	1885	30,105	1,843,000	104
Sweden	1897	11,494	734,000	146
Switzerland	1897	5,131	513,000	164

[1] Derived from the *Statesman's Year-Book*, 1900. Where the number of and attendance at infant schools are recorded, these particulars are included; but for the reasons stated in the ninth edition, it is impossible to draw up a table in which all the entries are strictly comparable with one another. For the most part returns relating to private schools are not included. No particulars under the head of this table are obtainable for the entire German Empire.
[2] Schools inspected and number of pupils on the register.
[3] Private infant and primary schools included.
[4] Number of urban schools as in 1891; of pupils as in 1895–96; particulars for rural schools as in 1896–97.
[5] Whole empire.

and thus with the general European system; that bringing Bucarest into connexion with the Black Sea port of Kustenji by means of a bridge across the Danube at Chernavoda (opened in Sept. 1895); a line across the Carpathians connecting Debrecsen with Lemberg, the continuation of the line eastwards from Lemberg to Kiev; a network bringing the coal-field of the Donets basin into connexion with ports on the Sea of Azov; a line in the south-east of Russia connecting Novocherkassk with Vladikavkaz, and branches running from the same point connecting that line with Novorossyisk on the Black Sea on the one hand, and with Tsaritsyn at the last angle of the Volga on the other hand; a line in Northern Russia bringing Archangel into connexion with the European system at Vologda (opened in 1898); a detached line in the north-east across the Urals from Perm by Ekaterinburg (completed in 1878) to Tyumeñ (completed in 1884); and a line in the east connecting the European system at Samara with the great mining centre of Zlatoust, already in 1890 continued across the Urals to Miyas, and since then carried farther east as the great Siberian Railway. All the railways in Greece have been opened since 1878; and since that date Madrid has first been brought into fairly direct connexion with Lisbon and with Oporto. The growth of telegraphic communication is shown on the table on p. 318.

In recent years two European canals of international interest have been excavated: the canal through the Isthmus of Corinth, opened in 1893 (August 6), and the Kaiser Wilhelm Canal between the Elbe and the Baltic Sea, opened in 1895 (June 20).

The table on p. 318 shows the condition of elementary education for the years named, and the following table that of religions:—

Religions.[1]

	Roman Catholics.	Greeks.	Other Christians, chiefly Protestants.	Jews.	Mahommedans.
Austria (1890) .	18,934,000	3,359,000	454,000	1,143,000	(?)
Belgium . .	6,650,000	...	10,000	4,000	...
Bosnia - Herzegovina (1895) . .	334,000	673,000	3,850	8,200	549,000
Bulgaria (1893) .	22,600	2,607,000	9,000	28,300	643,000
Denmark (1890) .	3,650	...	2,174,000	4,100	...
German Empire (1890) . .	17,675,000	...	31,172,000	568,000	...
Greece (before census 1889) . .	(?)[2]	1,903,000	(?)	5,800	24,200
Hungary (1890) .	8,221,000	4,303,000	3,491,000	725,000	...
Ireland (1891) .	3,550,000	...	526,000	1,800	...
Italy (1881) .	28,350,000	...	62,000	38,000	...
Luxemburg (1895)	215,000	...	Abt. 1,500	1,050	...
Montenegro (?) .	13,000	201,000	...	...	14,000
Netherlands (1889)	1,596,000	...	2,735,000	97,000	...
Norway . .	1,000	...	2,000,000	...	...
Poland (1890) .	6,215,000	400,000	445,000	1,134,000	...
Portugal . .	5,049,000	...	500	...	...
Rumania . .	150,000	4,950,000	25,000	300,000	25,000
Russia (excluding Poland) . .	8,300,000	75,000,000	3,000,000	3,000,000	2,600,000
Servia (1891). .	11,600	2,128,000	1,100	4,650	16,800
Spain (1887). .	17,535,000	...	6,600	400	...
Sweden (1890) .	1,400	...	4,780,000	...	...
Switzerland (1888)	1,184,000	...	1,717,000	8,000	...
United Kingdom .	...	...	...	93,000	...

[1] Compiled from the *Statesman's Year-Book*, 1900. There are no data under this head for France, Great Britain, and Turkey. The last religious census in France was in 1872.

[2] 14,677 other Christians, mainly Roman Catholics.

AUTHORITIES:—PRESTWICH.—*Geological Map of Europe.* Oxford, 1880.—STRELBITSKY. *La Superficie de l'Europe.* St Petersburg, 1882.—OPPEL. "Die progressive Zunahme der Bevölkerung Europas," *Petermanns Mitteil.* Gotha, 1886.—KIRCHHOFF and others. *Die Länderkunde des Erdteils Europa*, vols. ii. and iii. of *Unser Wissen von der Erde* (comprising all the countries of Europe except Russia). Vienna, &c., 1887–1893.—Papers relating to the climate of Europe:—SUPAN, "Die mittlere Dauer der Haupt-Wärme-perioden in Europa," *Petermanns Mitteil.*, 1887, Pl. 10, and pp. 165–172.—SUPAN. "Die jahreszeitliche Verteilung der Niederschläge in Europa, &c., *ibid.* 1890, Pl. 21, and pp. 296, 297.—ELFERT. "Die Bewölkung in Mitteleuropa mit Einschluss der Karpatenländer, *ibid.* 1890, Pl. 11 and pp. 137–145.—KÖNIG. "Die Dauer des Sonnenscheins in Europa," in *Nova Acta Leopoldina Karol. der deutschen Akad. der Naturforscher*, vol. lxvii. No. 3 (Halle, 1896).—ANGOT. "Régime des pluies de la péninsule ibérique," in *Annales du Bur. Cent. Météor. de France* (1893, B. pp. 157–194), and "Régime des pluies de l'Europe occidentale," *ibid.* (1895, B, pp. 155–192).—BRÜCKNER. "Die Klimaschwankungen seit 1700," in Penck's *Geographische Abhandlungen*, iv. Pl. 2 (Vienna, 1890).—MUNRO. *Lake Dwellings of Europe.* London, 1890.—SUPAN. "Die Verschiebung der Bevölkerung in Mitteleuropa mit Einschluss der Karpatenländer," *Petermanns Mitteil.*, 1892.—BLOCK. *L'Europe Politique et Sociale.* 2nd edition, 1892.—E. RECLUS. "Hégémonie de l'Europe," in *La Société Nouvelle.* Brussels, 1894.—PHILIPPSON and NAUMANN. *Europa. Eine allgemeine Landeskunde.* Leipzig, 1895.—Publications relating to the measurement of a degree of longitude on the parallel of 52° N. from Valentia (Ireland) to the eastern frontier of Russia:—(1) STEBNITSKY. Account of the Russian section of this work in the *Memoirs* (Zapiski) *of the Milit. Topog. Section of the Russian General Staff*, vols. xlix. and l. St Petersburg, 1893. (In Russian, see notice in *Petermanns Mitteil.*, 1894; *Litteraturbericht*, No. 289.) (2) and (3) *Die europäische Längengradmessung in 52° Br. von Greenwich bis Warschau.* (2) Part i.—HELMERT. *Hauptdreiecke und Grundlinienanschlüsse von England bis Polen.* Berlin, 1893.—(3) Part ii. BÖRSCH and KRÜGER. *Geodätische Linien, Parallelbogen, und Lothabweichungen zwischen Feaghmain und Warschau.* Berlin, 1896.—MEURIOT. *Des agglomérations urbaines dans l'Europe contemporaine.* Paris, 1898.—CHISHOLM. *Europe*, vol. i. (in Stanford's Compendium of Geography and Travel)—*The Countries of the Mainland (excluding the North-West).* London, 1899.—SCHARFF. *The History of the European Fauna.* London, 1899.—RIPLEY. *The Races of Europe.* London, 1900.—DENIKER. *The Races of Man.* London, 1900.—SUPAN. *Die Bevölkerung der Erde*, x. Gotha, 1899.

(G. G. C.)

II. HISTORY, 1870–1900.

By the Franco-German War of 1870–71 and the creation of the German Empire the political condition of Europe was profoundly changed. Germany became for a time the leading Power on the Continent, and German statesmanship had to devise means for preventing, until the new edifice was thoroughly consolidated, the formation of a hostile coalition of jealous rivals. The first thing to be done in this direction was to secure the support of Russia and Austria to the new order of things.

Russian policy towards Germany.

With regard to Russia there was little cause for apprehension. She had aided Bismarck to carry out his audacious schemes in the past, and there was no reason to suppose that she would change her policy in the immediate future. The *rapprochement* dated from the Polish Insurrection of 1863, when the Governments of France and England, yielding to popular excitement, made strong diplomatic representations to Russia in favour of the Poles, whereas Bismarck not only refused to join in the diplomatic campaign, but made a Convention with the Cabinet of St Petersburg by which the Russian and German military authorities on the frontiers should aid each other in suppressing the disturbances. From that time the friendship ripened steadily. The relations between the two Powers were not, it is true, always without a cloud. More than once the bold designs of Bismarck caused uneasiness and dissatisfaction in St Petersburg, especially during the Schleswig-Holstein complications of 1864 and the Austro-Prussian conflict of 1866; but the wily statesman of Berlin, partly by argument and partly by dexterously manipulating the mutual trust and affection between the two Sovereigns, always succeeded in having his own way without producing a rupture, so that during the Franco-German War Russia maintained an extremely benevolent neutrality, and prevented Austria and Italy from taking part in the struggle. So benevolent was the neutrality that the Emperor William at the end of the campaign felt constrained to write to the Tsar that he owed to His Majesty the happy issue of the war. Having thus helped to create the German Empire, Alexander II. was not likely to take an active part in destroying it, and Bismarck could look forward confidently to a long continuance of the cordial relations between the two Courts.

The second part of the German Chancellor's programme, the permanent conciliation of Austria, was not so easily carried out. Austria had been the great sufferer, more perhaps even than France, from Bismarck's aggressive policy. For generations she had resisted strenuously and successfully the efforts of the Hohenzollerns to play the leading part in Germany, and she had always considered her own influence in Germany as essential to the maintenance of her position as a first-class Power. By the disastrous campaign of 1866 and the consequent Treaty of Prague, Austria had been formally excluded from all direct influence in German affairs. With these events still fresh in his recollection, the Emperor Francis Joseph could hardly be expected to support the new Empire created by his rival at Austria's expense, and it was known that on the eve of the Franco-German War he had been negotiating with the French Government for a combined attack on Prussia. To an ordinary statesman the task of permanently conciliating such a Power might well have seemed hopeless, but Bismarck did not shrink from it, and even before the signature of the Treaty of Prague he had prepared the way for attaining his object. "With regard to Austria," he himself explained on one occasion, "I had two courses open to me after her defeat, either to destroy her entirely or to respect her integrity and prepare for our future reconciliation when the fire of revenge had died out. I chose the latter course, because the former would have been the greatest possible act of folly. Supposing that Austria had disappeared, consider the consequences." He then described very graphically those probable consequences, and drew the conclusion: "for the sake of our own life Austria must live. I had no hesitation, therefore, and ever since 1866 my constant effort has been to stitch up the great torn texture and to re-establish amicable relations with our ancient associate of the Confederation." For this purpose he tried to soothe Austrian susceptibilities, and suggested confidentially that compensation for the losses of territory, influence, and prestige in Italy and Germany might be found in South-Eastern Europe, especially by the acquisition of Bosnia and Herzegovina; but so long as his rival Count Beust was Minister for Foreign Affairs in Vienna, and Austria had the prospect of being able to recover her lost position by the assistance of Russia and France, these efforts had no success. It was only when Prince Gortchakoff had declined Count Beust's advances, which took the form of suggesting the abolition of the Black Sea clauses of the Treaty of Paris, and when France had been paralysed for some years by her war with Germany, that a *rapprochement* between the Cabinets of Vienna and Berlin became possible. Bismarck lost no time in making advances. From the German headquarters at Versailles he sent a despatch to Vienna suggesting the establishing of more cordial relations between the two countries, and Count Beust replied in an equally amicable tone. The Emperor Francis Joseph, finding himself isolated, had evidently accepted the inevitable with his customary resignation, and abandoned his dreams of again playing the leading part in Germany. As a further proof of the change in his disposition and aims he replaced Count Beust by Count Andrassy, who was a personal friend of Bismarck, and who wished, as a Hungarian, to see Austria liberated from her German entanglement, and he consented to pay a visit to Berlin for the purpose of drawing still closer the relations between the two Governments.

Austrian relations with Germany.

Bismarck was delighted at this turn of affairs, but he advanced with his usual caution. He gave it to be clearly understood that improvement in his relations with Vienna must not disturb the long-established friendship with St Petersburg. The Tsar, on hearing privately of the intended meeting, gave a hint to Prince Reuss, the German ambassador, that he expected an invitation, and was invited accordingly. The meeting of the three Sovereigns took place at Berlin at the end of August 1872. The three Ministers, Prince Bismarck, Prince Gortchakoff, and Count Andrassy, held daily conferences, on the basis that the chief aim in view should be the maintenance of peace in Europe, and that in all important international affairs the three Powers should consult with each other and act in concert. As a result of three days' consultation the Three Emperors' League was founded, without any formal treaty being signed. In this way the danger of a powerful coalition being formed against the young German Empire was averted, for in the event of a conflict with France, Germany could count on at least the benevolent neutrality of Russia and Austria, and from the other Powers she had nothing to fear. What ulterior designs Bismarck may have had in forming the League, or Alliance as it is often called, must be to some extent a matter of conjecture, but we shall probably not be far wrong in adopting the view of a competent Russian authority, who defines the policy of the German Chancellor thus: "To make Austria accept definitively her deposition as a Germanic Power, to put her in perpetual conflict with Russia in the Balkan Peninsula, and to found on that irreconcilable rivalry the hegemony of Germany."

The Dreikaiserbund.

For more than two years there was an outward appearance of extreme cordiality between the three Powers. They acted together diplomatically, and on all suitable occasions the three allied monarchs exchanged visits and sent each other congratulations and good wishes. There was, however, from the beginning very little genuine confidence between them. Before the breaking up of the Conferences at Berlin, Alexander II. and his Chancellor had conversations with the French Ambassador, in which they not only showed that they had suspicions of future aggressive designs on the part of Germany, but also gave an assurance that so long as France fulfilled her engagements to Germany she had nothing to fear. A few months later, when the Emperor William paid his return visit to the Tsar in St Petersburg, a defensive convention was concluded by the two monarchs behind the back of their Austrian ally. Without knowing anything about the existence of this convention, the Austrian ally did not feel comfortable in his new position. In Vienna the old anti-Prussian feeling was still strong. The so-called party of the Archdukes and the military resisted the policy of Andrassy, and sought to establish closer relations with Russia, so that German support might be unnecessary, but as Bismarck has himself testified, "Russia did not yet respond. The wound caused by the conduct of Austria during the Crimean War was not yet healed. Andrassy made himself very popular in the Court Society of St Petersburg during his visit there with his Imperial Master, but the traditional suspicion of Austrian policy remained." Altogether, the new League was not a happy family. So long as all the members of it were content to accept the *status quo*, the latent germs of dissension remained hidden from the outside world, but as soon as the temporary state of political quietude was replaced by a certain amount of activity and initiative, they forced their way to the surface. No one of the three Powers regarded the *status quo* as a satisfactory permanent arrangement. In Berlin much anxiety was caused by the rapid financial and military recovery of France, and voices were heard suggesting that a new campaign and a bigger war indemnity might be necessary before the recuperation was complete. In St Petersburg there was a determination to take advantage of any good opportunity for recovering the portion of Bessarabia ceded by the Treaty of Paris, and thereby removing the last tangible results of the Crimean War. In Vienna there was a desire to obtain in the Balkan Peninsula, in accordance with the suggestion of Bismarck, compensation for the losses in Italy and Germany. Thus each of the members of the League was hatching secretly a little aggressive scheme for its own benefit, and the danger for the rest of Europe lay in the possibility of their reconciling their schemes so far as to admit of an agreement for action in common. Fortunately for the onlookers there were important conflicting interests, and the task of reconciling them was extremely difficult, as the subsequent course of events proved.

The first of the three Powers to move was Germany. In February 1875 M. de Radowitz was despatched to St Petersburg on a secret mission in order to discover whether, in the event of hostilities between Germany and France, Russia would undertake to maintain a neutral attitude, as she had done in 1870–71; in that case Germany might be relied on to co-operate with her in her great designs in the East. Prince Gortchakoff did not take the bait with the alacrity that was expected. Having overcome in some measure his hatred of Austria, which had distorted for so many years his political vision, he had come to understand that it was not for the interests of his own country to have as neighbour a powerful united Germany instead of a weak confederation of small states, and he now perceived that it would be a grave error of policy to allow Germany to destroy still more to her own advantage the balance of power in Europe by permanently weakening France. No doubt he desired to recover the lost portion of Bessarabia and to raise Russian prestige in the East, but he did not wish to run the risk of exciting a great European war, and he believed that what he desired might be effected without war by the diplomatic skill which had warded off European intervention during the Polish troubles of 1863, and had recovered for Russia her freedom of action in the Black Sea during the Franco-Prussian War of 1870–71. In reply, therefore, to M. de Radowitz's inquiries and suggestions, he declared that the Russian Court fostered no ambitious designs in the East or in the West, and desired only peace and the maintenance of the *status quo*, with possibly an amelioration in the miserable condition of the Christian subjects of the Sultan. This rebuff did not suffice to dispel the gathering storm. The warlike agitation in the German inspired press continued, and the French Government became thoroughly alarmed. General Leflô, the French Ambassador in St Petersburg, was instructed to sound the Russian Government on the subject. Prince Gortchakoff willingly assured him that Russia would do all in her power to incline the Berlin Cabinet to moderation and peace, and that the Emperor would take advantage of his forthcoming visit to Berlin to influence the Emperor William in this sense. A few days later General Leflô received similar assurances from the Emperor himself, and about the same time the British Government volunteered to work likewise in the cause of peace. Representations were accordingly made by both Governments during the Tsar's visit to Berlin, and both the Emperor William and his Chancellor declared that there was no intention of attacking France. The danger of war, which the well-informed German press believed to be "in sight," was thus averted, but the incident sowed the seeds of future troubles, by awakening in Bismarck a bitter personal resentment against his Russian colleague. By certain incautious remarks to those around him, and still more by a circular to the representatives of Russia abroad, dated Berlin and beginning with the words *maintenant la paix est assurée*, Gortchakoff seemed to take to himself the credit of having checkmated Bismarck and saved Europe from a great war. Bismarck resented bitterly this conduct on the part of his old friend, and told him frankly that he would have reason to regret it. In the Russian official world it is generally believed that he took his revenge in the Russo-Turkish War and the Congress of Berlin. However this may be, he has himself explained that "the first cause of coldness" was the above incident, "when Gortchakoff, aided by Decazes, wanted to play at my expense the part of a saviour of France, to represent me as the enemy of European peace, and to procure for himself a triumphant *quos ego* to arrest by a word and shatter my dark designs!" In any case the incident marks the beginning of a new phase in the relations of the three Powers: henceforth Bismarck can no longer count on the unqualified support of Russia, and in controlling the Russo-Austrian rivalry in South-Eastern Europe, while professing to be impartial, he will lean to the side of Count Andrassy rather than to that of Prince Gortchakoff. He is careful, however, not to carry this tendency so far as to produce a *rapprochement* between Russsia and France. The danger of a Franco-Russian alliance hostile to Germany is already appearing on the political horizon, but it is only a little cloud no bigger than a man's hand.

The Storm-cloud of 1875.

Russia and Germany divided.

The next move in the aggressive game was made by Austria, with the connivance of Russia. During the summer of 1875 an insurrection of the Christian Slavs in Herzegovina, which received support from the neighbouring Principalities of Montenegro and Servia, was fostered by the Austrian authorities and encouraged by the Russian consuls on the Adriatic coast. A European Concert was formed for the purpose of settling the disturbance by means of local administrative reforms, but the efforts of the Powers failed, because the insurgents hoped to obtain complete liberation from Turkish rule; and in the beginning of July, with a view to promoting this solution, Servia and Montenegro declared war against the Porte. Thereupon Russia began to show her hand more openly. The Government allowed volunteers to be recruited in Moscow and St Petersburg, and the Russian General Tchernayef, who had distinguished himself in Central Asia, was appointed to the command of the Servian army. When the ball had thus been set rolling, the two Powers chiefly concerned considered that the time had come for embodying the result of their informal confidential pourparlers in a secret agreement, which is known as the agreement of Reichstadt, because it was concluded by the two Emperors in the little Bohemian town of that name. It bore the date of July 8, 1876,—exactly a week after Servia and Montenegro had declared war,—and it contained the following stipulations:—(1) That so long as the struggle which had just begun remained undecided, the two Sovereigns should refrain from interference, and that in the event of the Principalities being defeated, any modification of the territorial or political *status quo ante* to their detriment should be prevented; (2) That in the event of the Principalities proving victorious, and territorial changes taking place, Austria would claim compensation in Bosnia and Herzegovina, and Russia would demand the restitution of the portion of Bessarabia which she had lost by the Crimean War; (3) That in the event of the collapse of the Ottoman Empire, the two Powers should act together to create autonomous principalities in European Turkey, to unite Thessaly and Crete to Greece, and to proclaim Constantinople a free town. The contracting parties evidently expected that the two Principalities would be victorious in their struggle with the Porte, and that the compensations mentioned would be secured without a great European war. Their expectations were disappointed. Montenegro made a brave stand against superior forces, but before five months had passed Servia was at the mercy of the Turkish army, and Russia had to come to the assistance of her protégé. A Russian ultimatum stopped the advance of the Turks on Belgrade, and an armistice, subsequently transformed into a peace, was signed.

Austro-Russian agreement, 1876.

Russia and Austria had now to choose between abandoning their schemes and adopting some other course of action, and unforeseen incidents contributed towards making them select the latter alternative. In June an attempt at insurrection in Bulgaria had been repressed with savage brutality by the Turks, and the details, as they became known some weeks later, produced much indignation all over Europe. In England the excitement, fanned by the eloquence of Mr Gladstone, became intense, and compelled the Disraeli Cabinet to take part, very reluctantly, in a diplomatic campaign, with the object of imposing radical reforms on Turkey. In Russia the excitement and indignation were equally great, and the Tsar gradually formed the resolution that if the Powers would not act collectively and energetically, so as to compel the Porte to yield, he would undertake the work single-handed. This resolution he announced publicly in a speech delivered at Moscow on November 10. The Powers did not like the idea of separate Russian action, and in order to prevent it they agreed to hold a Conference in Constantinople for the purpose of inducing the Porte to introduce the requisite reforms. The Porte was at that moment under the influence of popular patriotic excitement which made it indisposed to accept orders, or even well-meant advice, from Governments more or less hostile to it, and the inconsiderate mode of procedure suggested by General Ignatief, and adopted by the other delegates, made it still more unconciliatory. At the first plenary sitting of the Conference the proceedings were disturbed by the sound of artillery, and the Turkish representative explained that the salvo was in honour of the new Ottoman Constitution, which was being promulgated by the Sultan. The inference suggested was that as soon as Turkey had spontaneously entered on the path of liberal and constitutional reform for all Ottoman subjects, it became superfluous and absurd to talk of small reforms for particular provinces, such as the Conference was about to propose. The deliberations continued, but finally the Porte refused to accept what the plenipotentiaries considered an irreducible minimum, and the Conference broke up without obtaining any practical result. The Tsar's Moscow declaration about employing single-handed the requisite coercive measures now came to be fulfilled.

Bulgarian Question.

In order to make a successful aggressive move on Turkey, Russia had first of all to secure her rear and flank by an arrangement with her two allies. In Berlin she encountered no difficulties. Bismarck had no objection to seeing Russia weaken herself in a struggle with Turkey, provided she did not upset the balance of Power in South-Eastern Europe, and he felt confident that he could prevent by diplomatic means any such catastrophe. He was inclined, therefore, to encourage rather than restrain the bellicose tendencies of St Petersburg. In Vienna the task of coming to a definite arrangement was much more difficult, and it was only after protracted and laborious negotiations that a Convention was concluded on January 15, 1877, and formally signed three months later. It was a development of the agreement of Reichstadt, modified according to the changes in the situation, but retaining the essential principle that in the event of the territorial *status quo* being altered, Russia should recover the lost portion of Bessarabia, and Austria should get Bosnia and a part of Herzegovina. Having made these preliminary arrangements, Russia began the campaign simultaneously in Europe and Asia Minor, and after many reverses and enormous sacrifices of blood and treasure, she succeeded in imposing on the Turks the "preliminary peace" of San Stefano. That peace was negotiated with very little consideration for the interests of the other Powers, and as soon as the terms of it became known in Vienna and London, there was an outburst of indignation. In negotiating the treaty General Ignatief had ignored the wishes of Austria, and had even, according to the contention of Andrassy, infringed the Convention signed at the beginning of the war. However this may be, the Peace of San Stefano brought to the surface the latent conflict of interests between the two Empires. Russia's aim was to create a big Bulgaria under the influence of St Petersburg, and to emancipate Servia and Montenegro as far as possible from Austrian influence, whereas Austria objected to the creation of any large Slav State in the Balkan Peninsula, and insisted on maintaining her influence in Servia and Montenegro. In vain Prince Gortchakoff endeavoured to conciliate Austria and to extract from Count Andrassy a clear statement of the terms he would accept. Count Andrassy was in no hurry to extricate Russia from her difficulties, and suggested that the whole question should be submitted to a European Congress. The suggestion was endorsed by Great Britain, which likewise objected to the San Stefano arrangements, and Bismarck declined to bring any pressure to bear on the Cabinet of Vienna.

San Stefano.

Deceived in her expectations of active support from her two allies, Russia found herself in an awkward position. From a military point of view it was absolutely necessary for her to come to an arrangement either with Austria or with England, because the communications of her army before Constantinople with its base could be cut by these two Powers acting in concert — the land route being dominated by Austria, and the Black Sea route by the British fleet, which was at that time anchored in the Sea of Marmora. As soon, therefore, as the efforts to obtain the support of her two allies against the demands of England had failed, negotiations were opened in London, and on May 30 a Secret Convention was signed by Lord Salisbury and Count Schuwaloff. By that agreement the obstacles to the assembling of the Congress were removed. The Congress met in Berlin on 13th June, and after many prolonged sittings and much secret negotiations, the Treaty of Berlin was signed on 13th July. By that treaty the Preliminary Peace of San Stefano was considerably modified. The big Bulgaria defined by General Ignatief was divided into three portions, the part between the Danube and the Balkans being transformed into a vassal Principality, the part between the Balkans and the Rhodope being made into an autonomous province, with a Christian governor named by the Sultan, with the assent of the Powers, and the remainder being placed again under the direct rule of the Porte. The independence of Montenegro, Servia, and Rumania was formally recognized, and each of these Principalities received a considerable accession of territory. Rumania, however, in return for the Dobrudja, which it professed not to desire, was obliged to give back to Russia the portion of Bessarabia ceded after the Crimean War. In Asia Minor Russia agreed to confine her annexations to the districts of Kars, Ardahan, and Batum, and to restore to Turkey the remainder of the occupied territory. As a set-off against the large acquisitions of the Slav races, the Powers recommended that the Sultan should cede to the kingdom of Greece the greater part of Thessaly and Epirus, under the form of a rectification of frontiers. At first the Sultan refused to act on this recommendation, but in March 1881 a compromise was effected by which Greece obtained Thessaly without Epirus. Bosnia and Herzegovina were to be occupied and administered by Austria-Hungary, and the Austrian authorities were to have the right of making

Berlin Congress.

roads and keeping garrisons in the district of Novi-Bazar, which lies between Servia and Montenegro. In all the provinces of European Turkey for which special arrangements were not made in the Treaty, the Porte undertook (Art. 23) to introduce organic statutes similar to that of Crete, adapted to the local conditions. This article, like many of the subordinate stipulations of the Treaty, has remained a dead letter. We may mention specially Art. 61, in which the Sublime Porte undertook to realize without delay the ameliorations and reforms required in the provinces inhabited by Armenians, and to guarantee their safety against the Circassians and Kurds. Equally unreliable proved the scheme of Lord Beaconsfield to secure good administration throughout the whole of Asia Minor by the introduction of reforms under British control, and to prevent the further expansion of Russia in that direction by a defensive alliance with the Porte. A Convention to that effect was duly signed at Constantinople a few days before the meeting of the Congress (4th June 1878), but the only part of it which was actually realized was the occupation and administration of Cyprus by the British Government. The new frontiers stipulated in the Treaty of San Stefano, and subsequently rectified by the Treaty of Berlin, are shown in the accompanying sketch-map.

Cyprus Convention.

B. V. Darbishire & O. J. R. Howarth. English Miles 0 50 100 200 Oxford, 1901.

The secret schemes of Russia and Austria, in so far as they were defined in the agreement of Reichstadt and the subsequent Austro-Russian Treaty of Vienna, had thus been realized. Russia had recovered the lost portion of Bessarabia, and Austria had practically annexed Bosnia and Herzegovina, though the nominal suzerainty of the Sultan over the two provinces was maintained. But Russia was far from satisfied with the results, which seemed to her not at all commensurate with the sacrifices imposed on her by the war, and her dissatisfaction led to a new grouping of the Powers. Before the opening of the Congress Bismarck had announced publicly that he would refrain from taking sides with any of the contending parties, and would confine himself to playing the part of an honest broker. The announcement was received by the Russians with astonishment and indignation. What they expected was not an impartial arbiter, but a cordial and useful friend in need. In 1871 the Emperor William, as we have seen, had spontaneously declared to the Tsar that Germany owed to His Majesty the happy issue of the war, and that she would never forget it, and we may add that on that occasion he signed himself "Your ever grateful Friend." Now, in 1878, when the moment had come for paying at least an instalment of this debt, and when Russia was being compelled to make concessions which she described as incompatible with her dignity, Bismarck had nothing better to offer than honest brokerage. The indignation in all classes was intense, and the views commonly held regarding Bismarck's "duplicity" and "treachery" were supposed to receive ample confirmation during the sittings of the Congress and the following six months. On February 4, 1879, Prince Gortchakoff wrote to the Ambassador in Vienna: "Needless to say, that in our eyes the Three Emperors' Alliance is practically torn in pieces by the conduct of our two allies. At present it remains for us merely to terminate the liquidation of the past, and to seek henceforth our support in ourselves alone." The same view of the situation was taken in Berlin and Vienna, though the result was attributed, of course, to different causes, and the danger of serious complications became so great that Bismarck concluded with Andrassy in the following October a formal defensive alliance, which was avowedly directed against Russia, and which subsequently developed into the Triple Alliance, directed against Russia and France.

Russian resentment against Bismarck.

The causes of the rupture are variously described by the different parties interested. According to Bismarck the Russian Government began a venomous campaign against Germany in the press, and collected, with apparently hostile intentions, enormous masses of troops near the German and Austrian frontiers, whilst the Tsar adopted in his correspondence with the Emperor William an arrogant and menacing tone which could not be tolerated. On the other hand, the Russians declare that the so-called Press-Campaign was merely the spontaneous public expression of the prevailing disappointment among all classes in Russia, that the military preparations had a purely defensive character, and that the Tsar's remarks, which roused Bismarck's ire, did not transgress the limits of friendly expostulation such as Sovereigns in close friendly relations might naturally employ. Subsequent revelations tend rather to confirm the Russian view. After an exhausting war and without a single powerful ally, Russia was not likely to provoke wantonly a great war with Germany and Austria. The press attacks were not more violent than those which frequently appear in newspapers which draw their inspiration from the German Foreign Office, and the accusations about the arrogant attitude and menacing tone of Alexander II. are not at all in harmony with his known character, and are refuted by the documents since published by Dr Busch. The truth seems to be that the self-willed Chancellor was actuated by nervous irritation and personal feeling more than by considerations of statecraft. His Imperial master was not convinced by his arguments, and showed great reluctance to permit the conclusion of a separate treaty with Austria. Finally, with much searching of heart, he yielded to the importunity of his Minister; but in thus committing an unfriendly act towards his old ally, he so softened the blow that the personal good relations between the two Sovereigns suffered merely a momentary interruption. Bismarck himself soon recognized that the permanent estrangement of Russia would be a grave mistake of policy, and the very next year (1880), negotiations for a treaty of defensive alliance between the two Cabinets were begun. Nor did the accession to the throne of Russia of Alexander III., who had long enjoyed the reputation of being systematically hostile to Germans, produce a rupture, as was expected. Six months after his father's death, the young Tsar met the old Kaiser at Danzig (Sept. 1881), and some progress was made towards a complete renewal of the traditional friendship. Immediately afterwards a further step was taken towards re-establishing the old state of things with regard also to Austria. On his return to St Petersburg, Alexander III. remembered that he had received some time previously a telegram of congratulation from the Emperor Francis Joseph, and he now replied to it very cordially, referring to the meeting at Danzig, and describing the Emperor William as "that venerable friend with whom we are united in the common bonds of a profound affection." The words foreshadowed a revival of the Three Emperors' League, which actually took place three years later.

Growth of the Triple Alliance.

The removal of all immediate danger of a Franco-Russian alliance did not prevent Bismarck from strengthening in other ways the diplomatic position of Germany, and the result of his efforts soon became apparent in the alliance of Italy with the two Central Powers. Ever since the Franco-German War of 1870–71, and more especially since the Congress of Berlin in 1878, the Italian Government had shown itself restless and undecided in its foreign policy. As it was to France that Italy owed her emancipation from Austrian rule, it seemed natural that the two countries should remain allies, but anything like cordial co-operation was prevented by conflicting interests and hostile feeling. The French did not consider the acquisition of Savoy and Nice as sufficient compensation for the assistance they had given to the cause of Italian unity, and they did not know, or did not care to remember, that their own Government was greatly to blame for the passive attitude of Italy in the hour of their great national misfortunes. On the other hand, a considerable amount of bitterness against France had been gradually accumulating in the hearts of the Italians. As far back as the end of the war of 1859, popular opinion had been freely expressed against Napoleon III., because he had failed to keep his promise of liberating Italy "from the Alps to the Adriatic." The feeling was revived and intensified when it became known that he was opposing the annexation of Central and Southern Italy, and that he obtained Savoy and Nice as the price of partly withdrawing his opposition. Subsequently, in the war of 1866, he was supposed to have insulted Italy by making her conclude peace with Austria, on the basis of the cession of Venetia, before she could wipe out the humiliation of her defeats at Custozza and Lissa. Then came the French protection of the Pope's temporal power as a constant source of irritation, producing occasional explosions of violent hostility, as when the new Chassepôt rifles were announced to have "worked wonders" among the Garibaldians at Mentana. When the Second Empire was replaced by the Republic, the relations did not improve. French statesmen of the Thiers school had always condemned the Imperial policy of permitting and even encouraging the creation of large, powerful states on the French frontiers, and Thiers himself publicly attributed to this policy the misfortunes of his country. With regard to Italy, he said openly that he regretted what had been done, though he had no intention of undoing it. The first part of this statement was carefully noted in Italy, and the latter part was accepted with scepticism. In any case his hand might perhaps be forced, for in the first Republican Chamber the Monarchical and Clerical element was very strong, and it persistently attempted to get something done in favour of the Temporal Power. Even when the party of the Left undertook the direction of affairs in 1876, the Government did not become anti-Clerical in its foreign policy, and Italian statesmen resigned themselves to a position of political isolation. The position had its advantages. Events in the Balkan Peninsula foreshadowed a great European war, and it seemed that in the event of Europe's being divided into two hostile camps, Italy might have the honour and the advantage of regulating the balance of power. By maintaining good relations with all her neighbours and carefully avoiding all inconvenient entanglements, she might come forward at the critical moment and dictate her own terms to either of the contending parties, or offer her services to the highest bidder. This Machiavellian policy did not give the expected results. Being friends with everybody in a general way may be the best course for an old, conservative country which desires merely the maintenance of the *status quo*, but it does not secure the energetic diplomatic support required by a young enterprising state which wishes to increase its territory and influence. At the Congress of Berlin, when several of the Powers got territorial acquisitions, Italy got nothing. The Italians, who were in the habit of assuming, almost as a matter of principle, that from all European complications they had a right to obtain some tangible advantage, were naturally disappointed, and they attributed their misfortune to their political isolation. The policy of the free hand consequently fell into disrepute, and the desire for a close, efficient alliance revived. But with what Power or Powers should an alliance be made? The remnants of the old party of action, who still carried the *Italia Irredente* banner, had an answer ready. They recommended that alliances should be concluded with a view to wresting from Austria the Trentino and Trieste, with Dalmatia, perhaps, into the bargain. On the other hand, the Conservatives and the Moderates considered that the question of the Trentino and Trieste was much less important than that of political influence in the Mediterranean. A strong Austria was required, it was said, to bar the way of Russia to the Adriatic, and France must not be allowed to pursue unchecked her policy of transforming the Mediterranean into a French lake. Considerations of this kind led naturally to the conclusion that Italy should draw closer to the Powers of Central Europe. So the question appeared from the standpoint of "la haute politique." From the less elevated standpoint of immediate political interests, it presented conflicting considerations. A *rapprochement* with the Central Powers might prevent the conclusion of a commercial treaty with France, and thereby increase the financial and economic difficulties with which the young kingdom was struggling, whereas a *rapprochement* with France would certainly excite the hostility of Bismarck, who was retiring from the *Culturkampf* and journeying towards Canossa, and who might possibly conciliate the Pope by helping him to recover his temporal sovereignty at the expense of Italy. Altogether the problem was a very complicated one. The conflicting currents so nearly balanced each other, that the question as to which way the ship would drift might be decided by a little squall of popular sentiment. A very big squall was brewing.

France and Tunis.

During the Congress of Berlin, the French Government was very indignant when it discovered that Lord Beaconsfield had recently made a secret convention with the Sultan for the British occupation of Cyprus, and in order to calm its resentment Lord Salisbury gave M. Waddington to understand that, so far as England was concerned, France would be allowed a free hand in the Regency of Tunis, which she had long coveted. Though the conversations on the subject and a subsequent exchange of notes were kept strictly secret, the Italian Government soon got wind of the affair, and it was at first much alarmed. It considered, in common with Italians generally, that Tunis, on the ground of historic right and of national interests, should be reserved for Italy, and that an extension of French territory in that direction would destroy, to the detriment of Italy, the balance of power in the Mediterranean. These apprehensions were calmed for a time by assurances given to the Italian Ambassador in Paris. M. Gambetta assured General Cialdini that he had no intention of making Italy an irreconcilable enemy of France, and M. Waddington declared, on his word of honour, that so long as he remained Minister of Foreign Affairs nothing of the sort would be done by France without a previous understanding with the Cabinet of Rome. M. Waddington honourably kept his word, but his successor did not consider himself bound by the assurance; and when it was found that the Italians were trying systematically to establish their influence in the Regency at the expense of France, the French authorities, on the ground that a Tunisian tribe called the Kroumirs had committed depredations in Algeria, sent an armed force into the Regency, and imposed on the Bey the Bardo treaty, which transformed Tunis into a French Protectorate.

The establishment of a French Protectorate over a country which the Italians had marked out for themselves as necessary for the defence and colonial expansion of the kingdom had the effect which Gambetta had foreseen—it made Italy, for a time at least, the irreconcilable enemy of France. Whilst the French were giving free expression to their patriotic exultation, and even Gambetta himself, in defiance of what he had said to Cialdini, was congratulating Jules Ferry on having restored France to her place among the nations, the Italians were trying to smother their indignation and to discover some means of retrieving what they had lost. The only remedy seemed to be to secure foreign alliances, and there was now no hesitation as to where they should be sought. Simple people in Italy imagined that if an alliance had been concluded sooner with Germany and Austria, these Powers would have prevented France from trampling on the sacred interests of Italy. This idea was entirely erroneous, because Austria had little or no interest in the Tunisian Question, and Bismarck was not at all sorry to see France embark on an enterprise which distracted her attention from Alsace-Lorraine and removed all danger of a Franco-Italian alliance. The illusion, however, had a powerful influence on Italian public opinion. The Government was now urged to conclude without further delay an alliance with the Central Powers, and the recommendation was not unwelcome to the King, because most of the Italian Gallophils had anti-dynastic and Republican tendencies, and he was naturally disposed to draw nearer to Governments which proclaimed themselves the defenders of Monarchical institutions and the opponents of revolutionary agitation. After protracted negotiations, in which Italy tried in vain to secure protection for her own separate interests in the Mediterranean, defensive treaties of alliance were concluded with the Cabinets of Vienna and Berlin in May 1882.

Triple Alliance signed 1882.

Though the Italian statesmen did not secure by these treaties all they wanted, they felt that the kingdom was protected against any aggressive designs which might be entertained by France or the Vatican, and when the treaties were renewed in 1887, they succeeded in getting somewhat more favourable conditions.

By the creation of this Triple Alliance, which still subsists, the diplomatic position of Germany was greatly strengthened, but Bismarck was still haunted by the apprehension of a Franco-Russian alliance, and he made repeated attempts to renew the old cordial relations with the Court of St Petersburg. He was bold enough to hope that, notwithstanding the Austro-German treaty of October 1879, avowedly directed against Russia, and the New Triple Alliance, by which the Austro-German Alliance was strengthened, he might resuscitate the Three Emperors' League in such a form as to ensure, even more effectually than he had done on the former occasion, the preponderance of Germany in the arrangement. With this object he threw out a hint to the Russian Ambassador, M. Sabourof, in the summer of 1883, that the evil results of the Congress of Berlin might be counteracted by a formal agreement between the three Emperors. The suggestion was transmitted privately by M. Sabourof to the Tsar, and was favourably received. Alexander III. was disquieted by the continuance of the Nihilist agitation, and was not averse to drawing closer to the Conservative Powers; and as he desired tranquillity for some time in the Balkan Peninsula, he was glad to have security that his rival would do nothing in that part of the world without a previous understanding. M. de Giers, who had now succeeded Prince Gortchakoff in the direction of Foreign Affairs, was accordingly despatched to Friedrichsruh to discuss the subject with Bismarck. The practical result of the meeting was that negotiations between the two Governments were begun, and on March 21, 1884, a formal document was signed in Berlin. About six months later, in the month of September, the three Emperors met at Skiernevice and ratified the agreement. Thus, without any modification of the Triple Alliance, which was directed against Russia, the old Three Emperors' League, which included Russia, was revived.

Dreikaiserbund revived 1884.

Germany and Austria, being members of both, were doubly protected, for in the event of being attacked they could count on at least the benevolent neutrality of both Russia and Italy. France was thereby completely isolated.

In drawing up the secret treaty of Skiernevice, which may be regarded as the *chef d'œuvre* of Bismarckian diplomacy, the German Chancellor's chief aims evidently were to paralyse Russia by yoking her to Germany and Austria, to isolate France, and to realize his old scheme of holding the balance between Russia and Austria in the Balkan Peninsula. With a view to attaining the first two objects it was stipulated that if any one of the three Powers were forced to make war on a fourth Power, the two other contracting parties should observe a benevolent neutrality towards their ally. If we may believe a well-informed Russian authority, Bismarck wished it to be understood that in the event of *two* of the Powers being at war with a fourth, the stipulation about benevolent neutrality should still hold good, but Alexander III. objected, on the ground that he could not remain a passive spectator of a duel in which France would be confronted by two antagonists. In his third object Bismarck was successful, for it was expressly laid down that in all cases of a disagreement between two of the parties in the affairs of the Balkan Peninsula, the third Power should decide between them. This meant, of course, that in all discussions between Russia and Austria, the two great rivals in the Eastern Question, Bismarck should always have a casting vote. In return for all this, Russia obtained two small concessions: firstly, that Germany and Austria should seek to restrain the Sultan from permitting the passage of the Dardanelles to an English fleet, as he had done in 1878, when the Russian army was before Constantinople; and, secondly, that they should not oppose the union of Bulgaria and Eastern Rumelia, if it was accomplished by the force of things and within the limits traced by the Congress of Berlin.

This new form of the Three Emperors' League had all the organic defects of its predecessor, and was destined to be still more shortlived. The claims of Russia and Austria might be reconcilable in theory, but in practice they were sure to conflict; and however much Bismarck might try to play the part of an honest broker, he was certain to be suspected of opposing Russia and favouring Austria. It was, therefore, only during a period of political stagnation in South-Eastern Europe that the arrangement could work smoothly. The political stagnation did not last long. Prince Alexander of Bulgaria had for some time been fretting under the high-handed interference of the Russian agents in the Principality, and had begun to oppose systematically what the Russians considered their legitimate influence. Relations between Sofia and St Petersburg had consequently become strained, when a crisis was suddenly brought about by the revolution of Philippopolis in September 1885. The conspirators arrested and expelled the Governor-General, who had been appointed by the Sultan with the assent of the Powers, and at the same time proclaimed the union of the autonomous province of Eastern Rumelia with the Principality of Bulgaria, in defiance of the stipulations of the Treaty of Berlin. The revolution had been effected with the connivance and approval of the regularly accredited Russian agents in Philippopolis, but it had not received the sanction of the Russian Government, and was resented as a new act of insubordination on the part of Prince Alexander. When he arrived in Philippopolis and accepted the declaration of union, the Cabinet of St Petersburg protested against any such infraction of the Berlin Treaty, and the Porte prepared to send an army into the province. It was restrained from taking this step by the Ambassadors in Constantinople, so that an armed conflict between Turks and Bulgarians was prevented; but no sooner had the Bulgarians been relieved from this danger on their eastern frontier than they were attacked from the west by the Servians, who were determined to get ample compensation for any advantage which the Bulgarians might obtain. The Bulgarian army defeated the Servians at Slivnitza (Nov. 19–20, 1885), and was marching on Belgrade when its advance was stopped and an armistice arranged by the energetic intervention of the Austrian Government. Following the example of the Servians, the Greeks were preparing to exact territorial compensation likewise; but as their mobilization was a slow process, the Powers had time to restrain them from entering on active hostilities, first by an ultimatum (April 26, 1886), and afterwards by a blockade of their ports (May 1886). By that time, thanks to the intervention of the Powers, a peace between Bulgaria and Servia had been signed at Bucarest (March 3); and with regard to Eastern Rumelia, a compromise had been effected by which the formal union with the Principality was rejected, and the Prince was appointed Governor-General of the province for a term of five years. This was in reality union in disguise.

Bulgarian crisis.

The diplomatic solution of the problem averted the danger of a European war, but it left a great deal of dissatisfaction, which soon produced new troubles. Not only had Prince Alexander escaped punishment for his insubordination to Russia, but he and the anti-Russian party among the Bulgarians had obtained a decided success. This could not well be tolerated. Before six months had passed (August 21, 1886), Prince Alexander was kidnapped by conspirators in his palace at Sofia and conveyed secretly to Russian Bessarabia. As soon as the incident was reported to the Tsar, the Prince was released, and he at once returned to Sofia, where a counter-revolution had been effected in his favour; but he considered his position untenable, and formally abdicated. A fortnight after his departure General Kaulbars arrived from St Petersburg with instructions from the Tsar to restore order in accordance with Russian interests. In St Petersburg it was supposed that the Bulgarian people were still devoted to Russia, and that they were ready to rise against and expel the politicians of the Nationalist party led by Stambolof. General Kaulbars accordingly made a tour in the country and delivered speeches to the assembled multitudes, but Stambolof's political organization counteracted all his efforts, and on November 20 he left Bulgaria and took the Russian consuls with him. Stambolof maintained his position, suppressed energetically several insurrectionary movements, and succeeded in getting Prince Ferdinand of Coburg elected Prince (July 7, 1887), in spite of the opposition of Russia, who put forward as candidate a Russian subject, Prince Nicholas of Mingrelia. Prince Ferdinand was not officially recognized by the Sultan and the Powers, but he continued to reign under the direction of Stambolof, and the Russian Government, passively accepting the accomplished facts, awaited patiently a more convenient moment for action.

These events in the Balkan Peninsula necessarily affected the mutual relations of the Powers composing the Three Emperors' League. Austria could not remain a passive and disinterested spectator of the action of Russia in Bulgaria. Her agents gave a certain amount of support to Prince Alexander in his efforts to emancipate himself from Russian domination; and when the Prince was kidnapped and induced to abdicate, Count Kalnoky did not conceal his intention of opposing further aggression. Bismarck resisted the pressure brought to bear on him from several quarters in favour of the anti-Russian party in Bulgaria, but he was suspected by the Russians of siding with Austria and secretly encouraging the opposition to Russian influence. This revived the hatred against him which had been created by his pro-Austrian leanings after the Russo-Turkish War. The feeling was assiduously fomented by the Russian press, especially by M. Katkoff, the editor of the *Moscow Gazette*, who exercised great influence on public opinion and had personal relations with Alexander III. On July 31, 1886, three weeks before the kidnapping of Prince Alexander, he began a regular journalistic campaign against Germany, and advocated strongly a new orientation of Russian policy. M. de Giers,

Russian hostility to Germany.

Minister of Foreign Affairs, was openly attacked as a partisan of the German alliance, and his "pilgrimages to Friedrichsruh and Berlin" were compared to the humiliating journeys of the old Russian Grand Princes to the Golden Horde in the time of the Tartar domination. The moment had come, it was said, for Russia to emancipate herself from German diplomatic thraldom, and for this purpose a *rapprochement* with France was suggested. The idea was well received by the public, and it seemed to be not unpalatable to the Tsar, for the *Moscow Gazette* was allowed to continue its attacks on M. de Giers's policy of maintaining the German alliance. In Berlin such significant facts could not fail to produce uneasiness, because one of the chief aims of Bismarck's policy had always been to prevent a Russo-French *entente cordiale.* The German press were instructed to refute the arguments of their Russian colleagues, and to prove that if Russia had really lost her influence in the Balkan Peninsula, the fact was due to the blunders of her own diplomacy. The controversy had no practical result, and caused no serious estrangement between the Cabinets of Berlin and St Petersburg. When the Treaty of Skiernevice was about to expire in 1887, the Russian Government positively declined to renew the Three Emperors' League, but the seductive eloquence of the German Chancellor induced the Tsar to make a new secret treaty of alliance with Germany for three years; and feeling his hands strengthened by this new instrument Bismarck thought he might use pressure to obtain greater advantages. An attack was made in the press and elsewhere on Russian credit, which was rapidly gaining a footing in the Paris Bourse. In the use of this kind of pressure the German Government generally remained in the background, and even expressed its regret, but on one occasion it showed its hand plainly by prohibiting the Reichsbank from accepting Russian securities as guarantees. From that moment the Tsar's attitude changed. All his dormant suspicions of German policy revived. When he passed through Berlin in November 1887, Bismarck had a long audience, in which he defended himself with his customary ability, but Alexander III. remained unmoved in his conviction that the German Government had systematically opposed Russian interests, and had paralysed Russian action in the Balkan Peninsula for the benefit of Austria; and he failed to understand the ingenious theory put forward by the German Chancellor, that two Powers might have a severe economic struggle without affecting their political relations. Bismarck had to recognize that, for the moment at least, the Three Emperors' League, which had served his purposes so well, could not be resuscitated, but he had still a certain security against the hostility of Russia in the secret Russo-German defensive treaty of 1887, which had been concluded without the knowledge of Austria. Soon, however, this link was also to be broken. When the secret treaty expired in 1890 it was not renewed. By that time Bismarck had been dismissed, and he subsequently reproached his successor, Count Caprivi, with not having renewed it, but in reality Count Caprivi was not to blame. Alexander III. was determined not to renew the alliance, and was already gravitating slowly towards an understanding with France.

Franco-Russian entente.

No treaty or formal defensive engagement of any kind existed between Russia and France, but it was already tolerably certain that in the event of a great war the two nations would be found fighting on the same side, and the military authorities in both countries felt that if no arrangements were made beforehand for concerted action,—such arrangements having been long ago completed by the Powers composing the Triple Alliance,—they would begin the campaign at a great disadvantage. This was perfectly understood by both Governments; and after some hesitation on both sides, Generals Vannotski and Obrutchef, on the one side, and Generals Saussier, Miribel, and Boisdeffre on the other, were permitted to discuss plans of co-operation. At the same time a large quantity of Lebel rifles were manufactured in France for the Russian army, and the secret of making smokeless powder was communicated to the Russian military authorities. The French Government wished to go further and conclude a defensive alliance, but the Tsar was reluctant to bind himself with a Government which had so little stability, and which might be induced to provoke a war with Germany by the prospect of Russian support. Even the military convention was not formally ratified until 1894. The enthusiastic partisans of the alliance flattered themselves that the Tsar's reluctance had been overcome, when he received very graciously Admiral Gervais and his officers during the visit of the French fleet to Cronstadt in the summer of 1891, but their joy was premature. The formal *rapprochement* between the two Governments was much slower than the unofficial *rapprochement* between the two nations. More than two years passed before the Cronstadt visit was returned by the Russian fleet, under Admiral Avelan. The enthusiastic ovations which the admiral and his subordinates received in Toulon and Paris (October 1893) showed how eager and anxious the French people were for an alliance with Russia, but the Russian Government was in no hurry to gratify their wishes. Of the official action all we know with certainty is, that immediately after the Cronstadt visit in 1891 a diplomatic protocol about a defensive alliance was signed; that during the special mission of General Boisdeffre to St Petersburg in 1892 negotiations took place about a military convention; that in 1894 the military convention was ratified; that in the summer of 1895 M. Ribot, when Prime Minister, first spoke publicly of an alliance; and that during the visit of the President of the French Republic to St Petersburg, in August 1897, France and Russia were referred to as allies in the complimentary speeches of the Tsar and of M. Felix Faure. Though we are still in the dark as to the precise terms of the arrangement, there is no doubt that close friendly relations exist between the two Powers, and that in all important international affairs they seek to act in accord with each other. It is equally certain that hitherto Russia has been the predominant partner, and that, in accordance with the pacific tendencies of the Tsar, she has systematically exercised a restraining influence on France. The great expectations excited among the French people by the *entente cordiale* have consequently not been realized, and there have already been premonitory symptoms of a reaction in public opinion. So long, however, as the Triple Alliance of Germany, Austria, and Italy exists, the Dual Alliance of Russia and France is likely to be maintained as a measure of self-defence. England has persistently refrained from joining either group, in accordance with her traditional policy of making no alliances except for specific purposes; but as her interests in the East and in the Mediterranean conflict with those of Russia and France rather than with these of Germany, Austria, and Italy, she has a tendency to lean towards the Triple, rather than towards the Dual, Alliance.

The grouping of the great Continental States into two opposite but not necessarily hostile camps has helped to preserve the balance of power and the peace of Europe. Since the two groups were formed, the causes of conflict which have arisen from time to time have been localized. Among these may be specially mentioned the Armenian Question, the Cretan Question, the partition of Africa, and the conflicts of interest in the Far East.

The Armenian Question was brought prominently before Europe by the Russo-Turkish War of 1877–78. In the Treaties of San Stefano and Berlin the Sublime Porte undertook "to carry out without delay the ameliorations and reforms required by local needs in the provinces inhabited by the Armenians, and to guarantee their security against the Circassians and the Kurds." This stipulation remained a dead letter, and the relations between the Armenians and the Mussulmans became worse than before, because the protection of the Powers encouraged in the oppressed nationality far-reaching political aspirations, and the Sultan regarded the political aspirations and the intervention of the Powers as dangerous for the integrity and independence of his Empire. For some fifteen years the Armenians continued to hope in the efficacious intervention of their protectors, but when their patience became exhausted and the question seemed in danger of being forgotten, they determined to bring it again to the front. Some of them confined themselves to agitating abroad, especially in England, in favour of the cause, whilst others made preparations for exciting an insurrectionary movement in Constantinople and Asia Minor. These latter knew very well that an insurrection could be suppressed by the Turkish Government without much difficulty, but they hoped that the savage measures of repression which the Turks were sure to employ might lead to the active intervention of Europe and ensure their liberation from Turkish rule, as the famous "atrocities" of 1876 had led to the political emancipation of Bulgaria. In due course—1895–96—the expected attrocities took place, in the form of wholesale massacres in Constantinople and various towns of Asia Minor. The Sultan was subjected to diplomatic pressure and threatened with more efficient means of coercion. In the diplomatic campaign England took the lead, and was warmly supported by Italy, but Germany, Austria, and France showed themselves lukewarm, not to say indifferent, and Russia, departing from her traditional policy of protecting the Christians of Turkey, vetoed the employment of force for extracting concessions from the Sultan. In these circumstances the Porte naturally confined itself to making a few reforms on paper, which were never carried out. Thus the last state of the Armenians was worse than the first, but the so-called European Concert was maintained, and the danger of a great European war was averted.

Armenia.

The next attempt to raise the Eastern Question was made by the Greeks. In 1896 a semi-secret society called the Ethniké Hetairia began a Panhellenic agitation, and took advantage of one of the periodical insurrections in Crete to further its projects. In February 1897 the Cretan revolutionary committee proclaimed the annexation of the island to the Hellenic Kindgom, and a contingent of Greek regular troops landed near Canea under the command of Colonel Vassos to take possession of the island in the name of King George. The Powers, objecting to this arbitrary proceeding, immediately occupied Canea with a mixed force from the ships of war which were there at the time, and summoned the Greek Government to withdraw its troops. The summons was disregarded, and the whole of the Greek army was mobilized on the frontier of Thessaly and Epirus. In consequence of a raid into Turkish territory the Porte declared war on 17th April, and the short campaign ended in the defeat of the Greeks. The Powers intervened to put an end to the hostilities, and after prolonged negotiations a peace was concluded by which Greece had to consent to a strategical rectification of frontier and to pay a war indemnity of £4,000,000. Thus a second time the European Concert acted effectually in the interests of peace, but it did not stand the strain of the subsequent efforts to solve the Cretan Question. Finding the Turks less conciliatory after their military success, and being anxious to remain in cordial relations with the Porte, Germany withdrew from further co-operation with the Powers, and Austria followed her example. They did not, however, offer any active opposition, and the question received a temporary solution by the appointment of Prince George, second son of the King of Greece, as High Commissioner and Governor-General of the island.

Crete.

During the period under review the friendly relations of the leading European Powers were frequently troubled by the conflicting desires of several of these Powers to obtain colonial possessions in various parts of the world, and to forestall their competitors in the act of taking possession. In the complications of this kind England, as the greatest of Colonial Powers, was generally involved; and as the unappropriated portions of the earth's surface at the beginning of the period in question were to be found chiefly in Africa, it was in the Dark Continent that the conflicts of interests mostly took place. England's chief competitors were France and Germany. Her traditional policy, except in the south of the continent, where the conditions of soil and climate were favourable to European colonists, has been purely commercial. She had refrained from annexation of territory, as involving too much expenditure and responsibility, and confined her protection to the trading stations on the coast. When France came into the field this policy had to be abandoned. The policy of France was also commercial in a certain sense, but the methods she adopted were very different. Feeling that she could not compete with England on equal terms, she endeavoured to bring under her authority, by annexation or the establishment of protectorates, the largest possible extent of territory, in order to increase her trade by a system of differential tariffs; and not content with holding long strips of coast, she systematically encroached on the hinterland of British settlements, and endeavoured to direct artificially the native inland trade towards her own ports. A glance at the map of the African West Coast will suffice to show the success with which this policy has been carried out. When the British Government awoke to the danger, it was too late to prevent the evil. All that could be done was to prevent further encroachments by likewise annexing territory and creating protectorates. The final result has been a series of delimitation treaties, which are dealt with in the article AFRICA, HISTORY. In her dealings with France about the partition of Africa, England was generally very conciliatory, but on one point she felt the necessity of being firm, namely, regarding the two entrances to the Mediterranean. France has long coveted the possession of Morocco, but she has powerful rivals in the field, and she is well aware that an attempt to gain possession of Tangier, or any other part of the south coast of the Straits of Gibraltar, would meet with determined opposition from England. In like manner the eastern entrance to the Mediterranean by the Suez Canal is carefully watched. When England in 1882 considered it necessary to suppress the Arabi insurrection, she invited France to co-operate, but the French Government declined, and left the work to be done by England alone. England had no intention of occupying the country permanently, but she had to take precautions against the danger of French occupation after her withdrawal, and these precautions were embodied in an Anglo-Turkish Convention signed at Constantinople in May 1887. France prevented the ratification of the Convention by the Sultan, with the result that the British occupation has been indefinitely prolonged. She still clung persistently, however, to the hope of obtaining a

Africa.

predominant position in the valley of the Nile, and she tried to effect her purpose by gaining a firm foothold on the upper course of the river. The effort which she made in 1898 to attain this end, by simultaneously despatching the Marchand Mission from her Congo possessions and inciting the Emperor Menelek of Abyssinia to send a force from the east to join hands with Major Marchand at Fashoda, was defeated by the overthrow of the Mahdi and the British occupation of Khartum. For a few days the two nations seemed on the brink of war, but the French Government, receiving no encouragement from St Petersburg, consented to withdraw the Marchand Mission, and a convention was signed defining the respective spheres of influence of the two countries.

With Germany likewise, from 1880 onwards, England had some diplomatic difficulties regarding the partition of Africa, but they never reached a very acute phase, and were ultimately settled by mutual concessions. By the arrangement of 1890, in which several of the outstanding questions were solved, Heligoland was ceded to Germany in return for concessions in East Africa. A conflict of interest in the Southern Pacific was amicably arranged by the Anglo-German Convention of April 1886, in which a line of demarcation was drawn between the respective spheres of influence in the islands to the north and east of the Australian continent, and by the Convention of 1899, in virtue of which Germany gained possession of Samoa and renounced in favour of England all pretensions to the Tonga Archipelago.

Asia.

In Asia the tendencies of the European Powers to territorial expansion, and their desire to secure new markets for their trade and industry, have affected from time to time their mutual relations. More than once England and Russia have had disputes about the limits of their respective spheres of influence in Central Asia, but the causes of friction have steadily diminished as the work of frontier delimitation has advanced. The important agreement of 1872–73 was supplemented by the Protocol of 22nd July 1887 and the Pamir delimitation of 1895, so that the Russo-Afghan frontier, which is the dividing line between the Russian and British spheres of influence, has now been carried right up to the frontier of the Chinese Empire. The delimitation of the English and French spheres of influence in Asia has also progressed. In 1885 France endeavoured to get a footing on the Upper Irrawaddy, the hinterland of British Burma, and England replied in the following year by annexing the dominions of King Thebaw, including the Shan States as far east as the Mekong. Thereupon France pushed her Indo-Chinese frontier westwards, and in 1893 made an attack on the Kingdom of Siam, which very nearly brought about a conflict with England. After prolonged negotiations an arrangement was reached and embodied in a formal treaty (Jan. 1896), which clearly foreshadows a future partition between the two Powers, but guarantees the independence of the central portion of the kingdom, the Valley of the Menam, as a buffer-state. Further north, in Eastern China, the aggressive tendencies and mutual rivalries of the European Powers have produced a problem of a much more complicated kind. Firstly Germany, then Russia, next England, and finally France took portions of Chinese territory, under the thin disguise of long leases. They thereby excited in the Chinese population and Government an intense anti-foreign feeling, which produced the Boxer movement and culminated in the attack on the foreign legations at Pekin in the summer of 1900. An account of these events will be found in the article on CHINA.

In 1899–1901 the relations of the European Powers were disturbed by the war in South Africa. In nearly every country of Europe popular feeling was much excited against England, and in certain influential quarters the idea was entertained of utilizing this feeling for the formation of a coalition against the British Empire; but in view of the decided attitude assumed by the British Government, and the loyal enthusiasm displayed by the Colonies, no foreign Government ventured to take the initiative of intervention, and it came gradually to be recognized that no European state had any tangible interest in prolonging the independence and maladministration of the Boer Republics. One permanent factor in the history of Europe during the last thirty years has been the constant increase of armaments by all the great Powers, and the proportionate increase of taxation. The fact made such an impression on the young Emperor of Russia, Nicholas II., that he invited the Powers to consider whether the further increase of the burdens thereby imposed on the nations might not be arrested by mutual agreement; and a Conference for this purpose was convened at The Hague (18th May–29th July 1899), but the desirable object in view was not attained. (See ARBITRATION, INTERNATIONAL.) (D. M. W.)

Eutaw Springs, a village of Berkeley county, South Carolina, U.S.A. The Atlantic Coast Railway connects it with Charleston and its fine harbour. One of the battles of the Revolutionary War was fought here, 8th September 1781; the Americans losing 554, the British, 1000.

Eutin, a town of Prussia, capital of the principality of Lübeck, belonging to the grand duchy of Oldenburg. It is situated as an enclave in the most picturesque part of Holstein, 20 miles north from the city of Lübeck by the railway to Kiel. It dates from the 12th century, and possesses a grand ducal castle, with a fine park, and a monument to Weber, the musician, who was born here in 1786. Towards the end of the 18th century Eutin acquired some fame as the residence of a group of contemporary poets and writers, of whom the best known were Voss, the two Stolbergs, and F. H. Jacobi. Population (1900), 5204.

Evangelical Alliance.—This alliance, which is not a religious "denomination" but an association of individual members of various Christian bodies, continues its effort to "enable Christians of different denominations and in all countries to realize in themselves, and to exhibit to others, that living and essential union which binds all true believers together in the fellowship of Christ," meanwhile endeavouring to counteract "Infidelity, Romanism, and Ritualism, and the desecration of the Lord's Day." General conferences of the whole Alliance were held at Basle 1879, Copenhagen 1884, Florence 1891, and London 1896; and the fifty-fourth annual conference of the British organization was held in October 1900. The objects of the Alliance are now sometimes stated as follows:—(*a*) *The world girdled by prayer*: a world-wide week of prayer is held annually, beginning on the first Sunday in the year. (*b*) *The maintenance of religious liberty throughout the world.* (*c*) *The relief of persecuted Christians in all parts*: the Alliance has agents in many countries to help the persecuted, distribute relief, &c., and in Russia there is a travelling agent who endeavours to help the Stundists. (*d*) *The manifestation of the unity of all believers and the upholding of the evangelical faith.* The following publications may be mentioned:—*The Evangelical Alliance Magazine*, *The Evangelical Alliance Quarterly*, both published in London, and *Jubilee of the Evangelical Alliance*, London, 1897.

Evans, Sir John (1823-——), English archæologist, son of the Rev. Dr. Evans, headmaster of

Market Bosworth Grammar School, was born at Britwell Court, 17th November 1823. He was for many years head of the extensive paper manufactory at Nash Mills, Hemel Hempstead, still carried on by his family, but is especially distinguished as an antiquary and numismatist. He is the author of three books, standard in their respective departments, *The Coins of the Ancient Britons*, 1864; *The Ancient Stone Implements, Weapons, and Ornaments of Great Britain*, 1872; and *The Ancient Bronze Implements, Weapons, and Ornaments of Great Britain and Ireland*, 1881. He has also written a number of separate papers on archæological subjects. He was President of the Society of Antiquaries from 1885 to 1892, and has been President of the Numismatic Society since 1875; he has also presided over the Geological Society and the Anthropological Institute, and is a trustee of the British Museum. He was made a K.C.B. in 1892. His eldest son, Arthur John, born in 1851, has been keeper of the Ashmolean Museum at Oxford since 1884, and has taken a prominent part in the recent archæological discoveries in Crete.

Evanston, a town of Cook county, Illinois, U.S.A., north of Chicago, of which it is a suburb, on the shore of Lake Michigan, and connected with Chicago by branches of the Chicago and North-Western and the Chicago, Milwaukee, and St Paul Railways. It is the seat of North-Western University, a flourishing Methodist Episcopal coeducational institution, founded in 1855, of which the schools of medicine, law, pharmacy, and dentistry are located at Chicago. In 1900 its corps of professors and instructors in all departments numbered 265, and the students in attendance 2246, about one-quarter of whom were women; 643 of the students were in the academic department and the remainder in the professional departments. Population (1880), 6703; (1900), 19,259.

Evansville, capital of Vanderburg county, Indiana, U.S.A., in 38°·00 N. lat. and 87°·30 W. long., on the north bank of Ohio river, at an altitude of 400 feet. The site of the city is the level valley of the Ohio; the street plan is regular, and the houses are numbered on the decimal plan; the city is supplied with water by the Holly pumping system, and is well sewered. The central part of the city is well paved with brick. It is the most important commercial and manufacturing city of Southern Indiana, and the second city in population in the State. It has eight railways, affording communication in all directions, and these, with the Ohio river, which is open and navigable at all times of the year, afford excellent avenues for trade. The invested manufacturing capital was, in 1890, $9,166,859; 7435 hands were employed; and the product was valued at $12,809,334. The principal products were clothing, flour, iron and steel goods, lumber and leather goods. The assessed valuation of real and personal property was, in 1900, $25,321,680, the net debt of the city was $2,144,937, and the rate of taxation $27.80 per $1000. Population (1880), 29,280; (1900), 59,007, of whom 7518 were negroes. The death-rate in 1900 was 17·7.

Evarts, William Maxwell (1818–1901), American lawyer, was born in Boston, 6th February 1818. He graduated at Yale in 1837, was admitted to the Bar in New York in 1841, and soon took high rank in his profession. In 1860 he was chairman of the New York delegation to the Republican national convention. In 1861 he was an unsuccessful candidate for the United States senatorship from New York. He was chief counsel for President Johnson during the impeachment trial, and from July 1868 until March 1869 he was Attorney-General of the United States. In 1872 he was counsel for the United States in the *Alabama* arbitration. During President Hayes's administration, 1877–81, he was Secretary of State; and from 1885 to 1891 he was one of the senators from New York. As an orator Senator Evarts stood in the foremost rank, and some of his best speeches were published. He died on 28th February 1901.

Everett, a city of Middlesex county, Massachusetts, U.S.A., a few miles north of Boston, and adjoining Malden, of which it formed a part until 1870, when it was incorporated as a town. It received a city charter in 1893. It has an undulating surface, and its street plan is irregular. It is on a branch of the Boston and Maine Railway. Its manufactures, according to the State census of 1895, employed a capital of $714,757, with 807 hands, and produced goods valued at $1,884,193. Population (1880), 4159; (1900), 24,336, of whom 6882 were foreign-born.

Everett, a city of Snohomish county, Washington, U.S.A., on Puget Sound. At this point the main transcontinental line of the Great Northern Railway reaches the western coast, whence it turns southwards to Seattle and northwards to Vancouver. Regular steamboat lines connect Everett with Seattle, Tacoma, and other Puget Sound ports. It has a good harbour and some commerce; in manufactures it has several large lumber and shingle mills, and a smelter, which is supplied with ores from the Cascade range. The city is of very recent growth. Population (1900), 7838, of whom 1677 were foreign-born.

Eversley, Charles Shaw Lefevre, Viscount (1794–1888), Speaker of the British House of Commons, only son of Mr Charles Shaw (who assumed his wife's name of Lefevre in addition to his own on his marriage), was born in London on 27th February 1794, and educated at Winchester and at Trinity College, Cambridge. He was called to the Bar in 1819, and though a diligent student was also a keen sportsman. Marrying a daughter of Mr Samuel Whitbread, whose wife was the sister of Earl Grey, afterwards Premier, he thus became connected with two influential political families, and in 1830 he entered the House of Commons as member for Downton, in the Liberal interest. In 1831 he was returned, after a severe contest, as one of the county members for Hampshire, in which he resided; and after the passing of the Reform Act of 1832 he was elected for the Northern Division of Hampshire. For some years Mr Shaw Lefevre was Chairman of a Committee on Petitions for Private Bills. In 1835 he was Chairman of a Committee on Agricultural Distress, but as his report was not accepted by the House, he published it as a pamphlet addressed to his constituents. He acquired a high reputation in the House of Commons for his judicial fairness, combined with singular tact and courtesy, and when Mr Speaker Abercromby suddenly retired in 1839, he was nominated as the Liberal candidate for the chair. The Conservatives put forward Mr Goulburn, but Mr Shaw Lefevre was elected by 317 to 299 votes. The period was one of fierce party conflict, and the debates were frequently very acrimonious; but the dignity, temper, and firmness of the new Speaker were never at fault. In 1857 he had served longer than any of his predecessors except the celebrated Arthur Onslow, and retired on a pension, being raised to the peerage as Viscount Eversley of Heckfield, in the county of Southampton. His appearances in the House of Lords were very infrequent, but in his own county he was active in the public service. From 1859 he was an Ecclesiastical Commissioner, and he was also appointed a Trustee of the British Museum. He died on 29th December 1888, the title becoming extinct. (G. B. S.)

Evesham, a municipal borough and market town in the Evesham parliamentary division (since 1885) of Worcestershire, England, on the Avon, 15 miles south-east by east of Worcester by rail. A cottage hospital, a sanatorium, and a Catholic church have been erected. The Evesham Institute Buildings have been acquired by the Corporation and opened as a free library and for classes of technical education; and the grammar school has been reorganized. Area, 2265 acres; population (1881), 5112; (1901), 7100.

EVIDENCE, LAW OF.

EVIDENCE may be described briefly as consisting of facts presented to the mind of a person for the purpose of enabling him to decide a disputed question of fact. Evidence in the widest sense includes all such facts. In a narrower sense it includes only such facts as are allowed by English law to be so presented in the course of judicial proceedings. Thus we say that a fact is not evidence, meaning thereby that it is not admissible as evidence in accordance with the rules of English law. The law of evidence is part of the law of procedure. It determines the kinds of evidence which may be produced in judicial proceedings, and regulates the mode in which, and the conditions under which, evidence may be produced and tested.

History. The English law of evidence is of comparatively modern growth. It enshrines certain maxims, some derived from Roman law, some invented by Coke, who, as Mr. Thayer says, "spawned Latin maxims freely." But for the most part it was built up by English judges in the course of the 18th century, and consists of this judge-made law, as modified by statutory enactments of the 19th century. Early Teutonic procedure knew nothing of evidence in the modern sense, just as it knew nothing of trials in the modern sense. What it knew was "proofs." There were two modes of proof, ordeals and oaths. Both were appeals to the supernatural. The judicial combat was a bilateral ordeal. Proof followed, instead of preceding, judgment. A judgment of the court, called by German writers the *Beweis-urtheil*, and by Mr Bigelow the "medial judgment," awarded that one of the two litigants must prove his case, by his body in battle, or by a one-sided ordeal, or by an oath with oath-helpers, or by the oaths of witnesses. The court had no desire to hear or weigh conflicting testimony. To do so would have been to exercise critical faculties, which the court did not possess, and the exercise of which would have been foreign to the whole spirit of the age. The litigant upon whom the burden of furnishing proof was imposed had a certain task to perform. If he performed it, he won; if he failed, he lost. The number of oath-helpers varied in different cases, and was determined by the law or by the court. They were probably, at the outset, kinsmen, who would have had to take up the blood-feud. At a later stage they became witnesses to character. In the cases, comparatively rare, where the oaths of witnesses were admitted as proof, their oaths differed materially from the sworn testimony of modern courts. As a rule no one could testify to a fact unless, when the fact happened, he was solemnly "taken to witness." Then, when the witness was adduced, he came merely to swear to a set formula. He did not make a promissory oath to answer questions truly. He merely made an assertory oath in a prescribed form.

In the course of the 12th and 13th centuries the old formal, accusatory procedure began to break down, and to be superseded by another form of procedure known as *inquisitio*, inquest, or *enquête*. Its decay was hastened by the decree of the fourth Lateran Council in 1215, which forbade ecclesiastics to take part in ordeals. The Norman administrative system introduced into England by the Conquest was familiar with a method of ascertaining and determining facts by means of a verdict, return, or finding made on oath by a body of men drawn from the locality. The system may be traced to Carolingian, and even earlier, sources. Henry II., by instituting the Grand Assize and the four petty assizes, placed at the disposal of litigants in certain actions the opportunity of giving proof by the verdict of a sworn inquest of neighbours, proof "by the country." The system was gradually extended to other cases, criminal as well as civil. The verdict given was that of persons having a general, but not necessarily a particular, acquaintance with the persons, places, and facts to which the inquiry related. It was, in fact, a finding by local popular opinion. Had the finding of such an inquest been treated as final and conclusive in criminal cases, English criminal procedure might, like the Continental inquisition, the French *enquête*, have taken the path which, in the forcible language of Fortescue (De Laudibus, &c.) "leads to hell" (*Semita ipsa est ad gehennam*). Fortunately English criminal procedure took a different course. The spirit of the old accusatory procedure was applied to the new procedure by inquest. In serious cases the words of the jurors, the accusing jurors, were treated not as testimony, but as accusation, the new indictment was treated as corresponding to the old appeal, and the preliminary finding by the accusing jury had to be supplemented by the verdict of another jury. In course of time the second jury were required to base their findings not on their own knowledge, but on evidence submitted to them. Thus the modern system of inquiry by grand jury and trial by petty jury was gradually developed.

A few words may here be said about the parallel development of criminal procedure on the Continent. The tendency in the 12th and 13th centuries to abolish the old formal methods of procedure, and to give the new procedure the name of inquisition or inquest, was not peculiar to England. Elsewhere the old procedure was breaking down at the same time, and for similar reasons. It was the great pope Innocent III., the pope of the fourth Lateran Council, who introduced the new inquisitorial procedure into the canon law. The procedure was applied to cases of heresy, and, as so applied, especially by the Dominicans, speedily assumed the features which made it infamous. "Every safeguard of innocence was abolished or disregarded; torture was freely used. Everything seems to have been done to secure a conviction." Yet, in spite of its monstrous defects, the inquisitorial procedure of the ecclesiastical courts, secret in its methods, unfair to the accused, having torture as an integral element, gradually forced its way into the temporal courts, and may almost be said to have been adopted by the common law of western Europe. In connexion with this inquisitorial procedure Continental jurists elaborated a theory of evidence, or judicial proofs, which formed the subject of an extensive literature. Under the rules thus evolved full proof (*plena probatio*) was essential for conviction, in the absence of confession, and the standard of full proof was fixed so high that it was in most cases unattainable. It therefore became material to obtain confession by some means or other. The most effective means was torture, and thus torture became an essential feature in criminal procedure. The rules of evidence attempted to graduate the weight to be attached to different kinds of testimony and almost to estimate that weight in numerical terms. "*Le parlement de Toulouse*," said Voltaire, "*a un usage très singulier dans les preuves par témoins. On admet ailleurs des demi-preuves, . . . mais à Toulouse on admet des quarts et des huitièmes de preuves.*" Modern Continental procedure, as embodied in the most recent codes, has removed the worst features of inquisitorial procedure, and has shaken itself free from the trammels imposed by the old theory and technical rules of proof. But in this, as in other branches of law, France seems to have paid the penalty for having been first in the field with codification by lagging behind in material reforms. The French Code of Criminal Procedure was largely based on Colbert's Ordonnance of 1670, and though embodying some reforms, and since amended on certain points, still retains some of the features of the unreformed procedure which was condemned in the 18th century by Voltaire and the *philosophes*. Military procedure is in the rear of civil procedure, and the trial of Dreyfus at Rennes presented some interesting archaisms. Among these were the weight attached to the rank and position of witnesses as compared with the intrinsic character of their evidence, and the extraordinary importance attributed to confession even when made under suspicious circumstances and supported by flimsy evidence.

The history of criminal procedure in England has been traced by Sir James Stephen. The modern rules and practice as to evidence and witnesses in the Common Law courts, both in civil and in criminal cases, appear to have taken shape in the course of the 18th century. The first systematic treatise on the English law of evidence appears to have been written by Chief Baron Gilbert, who died in 1726, but whose *Law of Evidence* was not published until 1761. In writing it he is said to have been much influenced by Locke.[1] It is highly praised by Black-

[1] Reference may be made to a well-known passage in the *Essay*

stone as "a work which it is impossible to abstract or abridge without losing some beauty and destroying the charm of the whole"; but Bentham, who rarely agrees with Blackstone, speaks of it as running throughout "in the same strain of anility, garrulity, narrow-mindedness, absurdity, perpetual misrepresentation, and indefatigable self-contradiction." In any case it remained the standard authority on the law of evidence throughout the remainder of the 18th century. Bentham wrote his *Rationale of Judicial Evidence, specially applied to English Practice,* at various times between the years 1802 and 1812. By this time he had lost the nervous and simple style of his youth, and required an editor to make him readable. His great interpreter, Dumont, condensed his views on evidence into the *Traité des Preuves Judiciaires,* which was published in 1823. The manuscript of the *Rationale* was edited for English reading, and to a great extent rewritten, by J. S. Mill, and was published in five volumes in 1827. The book had a great effect both in England and on the Continent. The English version, though crabbed and artificial in style, and unmeasured in its invective, is a storehouse of comments and criticisms on the principles of evidence and the practice of the courts, which are always shrewd and often profound. Bentham examined the practice of the courts by the light of practical utility. Starting from the principle that the object of judicial evidence is the discovery of truth, he condemned the rules which excluded some of the best sources of evidence. The most characteristic feature of the common-law rules of evidence, was, as Bentham pointed out, and, indeed, still is, their exclusionary character. They excluded and prohibited the use of certain kinds of evidence which would be used in ordinary inquiries. In particular, they disqualified certain classes of witnesses on the ground of interest in the subject-matter of the inquiry, instead of treating the interest of the witness as a matter affecting his credibility. It was against this confusion between competency and credibility that Bentham directed his principal attack. He also attacked the system of paper evidence, evidence by means of affidavits instead of by oral testimony in court, which prevailed in the Court of Chancery, and in ecclesiastical courts. Subsequent legislation has endorsed his criticisms. The Judicature Acts have reduced the use of affidavits in Chancery proceedings within reasonable limits. A series of Acts of Parliament have removed, step by step, almost all the disqualifications which formerly made certain witnesses incompetent to testify.

Before Bentham's work appeared, an Act of 1814 (54 Geo. III. c. 170, s. 9) had removed the incompetency of ratepayers as witnesses in certain cases relating to parishes. The Civil Procedure Act, 1833, enacted that a witness should not be objected to as incompetent solely on the ground that the verdict or judgment would be admissible in evidence for or against him. An Act of 1840 (3 and 4 Vict. c. 26) removed some doubts as to the competency of ratepayers to give evidence in matters relating to their parish. The Evidence Act, 1843, enacted broadly that witnesses should not be excluded from giving evidence by reason of incapacity from crime or interest. The Evidence Act, 1851, made parties to legal proceedings admissible witnesses subject to a proviso that "nothing herein contained shall render any person who in any criminal proceeding is charged with the commission of any indictable offence, or any offence punishable on summary conviction, competent or compellable to give evidence for or against himself or herself, or shall render any person compellable to answer any question tending to criminate himself or herself, or shall in any criminal proceeding render any husband competent or compellable to give evidence for or against his wife, or any wife competent or compellable to give evidence for or against her husband." The Evidence (Scotland) Act, 1853, made a similar provision for Scotland. The Evidence Amendment Act, 1853, made the husbands and wives of parties admissible witnesses, except that husbands and wives could not give evidence for or against each other in criminal proceedings or in proceedings for adultery, and could not be compelled to disclose communications made to each other during marriage. Under the Matrimonial Causes Act, 1857, the petitioner can be examined and cross-examined on oath at the hearing, but is not bound to answer any question tending to show that he or she has been guilty of adultery. Under the Matrimonial Causes Act, 1859, on a wife's petition for dissolution of marriage on the ground of adultery coupled with cruelty or desertion, husband and wife are competent and compellable to give evidence as to the cruelty or desertion. The Crown Suits &c. Act, 1865, declared that revenue proceedings were not to be treated as criminal proceedings for the purposes of the Acts of 1851 and 1853. The Evidence Further Amendment Act, 1869, declared that parties to actions for breach of promise of marriage were competent to give evidence in the action, subject to a proviso that the plaintiff should not recover unless his or her testimony was corroborated by some other material evidence. It also made the parties to proceedings instituted in consequence of adultery, and their husbands and wives, competent to give evidence, but a witness in any such proceeding, whether a party or not, is not to be liable to be asked or bound to answer any question tending to show that he or she has been guilty of adultery, unless the witness has already given evidence in the same proceeding in disproof of the alleged adultery. There are similar provisions applying to Scotland in the Conjugal Rights (Scotland) Amendment Act, 1861, and the Evidence Further Amendment (Scotland) Act, 1874. The Evidence Act, 1877, enacts that "on the trial of any indictment or other proceeding for the non-repair of any public highway or bridge, or for a nuisance to any public highway, river, or bridge, and of any other indictment or proceeding instituted for the purpose of trying or enforcing a civil right only, every defendant to such indictment or proceeding, and the wife or husband of any such defendant shall be admissible witnesses and compellable to give evidence." From 1872 onwards numerous enactments were passed making persons charged with particular offences, and their husbands and wives, competent witnesses. The language and effect of these enactments were not always the same, but the insertion of some provision to this effect in an Act creating a new offence, especially if it was punishable by summary proceedings, gradually became almost a common form in legislation. In the year 1874 a bill to generalize these particular provisions, and to make the evidence of persons charged with criminal offences admissible in all cases was introduced by Mr Gladstone's Government, and was passed by the Standing Committee of the House of Commons. During the next fourteen years bills for the same purpose were repeatedly introduced, either by the Government of the day, or by Lord Bramwell as an independent member of the House of Lords. Finally, the Criminal Evidence Act, 1898, introduced by Lord Halsbury, has enacted in general terms that "every person charged with an offence, and the wife or husband, as the case may be, of the person so charged, shall be a competent witness for the defence at every stage of the proceedings, whether the person so charged is charged solely or jointly with any other person." But this general enactment is qualified by some special restrictions, the nature of which will be noticed below. The Act applies to Scotland but not to Ireland. It was not to apply to proceedings in courts-martial unless so applied by general orders or rules made under statutory authority. The provisions of the Act have been applied by rules to military courts-martial, but have not yet been applied to naval courts-martial. The removal of disqualifications for want of religious belief is referred to below under the head of "Witnesses."

The Act of 1898 finishes for the present the history of legislation on evidence. For a view of the legal literature on the subject it is necessary to take a step backwards.

Literature.

Early in the 19th century Chief Baron Gilbert was superseded as an authority on the English law of evidence by the books of Phillips (1814) and Starkie (1824), who were followed by Roscoe (*Nisi Prius,* 1827; *Criminal Cases,* 1835), Greenleaf (American, 1842), Taylor (based on Greenleaf, 1848), and Best (1849). In 1876 Sir James FitzJames Stephen brought out his *Digest of the Law of Evidence,* based upon the Indian Evidence Act, 1872, which he had prepared and passed as law member of the Council of the Governor-General of India. This Digest obtained a rapid and well-deserved success, and has materially influenced the form of subsequent writings on the English law of evidence. It sifted out what Stephen conceived to be the main rules of evidence from the mass of extraneous matter in which they had been embedded. Roscoe's Digests told the lawyer what things must be proved in order to sustain particular actions or criminal charges, and related as much to pleadings and to substantive law as to evidence proper. Taylor's two large volumes were a vast storehouse of useful information, but his book was one to consult, not to master. Stephen eliminated much of this extraneous matter, and summed up his rules in a series of succinct propositions, supplemented by apt illustrations, and couched in such a form that they could be easily read and remembered. Hence the English Digest, like the Indian Act, has been of much educational value. Its most original feature, but unfortunately also its weakest point, is its theory of relevancy. Pondering the multitude of "exclusionary" rules which had been laid down by the English courts, Stephen thought that he had discovered the general principle on which those rules reposed, and could devise a formula by which the principle could be expressed. "My study of the subject," he says, "both practically and in books has convinced me that the doctrine that all facts in issue

---

concerning Human Understanding (Book iv. ch. xv.):—"The grounds of probability are—First, the conformity of anything with our own knowledge, observation, and experience. Second, the testimony of others touching their observation and experience. In the testimony of others is to be considered (1) the number. (2) The integrity. (3) The skill of the witnesses. (4) The design of the author, where it is a testimony out of a book cited. (5) The consistency of the parts and circumstances of the relation. (6) Contrary testimonies."

and relevant to the issue, and no others, may be proved, is the unexpressed principle which forms the centre of and gives unity to all the express negative rules which form the great mass of the law." The result was the chapter on the Relevancy of Facts in the Indian Evidence Act, and the definition of relevancy in s. 7 of that Act. This definition was based on the view that a distinction could be drawn between things which were and things which were not causally connected with each other, and that relevancy depended on causal connexion. Subsequent criticism convinced Stephen that his definition was in some respects too narrow and in others too wide, and eventually he adopted a definition out of which all reference to causality was dropped. But even in their amended form the provisions about relevancy are open to serious criticism. The doctrine of relevancy, *i.e.*, of the probative effect of facts, is a branch of logic, not of law, and is out of place both in an enactment of the Legislature and in a compendium of legal rules. The necessity under which Stephen found himself of extending the range of relevant facts by making it include facts "deemed to be relevant," and then narrowing it by enabling the judge to exclude evidence of facts which are relevant, illustrates the difference between the rules of logic and the rules of law. Relevancy is one thing; admissibility is another; and the confusion between them, which is much older than Stephen, is to be regretted. Rightly or wrongly English judges have, on practical grounds, declared inadmissible evidence of facts, which are relevant in the ordinary sense of the term, and which are so treated in non-judicial inquiries. Under these circumstances the attempt so to define relevancy as to make it conterminous with admissibility is misleading, and most readers of Stephen's Act and Digest would find them more intelligible and more useful if "admissible" were substituted for "relevant" throughout. Indeed it is hardly too much to say that Stephen's doctrine of relevancy is theoretically unsound and practically useless. The other parts of the work contain terse and vigorous statements of the law, but a Procrustean attempt to make legal rules square with a preconceived theory has often made the language and arrangement artificial, and the work, in spite of its compression, still contains rules which, under a more scientific treatment, would find their appropriate place in other branches of the law. These defects are characteristic of a strong and able man, who saw clearly, and expressed forcibly what he did see, but was apt to ignore or to deny the existence of what he did not see, whose mind was vigorous rather than subtle or accurate, and who, in spite of his learning, was somewhat deficient in the historical sense. But notwithstanding these defects, the conspicuous ability of the author, his learning, and his practical experience, especially in criminal cases, attach greater weight to FitzJames Stephen's statements than to those of any other English writer on the law of evidence.

Before proceeding to summarize the existing rules of the law of evidence, it may be useful to make some preliminary remarks.

Rules.

The object of every trial is, or may be, to determine two classes of questions or issues, which are usually distinguished as questions of law, and questions of fact, although the distinction between them is not so clear as might appear on a superficial view. In a trial by jury these two classes of questions are answered by different persons. The judge lays down the law. The jury, under the guidance of the judge, find the facts. It was with reference to trial by jury that the English rules of evidence were originally framed; it is by the peculiarities of this form of trial that many of them are to be explained; it is to this form of trial alone that some of the most important of them are exclusively applicable. The negative, exclusive, or exclusionary rules which form the characteristic features of the English law of evidence, are the rules in accordance with which the judge guides the jury. There is no difference of principle between the method of inquiry in judicial and in non-judicial proceedings. In either case a person who wishes to find out whether a particular event did or did not happen, tries, in the first place, to obtain information from persons who were present and saw what happened (direct evidence), and, failing this, to obtain information from persons who can tell him about facts from which he can draw an inference as to whether the event did or did not happen (indirect evidence). But in judicial inquiries the information given must be given on oath, and be liable to be tested by cross-examination. And there are rules of law which exclude from the consideration of the jury certain classes of facts which, in an ordinary inquiry, would, or might, be taken into consideration. Facts so excluded are said to be "not admissible as evidence," or "not evidence," according as the word is used in the wider or in the narrower sense. And the easiest way of determining whether a fact is or is not evidence in the narrower sense, is first to consider whether it has any bearing on the question to be tried, and, if it has, to consider whether it falls within any one or more of the rules of exclusion laid down by English law. These rules of exclusion are peculiar to English law and to systems derived from English law. They have been much criticized, and some of them have been repealed or materially modified by legislation. Most of them may be traced to directions given by a judge in the course of trying a particular case, given with special reference to the circumstances of that case, but expressed in general language, and, partly through the influence of text-writers, eventually hardened into general rules. In some cases their origin is only intelligible by reference to obsolete forms of pleading or practice. But in most cases they were originally rules of convenience laid down by the judge for the assistance of the jury. The judge is a man of trained experience, who has to arrive at a conclusion with the help of twelve untrained men, and who is naturally anxious to keep them straight, and give them every assistance in his power. The exclusion of certain forms of evidence assists the jury by concentrating their attention on the questions immediately before them, and by preventing them from being distracted or bewildered by facts which either have no bearing on the question before them, or have so remote a bearing on those questions as to be practically useless as guides to the truth. It also prevents a jury from being misled by statements the effect of which, through the prejudice they excite, is out of all proportion to their true weight. In this respect the rules of exclusion may be compared to blinkers, which keep a horse's eyes on the road before him. In criminal cases the rules of exclusion secure fair play to the accused, because he comes to the trial prepared to meet a specific charge, and ought not to be suddenly confronted by statements which he had no reason to expect would be made against him. They protect absent persons against statements affecting their character. And lastly they prevent the infinite waste of time which would ensue in the discussion of a question of fact if an inquiry were allowed to branch out into all the subjects with which that fact is more or less connected. The purely practical grounds on which the rules are based, according to the view of a great judge, may be illustrated by some remarks of the late Mr Justice Willes. In discussing the question whether evidence of the plaintiff's conduct on other occasions ought to be admitted, he said:—

> It is not easy in all cases to draw the line and to define with accuracy where probability ceases and speculation begins; but we are bound to lay down the rule to the best of our ability. No doubt the rule as to confining the evidence to that which is relevant and pertinent to the issue is one of great importance, not only as regards the particular case, but also with reference to saving the time of the court, and preventing the minds of the jury from being drawn away from the real point they have to decide. . . . Now it appears to me that the evidence proposed to be given in this case, if admitted, would not have shown that it was more probable that the contract was subject to the condition insisted upon by the defendant. The question may be put thus, Does the fact of a person having once or many times in his life done a particular act in a particular way make it more probable that he has done the same thing in the same way upon another and different occasion? To admit such speculative evidence would, I think, be fraught with great danger. . . . If such evidence were held admissible it would be difficult to say that the defendant might not in any case, where the question was whether

or not there had been a sale of goods on credit, call witnesses to prove that the plaintiff had dealt with other persons upon a certain credit; or, in an action for an assault, that the plaintiff might not give evidence of former assaults committed by the defendant upon other persons, or upon other persons of a particular class, for the purpose of showing that he was a quarrelsome individual, and therefore that it was highly probable that the particular charge of assault was well founded. The extent to which this sort of thing might be carried is inconceivable. . . . To obviate the prejudices, the injustice, and the waste of time to which the admission of such evidence would lead, and bearing in mind the extent to which it might be carried, and that litigants are mortal, it is necessary not only to adhere to the rule, but to lay it down strictly. I think, therefore, the fact that the plaintiff had entered into contracts of a particular kind with other persons on other occasions could not be properly admitted in evidence where no custom of trade to make such contracts, and no connexion between such and the one in question, was shown to exist (*Hollingham* v. *Head*, 1858, 4 C.B. N.S. 388).

There is no difference between the principles of evidence in civil and in criminal cases, although there are a few special rules, such as those relating to confessions and to dying declarations, which are only applicable to criminal proceedings. But in civil proceedings the issues are narrowed by mutual admissions of the parties, more use is made of evidence taken out of court, such as affidavits, and, generally, the rules of evidence are less strictly applied. It is often impolitic to object to the admission of evidence, even when the objection may be sustained by previous rulings. The general tendency of modern procedure is to place a more liberal and less technical construction on rules of evidence, especially in civil cases. In recent volumes of law reports cases turning on the admissibility of evidence are conspicuous by their rarity. Various causes have operated in this direction. One of them has been the change in the system of pleading, under which each party now knows before the actual trial the main facts on which his opponent relies. Another is the interaction of chancery and common-law practice and traditions since the Judicature Acts. In the Chancery Courts the rules of evidence were always less carefully observed, or, as Westminster would have said, less understood, than in the courts of common law. A judge trying questions of fact alone might naturally think that blinkers, though useful for a jury, are unnecessary for a judge. And the chancery judge was apt to read his affidavits first, and to determine their admissibility afterwards. In the meantime they had affected his mind.

The tendency of modern text-writers, among whom the late Professor Thayer, of Harvard, was perhaps the most independent, instructive, and suggestive, is to restrict materially the field occupied by the law of evidence, and to relegate to other branches of the law topics traditionally treated under the head of evidence. Thus in every way the law of evidence, though still embodying some principles of great importance, is of less comparative importance as a branch of English law than it was half a century ago. Legal rules, like dogmas, have their growth and decay. First comes the judge who gives a ruling in a particular case. Then comes the text-writer who collects the scattered rulings, throws them into the form of general propositions, connects them together by some theory, sound or unsound, and often ignores or obscures their historical origin. After him comes the legislator who crystallizes the propositions into enactments, not always to the advantage of mankind. So also with decay. Legal rules fall into the background, are explained away, are ignored, are denied, are overruled. Much of the English law of evidence is at present in a stage of decay.

The subject-matter of the law of evidence may be arranged differently according to the taste or point of view of the writer. It will be arranged here under the following heads:—I. Preliminary Matter; II. Classes of Evidence; III. Rules of Exclusion; IV. Documentary Evidence; V. Witnesses.

I. *Preliminary Matter.*

Under this head may be grouped certain principles and considerations which limit the range of matters to which evidence relates.

1. *Law and Fact.*—Evidence relates only to facts. It is therefore necessary to touch on the distinction between law and facts. *Ad quaestionem facti non respondent judices; ad quaestionem juris non respondent juratores.* Thus Coke, attributing, after his wont, to Bracton a maxim which may have been invented by himself. The maxim became the subject of political controversy, and the two rival views are represented by Pulteney's lines—

> For twelve honest men have decided the cause
> Who are judges alike of the facts and the laws,

and by Lord Mansfield's variant—

> Who are judges of facts, but not judges of laws.

The particular question raised with respect to the law of libel was settled by Fox's Libel Act. Coke's maxim describes in a broad general way the distinction between the functions of the judge and of the jury, but is only true subject to important qualifications. Judges in jury cases constantly decide what may be properly called questions of fact, though their action is often disguised by the language applied or the procedure employed. Juries, in giving a general verdict, often practically take the law into their own hands. The border line between the two classes of questions is indicated by the "mixed questions of law and fact," to use a common phrase, which arise in such cases as those relating to "necessaries," "due diligence," "negligence," "reasonableness," "reasonable and probable cause." In the treatment of these cases the line has been drawn differently at different times, and two conflicting tendencies are discernible. On the one hand, there is the natural tendency to generalize common inferences into legal rules, and to fix legal standards of duty. On the other hand, there is the sound instinct that it is a mistake to define and refine too much in these cases, and that the better course is to leave broadly to the jury, under the general guidance of the judge, the question what would be done by the "reasonable" or "prudent" man in particular cases. The latter tendency predominates in modern English law, and is reflected by the enactments in the recent Acts codifying the law on bills of exchange and sale of goods, that certain questions of reasonableness are to be treated as questions of fact. On the same ground rests the dislike to limit the right of a jury to give a general verdict in criminal cases. Questions of custom begin by being questions of fact, but as the custom obtains general recognition it becomes law. Many of the rules of the English mercantile law were "found" as customs by Lord Mansfield's special juries. Generally, it must be remembered that the jury act in subordinate co-operation with the judge, and that the extent to which the judge limits or encroaches on the province of the jury is apt to depend on the personal idiosyncrasy of the judge.

2. *Judicial Notice.*—It may be doubted whether the subject of judicial notice belongs properly to the law of evidence, and whether it does not belong rather to the general topic of legal or judicial reasoning. Matters which are the subject of judicial notice are part of the equipment of the judicial mind. It would be absurd to require evidence of every fact; many facts must be assumed to be known. The judge, like the juryman, is supposed to bring with him to the consideration of the question which he

has to try common sense, a general knowledge of human nature and the ways of the world, and also knowledge of things that "everybody is supposed to know." Of such matters judicial notice is said to be taken. But the range of general knowledge is indefinite, and the range of judicial notice has, for reasons of convenience, been fixed or extended, both by rulings of the judges and by numerous enactments of the Legislature. It would be impossible to enumerate here the matters of which judicial notice must or may be taken. These are to be found in the text-books. For present purposes it must suffice to say that they include not only matters of fact of common and certain knowledge, but the law and practice of the courts, and many matters connected with the government of the country.

3. *Presumptions.*—A presumption in the ordinary sense is an inference. It is an argument, based on observation, that what has happened in some cases will probably happen in others of the like nature. The subject of presumptions, so far as they are mere inferences or arguments, belongs, not to the law of evidence, or to law at all, but to rules of reasoning. But a legal presumption, or, as it is sometimes called, a presumption of law, as distinguished from a presumption of fact, is something more. It may be described, in Stephen's language, as "a rule of law that courts and judges shall draw a particular inference from a particular fact, or from particular evidence, unless and until the truth" (perhaps it would be better to say 'soundness') "of the inference is disproved." Courts and legislatures have laid down such rules on grounds of public policy or general convenience, and the rules have then to be observed as rules of positive law, not merely used as part of the ordinary process of reasoning or argument. Some so-called presumptions are rules of substantive law under a disguise. To this class appear to belong "conclusive presumptions of law," such as the common-law presumption that a child under seven years of age cannot commit a felony. So again the presumption that every one knows the law is merely an awkward way of saying that ignorance of the law is not a legal excuse for breaking it. Of true legal presumptions, the majority may be dealt with most appropriately under different branches of the substantive law, such as the law of crime, of property, or of contract, and accordingly Stephen has included in his *Digest of the Law of Evidence* only some which are common to more than one branch of the law. The effect of a presumption is to impute to certain facts or groups of facts a *primâ facie* significance or operation, and thus, in legal proceedings, to throw upon the party against whom it works the duty of bringing forward evidence to meet it. Accordingly the subject of presumptions is intimately connected with the subject of the burden of proof, and the same legal rule may be expressed in different forms, either as throwing the advantage of a presumption on one side, or as throwing the burden of proof on the other. Thus the rule in Stephen's Digest, which says that the burden of proving that any person has been guilty of a crime or wrongful act is on the person who asserts it, appears in the article entitled "Presumption of Innocence." Among the more ordinary and more important legal presumptions are the presumption of regularity in proceedings, described generally as a presumption *omnia esse rite acta*, and including the presumption that the holder of a public office has been duly appointed, and has duly performed his official duties, the presumption of the legitimacy of a child born during the mother's marriage, or within the period of gestation after her husband's death, and the presumptions as to life and death. "A person shown not to have been heard of for seven years by those (if any) who, if he had been alive, would naturally have heard of him, is presumed to be dead unless the circumstances of the case are such as to account for his not being heard of without assuming his death; but there is no presumption as to the time when he died, and the burden of proving his death at any particular time is upon the person who asserts it. There is no presumption" (*i.e.*, legal presumption) "as to the age at which a person died who is shown to have been alive at a given time, or as to the order in which two or more persons died who are shown to have died in the same accident, shipwreck, or battle" (Stephen, *Dig.*, art. 99). A document proved or purporting to be thirty years old is presumed to be genuine, and to have been properly executed and (if necessary) attested if produced from the proper custody. And the legal presumption of a "lost grant," *i.e.*, the presumption that a right or alleged right which has been long enjoyed without interruption had a legal origin, still survives in addition to the common law and statutory rules of prescription.

4. *Burden of Proof.*—The expression *onus probandi* has come down from the classical Roman law, and both it and the Roman maxims, *Agenti incumbit probatio*, *Necessitas probandi incumbit ei qui dicit non ei qui negat*, and *Reus excipiendo fit actor*, must be read with reference to the Roman system of actions, under which nothing was admitted, but the plaintiff's case was tried first; then, unless that failed, the defendant's on his *exceptio;* then, unless that failed, the plaintiff's on his *replicatio*, and so on. Under such a system the burden was always on the "actor." In modern law the phrase "burden of proof" may mean one of two things, which are often confused —the burden of establishing the proposition or issue on which the case depends, and the burden of producing evidence on any particular point either at the beginning or at a later stage of the case. The burden in the former sense ordinarily rests on the plaintiff or prosecutor. The burden in the latter sense, that of going forward with evidence on a particular point, may shift from side to side as the case proceeds. The general rule is that he who alleges a fact must prove it, whether the allegation is couched in affirmative or negative terms. But this rule is subject to the effect of presumptions in particular cases, to the principle that in considering the amount of evidence necessary to shift the burden of proof regard must be had to the opportunities of knowledge possessed by the parties respectively, and to the express provisions of statutes directing where the burden of proof is to lie in particular cases. Thus many statutes expressly direct that the proof of lawful excuse or authority, or the absence of fraudulent intent, is to lie on the person charged with an offence. And the Summary Jurisdiction Act, 1848, provides that if the information or complaint in summary proceedings negatives any exemption, exception, proviso, or condition in the statute on which it is founded, the prosecutor or complainant need not prove the negative, but the defendant may prove the affirmative in his defence.

II. *Classes of Evidence.*

Evidence is often described as being either oral or documentary. To these two classes should be added a third, called by Bentham real evidence, and consisting of things presented immediately to the senses of the judge or the jury. Thus the judge or jury may go to view any place the sight of which may help to an understanding of the evidence, and may inspect anything sufficiently identified and produced in court as material to the decision. Weapons, clothes, and things alleged to have been stolen or damaged are often brought into court for this purpose. Oral evidence consists of the statements of witnesses. Documentary evidence consists of documents submitted to the judge or jury by way of proof. The distinction between primary and secondary evidence relates only to documentary evidence, and will be noticed in the section under that head. A division of evidence from another point of view is that into direct and indirect, or as it is sometimes called, circumstantial evidence. By direct evidence is meant the statement of a person who saw, or otherwise observed with his senses, the fact in question. By indirect or circumstantial evidence is meant evidence of facts from which the fact in question may be inferred. The difference between direct and indirect evidence is a difference of kind, not of degree, and therefore the rule or maxim as to "best evidence" has no application to it. Juries naturally attach more weight to direct evidence, and in some legal systems it is only this class of evidence which is allowed to have full probative force. In some respects indirect evidence is superior to direct evidence, because, as Paley puts it, "facts cannot lie," whilst witnesses can and do. On the other hand facts often deceive; that is to say, the inferences drawn from them are often erroneous. The circumstances in which crimes are ordinarily committed are such that direct evidence of their commission is usually not obtainable, and when criminality depends on a state of mind, such as intention, that state must necessarily be inferred by means of indirect evidence.

III. *Rules of Exclusion.*

It seems desirable to state the leading rules of exclusion in their crude form instead of obscuring their historical origin by attempting to force them into the shape of precise technical propositions forming parts of a logically connected system. The judges who laid the foundations of our modern law of evidence, like those who first discoursed on the duties of trustees, little dreamt of the elaborate and artificial system which was to be based upon their remarks. The rules will be found, as might be expected, to be vague, to overlap each other, to require much explanation, and to be subject to many exceptions. They may be stated as follows:—(1) Facts not relevant to the issue cannot be admitted as evidence. (2) The evidence produced must be the best obtainable under the circumstances. (3) Hearsay is not evidence. (4) Opinion is not evidence.

1. *Rule of Relevancy.*—The so-called rule of relevancy is sometimes stated by text-writers in the form in which it was laid down by Baron Parke in 1837 (*Wright* v. *Doe and Tatham*, 7 A. and E. 384), when he described "one great principle" in the law of evidence as being that "all facts which are relevant to the issue may be proved." Stated in different forms, the rule has been made by FitzJames Stephen the central point of his theory of evidence. But relevancy, in the proper and natural sense, as we have said, is a matter not of law, but of logic. If Baron Parke's dictum relates to relevancy in its natural sense it is not true; if it relates to relevancy in a narrow and artificial sense, as equivalent to admissible, it is tautological. Such practical importance as the rule of relevancy possesses consists, not in what it includes, but in what it excludes, and for that reason it seems better to state the rule in a negative or exclusive form. But whether the rule is stated in a positive or in a negative form its vagueness is apparent. No precise line can be drawn between "relevant" and "irrelevant" facts. The two classes shade into each other by imperceptible degrees. The broad truth is that the courts have excluded from consideration certain matters which have some bearing on the question to be decided, and which, in that sense, are relevant, and that they have done so on grounds of policy and convenience. Among the matters so excluded are matters which are likely to mislead the jury, or to complicate the case unnecessarily, or which are of slight, remote, or merely conjectural importance. Instances of the classes of matters so excluded can be given, but it seems difficult to refer their exclusion to any more general principle than this. Rules as to evidence of character and conduct appear to fall under this principle. Evidence is not admissible to show that the person who is alleged to have done a thing was of a disposition or character which makes it probable that he would or would not have done it. This rule excludes the biographical accounts of the prisoner which are so familiar in French trials, and is an important principle in English trials. It is subject to three exceptions: first, that evidence of good character is admissible in favour of the prisoner in all criminal cases; secondly, that a prisoner indicted for rape is entitled to call evidence as to the immoral character of the prosecutrix; and thirdly, that a witness may be called to say that he would not believe a previous witness on his oath. The exception allowing the good character of a prisoner to influence the verdict, as distinguished from the sentence, is more humane than logical, and seems to have been at first admitted in capital cases only. The exception in rape cases does not allow evidence to be given of specific acts of immorality with persons other than the prisoner, doubtless on the ground that such evidence would affect the reputations of third parties. Where the character of a person is expressly in issue, as in actions of libel and slander, the rule of exclusion, as stated above, does not apply. Nor does it prevent evidence of bad character from being given in mitigation of damages, where the amount of damages virtually depends on character, as in cases of defamation and seduction. As to conduct there is a similar general rule, that evidence of the conduct of a person on other occasions is not to be used merely for the purpose of showing the likelihood of his having acted in a similar way on a particular occasion. Thus, on a charge of murder, the prosecutor cannot give evidence of the prisoner's conduct to other persons for the purpose of proving a bloodthirsty and murderous disposition. And in a civil case a defendant was not allowed to show that the plaintiff had sold goods on particular terms to other persons for the purpose of proving that he had sold similar goods on the same terms to the defendant. But this general rule must be carefully construed. Where several offences are so connected with each other as to form parts of an entire transaction, evidence of one is admissible as proof of another. Thus, where a prisoner is charged with stealing particular goods from a particular place, evidence may be given that other goods, taken from the same place at the same time, were found in his possession. And where it is proved or admitted that a person did a particular act, and the question is as to his state of mind, that is to say, whether he did the act knowingly, intentionally, fraudulently, or the like, evidence may be given of the commission by him of similar acts on other occasions for the purpose of proving his state of mind on the occasion. This principle is most commonly applied in charges for uttering false documents or base coin, and not uncommonly in charges for false pretences, embezzlement, or murder. In proceedings for the receipt or possession of stolen property, the Legislature has expressly authorized evidence to be given of the possession by the prisoner of other stolen property, or of his previous conviction of an offence involving fraud or dishonesty (Prevention of Crimes Act, 1871). Again, where there is a question whether a person committed an offence, evidence may be given of any fact supplying a motive or constituting preparation for the offence, of any subsequent conduct of the person accused, which is apparently influenced by the commission of the offence, and of any act done by him, or by his

authority, in consequence of the offence. Thus, evidence may be given that, after the commission of the alleged offence, the prisoner absconded, or was in possession of the property, or the proceeds of the property, acquired by the offence, or that he attempted to conceal things which were or might have been used in committing the offence, or as to the manner in which he conducted himself when statements were made in his presence and hearing. Statements made to or in the presence of a person charged with an offence are admitted as evidence, not of the facts stated, but of the conduct or demeanour of the person to whom or in whose presence they are made, or of the general character of the transaction of which they form part (under the *res gestæ* rule mentioned below).

2. *Best Evidence Rule.*—Statements to the effect of the best evidence rule were often made by Chief Justice Holt about the beginning of the 18th century, and became familiar in the courts. Chief Baron Gilbert, in his book on evidence, which must have been written before 1726, says that "the first and most signal rule in relation to evidence is this, that a man must have the utmost evidence the nature of the fact is capable of." And in the great case of *Omichund* v. *Barker* (1744), Lord Hardwicke went so far as to say, "The judges and sages of the law have laid down that there is but one general rule of evidence, the best that the nature of the case will admit" (1 Atkyns 49). It is no wonder that a rule thus solemnly stated should have found a prominent place in text-books on the law of evidence. But, apart from its application to documentary evidence, it does not seem to be more than a useful guiding principle which underlies, or may be used in support of, several rules.

It is to documentary evidence that the principle is usually applied, in the form of the narrower rule excluding, subject to exceptions, secondary evidence of the contents of a document where primary evidence is obtainable. In this form the rule is a rule of exclusion, but may be most conveniently dealt with in connexion with the special subject of documentary evidence. As noticed above, the general rule does not apply to the difference between direct and indirect evidence. And, doubtless on account of its vague character, it finds no place in Stephen's Digest.

3. *Hearsay.*—The term "hearsay" primarily applies to what a witness has heard another person say in respect to a fact in dispute. But it is extended to any statement, whether reduced to writing or not, which is brought before the court, not by the author of the statement, but by a person to whose knowledge the statement has been brought. Thus the hearsay rule excludes statements, oral or written, made in the first instance by a person who is not called as a witness in the case. Historically this rule may be traced to the time when the functions of the witnesses were first distinguished from the functions of the jury, and when the witnesses were required by their formula to testify *de visu suo et auditu*, to state what they knew about facts from the direct evidence of their senses, not from the information of others. The rule excludes statements the effect of which is liable to be altered by the narrator, and which purport to have been made by persons who did not necessarily speak under the sanction of an oath, and whose accuracy or veracity is not tested by cross-examination. It is therefore of practical utility in shutting out many loose statements and much irresponsible gossip. On the other hand, it excludes statements which are of some value as evidence, and may indeed be the only available evidence. Thus, a statement has been excluded as hearsay, even though it can be proved that the author of the statement made it on oath, or that it was against his interest when he made it, or that he is prevented by insanity or other illness from giving evidence himself, or that he has left the country and disappeared, or that he is dead.

Owing to the inconveniences which would be caused by a strict application of the rule, it has been so much eaten into by exceptions that some persons doubt whether the rule and the exceptions ought not to change places. Among the exceptions the following may be noticed:—(*a*) *Certain sworn Statements.*—In many cases statements made by a person whose evidence is material, but who cannot come before the court, or could not come before it without serious difficulty, delay, or expense, may be admitted as evidence under proper safeguards. Under the Indictable Offences Act, 1848, where a person has made a deposition before a justice at a preliminary inquiry into an offence, his deposition may be read in evidence on proof that the deponent is dead, or too ill to travel, that the deposition was taken in the presence of the accused person, and that the accused then had a full opportunity of cross-examining the deponent. The deposition must appear to be signed by the justice before whom it purports to have been taken. Depositions taken before a coroner are admissible under the same principle. And the principle probably extends to cases where the deponent is insane, or kept away by the person accused. There are other statutory provisions for the admission of depositions, as in the Criminal Law Amendment Act, 1867; the Foreign Jurisdiction Act, 1890; and the Prevention of Cruelty to Children Act, 1894. In civil cases the rule excluding statements not made in court at the trial is much less strictly applied. Frequent use is made of evidence taken before an examiner, or under a commission. Affidavits are freely used for subordinate issues or under an arrangement between the parties, and leave may be given to use evidence taken in other proceedings. The old chancery practice, under which evidence, both at the trial and at other stages of a proceeding, was normally taken by affidavit, irrespectively of consent, was altered by the Judicature Acts. Under the existing rules of the supreme court evidence may be given by affidavit upon any motion, petition, or summons, but the court or a judge may, on the application of either party, order the attendance for cross-examination of the person making the affidavit. (*b*) *Dying Declarations.*—In a trial for murder or manslaughter a declaration by the person killed as to the cause of his death, or as to any of the circumstances of the transaction which resulted in his death, is admissible as evidence. But this exception is very strictly construed. It must be proved that the declarant, at the time of making the declaration, was in actual danger of death, and had given up all hope of recovery. (*c*) *Statements in Pedigree Cases.*—On a question of pedigree the statement of a deceased person, whether based on his own personal knowledge or on family tradition, is admissible as evidence, if it is proved that the person who made the statement was related to the person about whose family relations the statement was made, and that the statement was made before the question with respect to which the evidence is required had arisen. (*d*) *Statements as to Matters of Public or General Interest.*—Statements by deceased persons are admissible as evidence of reputation or general belief in questions relating to the existence of any public or general right or custom, or matter of public and general interest. Statements of this kind are constantly admitted in questions relating to right of way, or rights of common, or manorial or other local customs. Maps, copies of court rolls, leases and other deeds, and verdicts, judgments, and orders of court fall within the exception in cases of this kind. (*e*) *Statements in course of Duty or Business.*—A statement with respect to a particular fact made by a deceased person in pursuance of his duty in connexion with any office, employment, or business, whether public or private, is admissible as evidence of that fact, if the statement appears to have been made from personal knowledge, and at or about the time when the fact occurred. This exception covers entries by clerks and other employees. (*f*) *Statements against Interest.*—A statement made by a deceased person against his pecuniary or proprietary interest is admissible as evidence, without reference to the time at which it was made. Where such a statement is admissible the whole of it becomes admissible, though it may contain matters not against the interest of the person who made it, and though the total effect may be in his favour. Thus, where there was a question whether a particular sum was a gift or a loan, entries in an account book of receipt of interest on the sum were admitted, and a statement in the book that the alleged debtor had on a particular date acknowledged the loan was also admitted. (*g*) *Public Documents.*—Under this head may be placed recitals in public Acts of Parliament, notices in the *London*, *Edinburgh*, or *Dublin Gazette* (which are made evidence by statute in a large number of cases), and entries made in the performance of duty in official registers or records, such as registers of births, deaths, or marriages, registers of companies, records in judicial proceedings, and the like. An entry in a public document may be treated as a statement made in the course of duty, but it is admissible whether the person who made the statement is alive or dead, and without any evidence as to personal knowledge, or the time at which the statement is made. (*h*) *Admissions.*—By the term "admission," as here used, is meant a statement made out of the witness-box by a party to the proceedings, whether civil or criminal, or by some person whose statements are binding on that party, against the interest of that party. The term includes admissions made in answer to interrogatories, or to a notice to admit facts, but not admissions made on the pleadings. Admissions, in this sense of the term, are admissible as evidence against the person by whom they are made, or on whom they are binding, without reference to the life or death of the person who made them. A person is bound by the statements of his agent, acting within the scope of his authority, and barristers and solicitors are agents for their clients in the conduct of legal proceedings. Conversely, a person suing or defending on behalf of another, *e.g.*, as agent or trustee, is bound by the statements of the person whom he represents. Statements respecting property made by a predecessor in title bind the successor. Where a statement is put in evidence as an admission by, or binding on, any person, that person is entitled to have the whole statement given in evidence. The principle of this rule is obviously sound, because it would be unfair to pick out from a man's statement what tells against him, and to suppress what is in his favour. But the application of the rule is sometimes attended with difficulty. An admission will not be allowed to be used as evidence if it was made under a stipulation, express or implied, that it should not be so used. Such admissions are said to be made "without prejudice." (*i*) *Confessions.*—A confession is an admission by a person accused of an offence that he has committed the offence of which he is accused. But the rules about admitting as evidence confessions in criminal proceedings are much more strict than the rules about admissions in civil proceedings. The general rule is, that a confession is not admissible as evidence against any person except the person who makes it. But a confession made by one accomplice in the presence of another is admissible against the latter to this extent, that, if it implicates him, his silence under the charge may be used against him, whilst on the other hand his prompt repudiation of the charge might tell in his favour. In other words, the confession may be used as evidence of the conduct of the person in whose presence it was made. A confession cannot be admitted as evidence unless proved to be voluntary. A confession is not treated as being voluntary if it appears to the court to have been caused by any inducement, threat, or promise which proceeded from a magistrate or other person in authority concerned in the charge, and which, in the opinion of the court, gave the accused person reasonable ground for supposing that by making a confession he would gain some advantage or avoid some evil in reference to the proceedings against him. This applies to any inducement, threat, or promise having reference to the charge, whether it is addressed directly to the accused person or is brought to his knowledge indirectly. But a confession is not involuntary merely because it appears to have been caused by the exhortations of a person in authority to make it as a matter of religious duty, or by an inducement collateral to the proceedings, or by an inducement held out by a person having nothing to do with the apprehension, prosecution, or examination of the prisoner. Thus, a confession made to a gaol chaplain in consequence of religious exhortation has been admitted as evidence. So also has a confession made by a prisoner to a gaoler in consequence of a promise by the gaoler, that if the prisoner confessed he should be allowed to see his wife. To make a confession involuntary, the inducement must have reference to the prisoner's escape from the charge against him, and must be made by some person having power to relieve him, wholly or partially, from the consequences of the charge. A confession is treated as voluntary if, in the opinion of the court, it was made after the complete removal of the impression produced by any inducement, threat, or promise which would have made it involuntary. Where a confession was made under an inducement which makes the confession involuntary, evidence may be given of facts discovered in consequence of the confession, and of so much of the confession as distinctly relates to those facts. Thus, A. under circumstances which make the confession involuntary, tells a policeman that he, A., had thrown a lantern into the pond. Evidence may be given that the lantern was found in the pond, and that A. said he had thrown it there. It is of course improper to try to extort a confession by fraud or under the promise of secrecy. But if a confession is otherwise admissible as evidence, it does not become inadmissible *merely* because it was made under a promise of secrecy, or in consequence of a deception practised on the accused person for the purpose of obtaining it, or when he was drunk, or because it was made in answer to questions, whether put by a magistrate or by a private person, or because he was not warned that he was not bound to make the confession, and that it might be used against him. If a confession is given in evidence, the whole of it must be given, and not merely the parts disadvantageous to the accused person. Evidence amounting to a confession may be used as such against the person who gave it, though it was given on oath, and though the proceeding in which it was given had reference to the same subject-matter as the proceeding in which it is to be used, and though the witness might have refused to answer the questions put to him. But if, after refusing to answer such questions, the witness is improperly compelled to answer, his answers are not a voluntary confession. The grave jealousy and suspicion with which the English law regards confessions offer a marked contrast to the importance attached to this form of evidence in other systems of procedure, such as the inquisitorial system which long prevailed, and still to some extent prevails, on the Continent. (*j*) *Res gestæ.*—Statements are often admitted as evidence on the ground that they form part of what is called the "transaction," or *res gestæ*, the occurrence or nature of which is in question. For instance, where an act may be proved, statements accompanying and explaining the act made by or to the person doing it, may be given in evidence. There is no difficulty in understanding the principle on which this exception from the hearsay rule rests, but there is often practical difficulty in applying it, and the practice has varied. How long is the "transaction" to be treated as lasting? What ought to be treated as "the immediate and natural effect of continuing action," and, for that reason, as part of the *res gestæ?* When an act of violence is committed, to what extent are the terms of the complaint made by the sufferer, as distinguished from the fact of a complaint having been made, admissible as evidence? These are some of the questions raised. The cases in which statements by a person as to his bodily or mental condition may be put in evidence may perhaps be treated as falling under the same principle. In the Rugeley poisoning case, statements by the deceased person before his illness as to his state of health, and as to his symptoms during illness, were admitted as evidence for the prosecution. Under the same principle may also be brought the rule as to statements in conspiracy cases. In charges of conspiracy, after evidence has been given of the existence of the plot, and of the connexion of the accused with it, the charge against one conspirator may be supported by evidence of anything done, written, or said, not only by him, but by any other of the conspirators, in furtherance of the common purpose. On the other hand, a statement made by one conspirator, not in execution of the common purpose, but in narration of some event forming part of the conspiracy, would be treated, not as part of the "transaction," but as a statement excluded by the hearsay rule. Thus the admissibility of writings in conspiracy cases may depend on the time when they can be shown to have been in the possession of a fellow-conspirator, whether before or after the prisoner's apprehension. (*k*) *Complaints in rape cases, &c.*—In trials for rape and similar offences, the fact that shortly after the commission of the alleged offence a complaint was made by the person against whom the offence was committed, and also the terms of the complaint, have been admitted as evidence, not of the facts complained of, but of the consistency of the complainant's conduct with the story told by her in the witness-box, and as negativing consent on her part.

4. *Opinion.*—The rule excluding expressions of opinion also dates from the first distinction between the functions of witnesses and jury. It was for the witnesses to state facts, for the jury to form conclusions. Of course every statement of fact involves inference, and implies a judgment on phenomena observed by the senses. And the inference is often erroneous, as in the answer to the question, "Was he drunk?" A prudent witness will often guard himself, and is allowed to guard himself, by answering to the best of his belief. But, for practical purposes, it is possible to draw a distinction between a statement of facts observed and an expression of opinion as to the inference to be drawn from these facts, and the rule telling witnesses to state facts and not express opinions is of great value in keeping their statements out of the region of argument and conjecture. The evidence of "experts," that is to say, of persons having a special knowledge of some particular subject, is generally described as constituting the chief exception to the rule. But perhaps it would be more accurate to say that experts are allowed a much wider range than ordinary witnesses in the expression of their opinions, and in the statement of facts on which their opinions are based. Thus, in a poisoning case, a doctor may be asked as an expert whether, in his opinion, a particular poison produces particular symptoms.

And, where lunacy is set up as a defence, an expert may be asked whether, in his opinion, the symptoms exhibited by the alleged lunatic commonly show unsoundness of mind, and whether such unsoundness of mind usually renders persons incapable of knowing the nature of their acts, or of knowing that what they do is either wrong or contrary to the law. Similar principles are applied to the evidence of engineers, and in numerous other cases. In cases of disputed handwriting the evidence of experts in handwriting is expressly recognized by statute (28 and 29 Vict. c. 18, s. 8).

IV. *Documentary Evidence.*

Charters and other writings were exhibited to the jury at a very early date, and it is to writings so exhibited that the term "evidence" or "evidences" seems to have been originally applied *par excellence.* The oral evidence of witnesses came later. Where a document is to be used as evidence the first question is how its contents are to be proved. To this question the principle of "best evidence" applies, in the form of the rule that primary evidence must be given except in the cases where secondary evidence is allowed. By primary evidence is meant the document itself produced for inspection. By secondary evidence is meant a copy of the document, or verbal accounts of its contents.

The rule as to the inadmissibility of a copy of a document is applied much more strictly to private than to public or official documents. Secondary evidence may be given of the contents of a private document in the following cases:—

(*a*) Where the original is shown or appears to be in the possession of the adverse party, and he, after having been served with reasonable notice to produce it, does not do so.

(*b*) Where the original is shown or appears to be in the possession or power of a stranger not legally bound to produce it, and he, after having been served with a writ of *subpœna duces tecum*, or after having been sworn as a witness and asked for the document, and having admitted that it is in court, refuses to produce it.

(*c*) Where it is shown that proper search has been made for the original, and there is reason for believing that it is destroyed or lost.

(*d*) Where the original is of such a nature as not to be easily movable, as in the case of a placard posted on a wall, or of a tombstone, or is in a country from which it is not permitted to be removed.

(*e*) Where the original is a document for the proof of which special provision is made by any Act of Parliament, or any law in force for the time being. Documents of that kind are practically treated on the same footing as private documents.

(*f*) Where the document is an entry in a banker's book, provable according to the special provisions of the Bankers' Books Evidence Act, 1879.

Secondary evidence of a private document is usually given either by producing a copy and calling a witness who can prove the copy to be correct, or, when there is no copy obtainable, by calling a witness who has seen the document, and can give an account of its contents. No general definition of public document is possible, but the rules of evidence applicable to public documents are expressly applied by statute to many classes of documents. Primary evidence of any public document may be given by producing the document from proper custody, and by a witness identifying it as being what it professes to be. Public documents may always be proved by secondary evidence, but the particular kind of secondary evidence required is in many cases defined by statute. Where a document is of such a public nature as to be admissible in evidence on its mere production from the proper custody, and no statute exists which renders its contents provable by means of a copy, any copy thereof or extract therefrom is admissible as proof of its contents, if it is proved to be an examined copy or extract, or purports to be signed or certified as a true copy or extract by the officer to whose custody the original is entrusted. Many statutes provide that various certificates, official and public documents, documents and proceedings of corporations and of joint stock and other companies, and certified copies of documents, bye-laws, entries in registers and other books, shall be receivable as evidence of certain particulars in courts of justice, if they are authenticated in the manner prescribed by the statutes. Whenever, by virtue of any such provision, any such certificate or certified copy is receivable as proof of any particular in any court of justice, it is admissible as evidence, if it purports to be authenticated in the manner prescribed by law, without calling any witness to prove any stamp, seal, or signature required for its authentication, or the official character of the person who appears to have signed it. The Documentary Evidence Acts, 1868, 1882, and 1895, provide modes of proving the contents of several classes of proclamations, orders, and regulations.

If a document is of a kind which is required by law to be attested, but not otherwise, an attesting witness must be called to prove its due execution. But this rule is subject to the following exceptions:—

(*a*) If it is proved that there is no attesting witness alive, and capable of giving evidence, then it is sufficient to prove that the attestation of at least one attesting witness is in his handwriting, and that the signature of the person executing the document is in the handwriting of that person.

(*b*) If the document is proved, or purports to be, more than thirty years old, and is produced from what the court considers to be its proper custody, an attesting witness need not be called, and it will be presumed without evidence that the instrument was duly executed and attested.

Where a document embodies a judgment, a contract, a grant, or disposition of property, or any other legal transaction or "act in the law," on which rights depend, the validity of the transaction may be impugned on the ground of fraud, incapacity, want of consideration, or other legal ground. But this seems outside the law of evidence. In this class of cases a question often arises whether extrinsic evidence can be produced to vary the nature of the transaction embodied in the document. The answer to this question seems to depend on whether the document was or was not intended to be a complete and final statement of the transaction which it embodies. If it was, you cannot go outside the document for the purpose of ascertaining the nature of the transaction. If it was not, you may. But the mere statement of this test shows the difficulty of formulating precise rules, and of applying them when formulated. FitzJames Stephen mentions, among the facts which may be proved in these cases, the existence of separate and consistent oral agreements as to matters on which the document is silent, if there is reason to believe that the document is not a complete and final statement of the transaction, and the existence of any usage or custom with reference to which a contract may be presumed to have been made. But he admits that the rules on the subject are "by no means easy to apply, inasmuch as from the nature of the case an enormous number of transactions fall close on one side or the other of most of them." The underlying principle appears to be a rule of substantive law rather than of evidence. When parties to an arrangement have reduced the terms of the arrangement to a definite, complete, and final written form, they should be bound exclusively by the terms embodied in that form. The question in each case is under what circumstances they ought to be treated as having done so.

The expression "parol evidence," which includes written as well as verbal evidence, has often been applied to the extrinsic evidence produced for the purpose of varying the nature of the transaction embodied in a document. It is also applied to extrinsic evidence used for another purpose, namely, that of explaining the meaning of the terms used in a document. The two questions, What is the real nature of the transaction referred to in a document? and, What is the meaning of a document? are often confused, but are really distinct from each other. The rules bearing on the latter question are rules of construction or interpretation rather than of evidence, but are ordinarily treated as part of the law of evidence, and are for that reason included by FitzJames Stephen in his Digest. In stating these rules he adopts, with verbal modifications, the six propositions laid down by Vice-Chancellor Wigram in his

Examinations of the Rules of Law respecting the admission of Extrinsic Evidence in Aid of the Interpretation of Wills. The substance of these propositions appears to be this, that wherever the meaning of a document cannot be satisfactorily ascertained from the document itself, use may be made of any other evidence for the purpose of elucidating the meaning, subject to one restriction, that, except in cases of equivocation, *i.e.*, where a person or thing is described in terms applicable equally to more than one, resort cannot be had to extrinsic expressions of the author's intention.

V. *Witnesses.*

1. *Attendance.*—If a witness does not attend voluntarily he can be required to attend by a writ of *subpœna*.

2. *Competency.*—As a general rule every person is a competent witness. Formerly persons were disqualified by crime or interest, or by being parties to the proceedings, but these disqualifications have now been removed by statute, and the circumstances which formerly created them do not affect the competency, though they may often affect the credibility, of a witness.

Under the general law as it stood before the Criminal Evidence Act, 1898, came into force, a person charged with an offence was not competent to give evidence on his own behalf. But many exceptions had been made to this rule by legislation, and the rule itself was finally abolished by the Act of 1898. Under the new law a person charged is a competent witness, but he can only give evidence for the defence, and can only give evidence if he himself applies to do so. Under the law as it stood before 1898, persons jointly charged and being tried together were not competent to give evidence either for or against each other. Under the new law a person charged jointly with another is a competent witness, but only for the defence, and not for the prosecution. If, therefore, one of the persons charged applies to give evidence his cross-examination must not be conducted with a view to establish the guilt of the other. Consequently, if it is thought desirable to use against one prisoner the evidence of another who is being tried with him, the latter should be released, or a separate verdict of not guilty taken against him. A prisoner so giving evidence is popularly said to turn King's evidence. It follows that, subject to what has been said above as to persons tried together, the evidence of an accomplice is admissible against his principal, and *vice versâ*. The evidence of an accomplice is, however, always received with great jealousy and caution. A conviction on the unsupported testimony of an accomplice may, in some cases, be strictly legal, but the practice is to require it to be confirmed by unimpeachable testimony in some material part, and more especially as to his identification of the person or persons against whom his evidence may be received. The wife of a person charged is now a competent witness, but, except in certain special cases, she can only give evidence for the defence, and can only give evidence if her husband applies that she should do so. The special cases in which a wife can be called as a witness either for the prosecution or for the defence, and without the consent of the person charged, are cases arising under particular enactments scheduled to the Act of 1898, and relating mainly to offences against wives and children, and cases in which the wife is by common law a competent witness against her husband, *i.e.*, where the proceeding is against the husband for bodily injury or violence inflicted on his wife. The rule of exclusion extends only to a lawful wife. There is no ground for supposing that the wife of a prosecutor is an incompetent witness. A witness is incompetent if, in the opinion of the court, he is prevented by extreme youth, disease affecting his mind, or any other cause of the same kind, from recollecting the matter on which he is to testify, from understanding the questions put to him, from giving rational answers to those questions, or from knowing that he ought to speak the truth. A witness unable to speak or hear is not incompetent, but may give his evidence by writing or by signs, or in any other manner in which he can make it intelligible. The particular form of the religious belief of a witness, or his want of religious belief, does not affect his competency. This ground of incompetency has now been finally removed by the Oaths Act, 1888 (see below). It will be seen that the effect of the successive enactments which have gradually removed the disqualifications attaching to various classes of witnesses has been to draw a distinction between the *competency* of a witness and his *credibility*. No person is disqualified on moral or religious grounds, but his character may be such as to throw grave doubts on the value of his evidence. No relationship, except to a limited extent that of husband and wife, excludes from giving evidence. The parent may be examined on the trial of the child, the child on that of the parent, master for or against servant, and servant for or against master. The relationship of the witness to the prosecutor or the prisoner in such cases may affect the credibility of the witness, but does not exclude his evidence.

3. *Privilege.*—It does not follow that, because a person is *competent* to give evidence, he can therefore be compelled to do so.

No one, except a person charged with an offence when giving evidence on his own application, and as to the offence wherewith he is charged, is bound to answer a question if the answer would, in the opinion of the court, have a tendency to expose the witness, or the wife or husband of the witness, to any criminal charge, penalty, or forfeiture, which the court regards as reasonably likely to be preferred or sued for. Accordingly, an accomplice cannot be examined without his consent, but if an accomplice who has come forward to give evidence on a promise of pardon, or favourable consideration, refuses to give full and fair information, he renders himself liable to be convicted on his own confession. However, even accomplices in such circumstances are not required to answer on their cross-examination as to other offences. Where, under the new law, a person charged with an offence offers himself as a witness, he may be asked any question in cross-examination, notwithstanding that it would tend to criminate him as to the offence charged. But he may not be asked, and if he is asked must not be required to answer, any question tending to show that he has committed, or been convicted of, or been charged with, any other offence, or is of bad character, unless:—

(i.) The proof that he has committed, or been convicted of, the other offence is admissible evidence to show that he is guilty of the offence with which he is then charged; or,

(ii.) He has personally, or by his advocate, asked questions of the witnesses for the prosecution, with a view to establish his own good character, or has given evidence of his good character, or the nature or conduct of the defence is such as to involve imputations on the character of the prosecutor or the witnesses for the prosecution; or,

(iii.) He has given evidence against any other person charged with the same offence.

He may not be asked questions tending to criminate his wife.

The privilege as to criminating answers does not cover answers merely tending to establish a civil liability. No one is excused from answering a question or producing a document only because the answer or document may establish or tend to establish that he owes a debt, or is otherwise liable to any civil proceeding. It is a privilege for the protection of the witness, and therefore may be waived by him. But there are other privileges which cannot be so waived. Thus, on grounds of public policy, no one can be compelled, or is allowed, to give evidence relating to any affairs of state, or as to official communications between public officers upon public affairs, except with the consent of the head of the department concerned, and this consent is refused if the production of the information asked for is considered detrimental to the public service.

Again, in cases in which the Government is immediately concerned, no witness can be compelled to answer any question the answer to which would tend to discover the names of persons by or to whom information was given as to the commission of offences. It is, as a rule, for the court to decide whether the permission of any such question would or would not, under the circumstances of the particular case, be injurious to the administration of justice.

A husband is not compellable to disclose any communication made to him by his wife during the marriage; and a wife is not compellable to disclose any communication made to her by her husband during the marriage.

A legal adviser is not permitted, whether during or after the termination of his employment as such, unless with his client's express consent, to disclose any communication, oral or documentary, made to him *as such legal adviser*, by or on behalf of his client, during, in the course of, and for the purpose of his employment, or to disclose any advice given by him to his client during, in the course of, and for the purpose of such employment. But this protection does not extend to—

(*a*) any such communication if made in furtherance of any criminal purpose; nor

(*b*) any fact observed by a legal adviser in the course of his employment as such, showing that any crime or fraud has been committed since the commencement of his employment, whether his attention was directed to such fact by or on behalf of his client or not; nor

(*c*) any fact with which the legal adviser became acquainted otherwise than in his character as such.

Medical men and clergymen are not privileged from the disclosure of communications made to them in professional confidence, but it is not usual to press for the disclosures of communications made to clergymen.

4. *Oaths.*—A witness must give his evidence under the sanction of an oath, or of what is equivalent to an oath, that is to say, of a solemn promise to speak the truth. The ordinary form of oath is adapted to Christians, but a person belonging to a non-Christian religion may be sworn in any form prescribed or recognized by the custom of his religion.

Special provisions have been made by statute for two classes of persons: (1) Christians who object on conscientious grounds to the taking of an oath; and (2) persons who refuse to admit the binding force of an oath. Special provision was first made for Quakers and Moravians (9 Geo. IV. c. 32; 3 and 4 Will. IV. c. 49; 1 and 2 Vict. c. 77) and for Separatists. Then came general enactments relating to civil (Common Law Procedure Act, 1854, s. 20) and criminal (24 and 25 Vict. c. 66, s. 1) proceedings respectively, and allowing a witness who alleged conscientious objections to being sworn to make a solemn affirmation. The Evidence Further Amendment Act, 1869, s. 4, enabled any person who objected to take an oath, or was objected to as incompetent to take an oath (*i.e.*, on the ground that he did not recognize its binding force) to make a solemn promise and declaration in a prescribed form. The law is now embodied in the Oaths Act, 1888, under which any person, on objecting to being sworn, and stating as the ground of his objection, either that he has no religious belief, or that the taking of an oath is contrary to his religious belief, may make a solemn affirmation, which is to have the same effect, and involve the same penalties for false statement, as an oath. Under s. 5 of the same Act a person may swear in the Scottish form, with uplifted hand, and if he desires to do so "the oath shall be administered to him in such form and manner without further question"—in other words, he must not be asked as to his religious belief.

5. *Publicity.*—The evidence of a witness at a trial must, as a general rule, be given in open court in the course of the trial. The secrecy which was such a characteristic feature of the "inquisition" procedure is abhorrent to English law, and, even where publicity conflicts with decency, English courts are very reluctant to dispense with or relax the safeguards for justice which publicity involves.

6. *Examination.*—The normal course of procedure is this. The party who begins, *i.e.*, ordinarily the plaintiff or prosecutor, calls his witnesses in order. Each witness is first examined on behalf of the party for whom he is called. This is called the examination in chief. Then he is liable to be cross-examined on behalf of the other side. And, finally, he may be re-examined on behalf of his own side. After the case for the other side has been opened, the same procedure is adopted with the witnesses for that side. In some cases the party who began is allowed to adduce further evidence in reply to his opponent's evidence. The examination is conducted, not by the court, but by or on behalf of the contending parties. It will be seen that the principle underlying this procedure is that of the duel, or conflict between two contending parties, each relying on and using his own evidence, and trying to break down the evidence of his opponent. It differs from the principle of the "inquisition" procedure, in which the court takes a more active part, and in which the cases for the two sides are not so sharply distinguished. In a Continental trial it is often difficult to determine whether the case for the prosecution or the case for the defence is proceeding. Conflicting witnesses stand up together and are "confronted" with each other. In the examination in chief questions must be confined to matters bearing on the main question at issue, and a witness must not be asked leading questions, *i.e.*, questions suggesting the answer which the person putting the question wishes or expects to receive, or suggesting disputed facts about which the witness is to testify. But the rule about leading questions is not applied where the questions asked are simply introductory, and form no part of the real substance of the inquiry, or where they relate to matters which, though material, are not disputed. And if the witness called by a person appears to be directly hostile to him, or interested on the other side, or unwilling to reply, the reason for the rules applying to examination in chief breaks down, and the witness may be asked leading questions and cross-examined, and treated in every respect as though he was a witness called on the other side, except that a party producing a witness must not impeach his credit by general evidence of bad character (28 and 29 Vict. c. 18, s. 3). In cross-examination questions not bearing on the main issue and leading questions may be put and (subject to the rules as to privilege) must be answered, as the cross-examiner is entitled to test the examination in chief by every means in his power. Questions not bearing on the main issue are often asked in cross-examination merely for the purpose of putting off his guard a witness who is supposed to have learnt up his story. In cross-examination questions may also be asked which tend either to test the accuracy or credibility of the witness, or to shake his credit by impeaching his motives or injuring his character. The license allowed in cross-examination has often been seriously abused, and the power of the court to check it is recognized by one of the rules of the supreme court (R.S.C. xxxvi. 39, added in 1883). It is

considered wrong to put questions which assume that facts have been proved which have not been proved, or that answers have been given contrary to the fact. A witness ought not to be pressed in cross-examination as to any facts which, if admitted, would not affect the question at issue or the credibility of the witness. If the cross-examiner intends to adduce evidence contrary to the evidence given by the witness, he ought to put to the witness in cross-examination the substance of the evidence which he proposes to adduce, in order to give the witness an opportunity of retracting or explaining. Where a witness has answered a question which only tends to affect his credibility by injuring his character, it is only in a limited number of cases that evidence can be given to contradict his answer. Where he is asked whether he has ever been convicted of any felony or misdemeanour, and denies or refuses to answer, proof may be given of the truth of the facts suggested (28 and 29 Vict. c. 15, s. 6). The same rule is observed where he is asked a question tending to show that he is not impartial. Where a witness has previously made a statement inconsistent with his evidence, proof may be given that he did in fact make it. But before such proof is given the circumstances of the alleged statement, sufficient to designate the particular occasion, must be mentioned to the witness, and he must be asked whether he did or did not make the statement. And if the statement was made in, or has been reduced to writing, the attention of the witness must, before the writing is used against him, be called to those parts of the writing which are to be used for the purpose of contradicting him (28 and 29 Vict. c. 18, ss. 4, 5). The credibility of a witness may be impeached by the evidence of persons who swear that they, from their knowledge of the witness, believe him to be unworthy of credit on his oath. These persons may not on their examination in chief give reasons for their belief, but they may be asked their reasons in cross-examination, and their answers cannot be contradicted. When the credit of a witness is so impeached, the party who called the witness may give evidence in reply to show that the witness is worthy of credit. Re-examination must be directed exclusively to the explanation of matters referred to in cross-examination, and if new matter is, by the permission of the court, introduced in re-examination, the other side may further cross-examine upon it. A witness under examination may refresh his memory by referring to any writing made by himself at or about the time of the occurrence to which the writing relates, or made by any other person, and read and found accurate by the witness at or about the time. An expert may refresh his memory by reference to professional treatises.

For the history of the English law of evidence, see BRUNNER, *Entstehung der Schwurgerichte* ; BIGELOW, *History of Procedure in England* ; STEPHEN (Sir J. F.), *History of the Criminal Law of England* ; POLLOCK and MAITLAND, *History of English Law*, bk. ii. ch. ix. ; THAYER, *Preliminary Treatise on Evidence at the Common Law*. The principal text-books now in use are—ROSCOE, *Digest of the Law of Evidence on the Trial of Actions at Nisi Prius*, 16th ed., 1891 ; ROSCOE, *Digest of the Law of Evidence in Criminal Cases*, 12th ed., 1898 ; TAYLOR, *Treatise on the Law of Evidence*, 9th ed., 1895 ; BEST, *Principles of the Law of Evidence*, 8th ed., 1893 ; POWELL, *Principles and Practice of the Law of Evidence*, 7th ed., 1898 ; STEPHEN, *Digest of the Law of Evidence*, 5th ed., 1899 ; WILLS, *Theory and Practice of the Law of Evidence*, 1894. For history of the law of criminal evidence in France, see ESMEIN, *Hist. de la procédure criminelle en France*. For Germany, see HOLTZENDORFF, *Encyclopädie der Rechtswissenschaft* (passages indexed under head "Beweis") ; HOLTZENDORFF, *Rechtslexikon*, ("Beweis"). (C. P. I.)

Evolution.—Since Professors Huxley and Sully wrote their masterly essays in the ninth edition of this Encyclopædia, the doctrine of evolution has outgrown the trammels of controversy and has been accepted as a fundamental principle. Writers on biological subjects no longer have to waste space in weighing evolution against this or that philosophical theory or religious tradition ; philosophical writers have frankly accepted it, and the supporters of religious tradition have made broad their phylacteries to write on them the new words. A closer scrutiny of the writers of all ages who preceded Charles Darwin, and, in particular, the light thrown back from Darwin on the earlier writings of Herbert Spencer, have made plain that without Darwin the world by this time might have come to a general acceptance of evolution ; but it seems established as a historical fact that the world has come to accept evolution, first, because of Darwin's theory of natural selection, and second, because of Darwin's exposition of the evidence for the actual occurrence of organic evolution. The evidence as set out by Darwin has been added to enormously ; new knowledge has in many cases altered our conceptions of the mode of the actual process of evolution, and from time to time a varying stress has been laid on what are known as the purely Darwinian factors in the theory. The balance of these tendencies has been against the attachment of great importance to sexual selection, and in favour of attaching a great importance to natural selection ; but the dominant feature in the history of the theory since 1875 has been its universal acceptance and the recognition that this general acceptance has come from the stimulus given by Darwin.

Ontogeny.

A change has taken place in the use of the word evolution. Huxley, following historical custom, devoted one section of his article to the "Evolution of the Individual." The facts and theories respecting this are now discussed under such headings as EMBRYOLOGY, HEREDITY, and VARIATION ; under these headings must be sought information on the important recent modifications with regard to the theory of the relation between the development of the individual and the development of the race, the part played by the environment on the individual, and the modern developments of the old quarrel between evolution and epigenesis. The most striking general change has been against seeing in the facts of ontogeny any direct evidence as to phylogeny. The general proposition as to a parallelism between individual and ancestral development is no doubt indisputable, but extended knowledge of the very different ontogenetic histories of closely allied forms has led us to a much fuller conception of the mode in which stages in embryonic and larval history have been modified in relation to their surroundings, and to a consequent reluctance to attach detailed importance to the embryological argument for evolution.

Phylogeny.

The vast bulk of botanical and zoological work on living and extinct forms published during the last quarter of the 19th century increased almost beyond all expectation the evidence for the fact of evolution. The discovery of a single fossil creature in a geological stratum of a wrong period, the detection of a single anatomical or physiological fact irreconcilable with origin by descent with modification, would have been destructive of the theory and would have made the reputation of the observer. But in the prodigious number of supporting discoveries that have been made no single negative factor has appeared, and the evolution from their predecessors of the forms of life existing now or at any other period must be taken as proved. It is necessary to notice, however, that although the general course of the stream of life is certain, there is not the same certainty as to the actual individual pedigrees of the existing forms. In the attempts to place existing creatures in approximately phylogenetic order, a striking change, due to a more logical consideration of the process of evolution, has become established and is already resolving many of the earlier difficulties and banishing from the more recent tables the numerous hypothetical intermediate forms so familiar in the older phylogenetic trees. The older method was to attempt the comparison between the highest member of a lower group and the lowest member of a higher group—to suppose, for example, that the gorilla and the chimpanzee, the highest members of the apes, were the existing representatives of the ancestors of man, and to compare these forms with the lowest members of the human race. Such a comparison is necessarily illogical, as the existing apes are separated from the common ancestor by at least as large a number of generations as separate it from any of the forms of existing man. In the natural process of growth, the gap must necessarily be wider between the summits of the twigs than lower down, and, instead of imagining "missing links," it is necessary to trace each separate branch as low down as possible, and to institute the comparisons between the lowest points that can be reached. The method is simply the logical result of the fact that every existing form of life stands at the summit of a long branch of the whole tree of life. A due consideration of it leads to the curious paradox that if any two animals be compared, the zoologically lower will be separated from the common ancestor by a larger number of generations, since, on the average, sexual maturity is reached more quickly by the lower form. Naturally very many other factors have to be considered, but this alone is a sufficient reason to restrain attempts to place existing forms in linear phylogenetic series. In embryology the method finds its expression in the limitation of comparisons to the corresponding stages of low and high forms and the exclusion of the comparisons between the adult stages of low forms and the embryonic stages of higher forms. Another expression of the same method, due to Cope, and specially valuable to the taxonomist, is that when the relationship between Orders is being considered, characters of sub-ordinal rank must be neglected. It must not be supposed that earlier writers all neglected this method, or still less that all writers now employ it, but merely that formerly it was frequently overlooked by the best writers, and now is neglected only by the worst. The result is, on the one hand, a clearing away of much fantastic phylogeny, on the other, an enormous reduction of the supposed gaps between groups.

Comparative anatomy.

There has been a renewed activity in the study of existing forms from the point of view of obtaining evidence as to the nature and origin of species. Comparative anatomists have been learning to refrain from basing the diagnosis of a species, or the description of the condition of an organ, on the evidence of a single specimen. Naturalists who deal specially with museum collections have been compelled, it is true, for other reasons to attach an increasing importance to what is called the type specimen, but they find that this insistence on the individual, although convenient as a guard against rash or imperfect diagnosis, is unsatisfactory from the point of view of scientific zoology; and propositions for the amelioration of this condition of affairs range from a refusal of Linnæan nomenclature in such cases, to the institution of a division between *master species* for such species as have been properly revised by the comparative morphologist, and *provisional species* for such species as have been provisionally registered by those working at collections. Those who work with living forms of which it is possible to obtain a large number of specimens, and those who make revisions of the provisional species of palæontologists, are slowly coming to some such conception as that a species is the abstract central point around which a group of variations oscillate, and that the peripheral oscillations of one species may even overlap those of an allied species. It is plain that we have moved far from the connotation and denotation of the word *species* at the time when Darwin began to discuss the origin of species, and that the movement, on the one hand, tends to simplify the problem philosophically, and, on the other, to make it difficult for the amateur theorist.

The conception of evolution is being applied more rigidly to the comparative anatomy of organs and systems of organs. When a series of the modifications of an anatomical structure has been sufficiently examined, it is frequently possible to decide that one particular condition is primitive, ancestral, or central, and that the other conditions have been derived from it. Such a condition has been termed, with regard to the group of animals or plants the organs of which are being studied, *archecentric*. The possession of the character in the archecentric condition in (say) two of the members of the group does not indicate that these two members are more nearly related to one another than they are to other members of the group; the archecentric condition is part of the common heritage of all the members of the group, and may be retained by any. On the other hand, when the ancestral condition is modified, it may be regarded as having moved outwards along some radius from the archecentric condition. Such modified conditions have been termed *apocentric*. It is obvious that the mere apocentricity of a character can be no guide to the affinities of its possessor. It is necessary to determine if the modification be a simple change that might have occurred in independent cases, in fact if it be a multiradial apocentricity, or if it involved intricate and precisely combined anatomical changes that we could not expect to occur twice independently; that is to say, if it be a uniradial apocentricity. Multiradial apocentricities lie at the root of many of the phenomena that have been grouped under the designation *Convergence*. Especially in the case of manifest adaptations, organs possessed by creatures far apart genealogically may be moulded into conditions that are extremely alike. Ray Lankester's term, *homoplasy*, has passed into currency as designating such cases where different genetic material has been pressed by similar conditions into similar moulds. These may be called heterogenous homoplasies, but it is necessary to recognize the existence of homogeneous homoplasies, here called multiradial apocentricities. A complex apocentric modification of a kind which we cannot imagine to have been repeated independently, and which is to be designated as uniradial, frequently forms a new centre around which new diverging modifications are produced. With reference to any particular group of forms such a new centre of modification may be termed a *metacentre*, and it is plain that the archecentre of the whole group is a metacentre of the larger group of which the group under consideration is a branch. Thus, for instance, the archecentric condition of any Avian structure is a metacentre of the Sauropsidan stem. A form of apocentricity extremely common and often perplexing may be termed *pseudocentric*; in such a condition there is an apparent simplicity that reveals its secondary nature by some small and apparently meaningless complexity.

Bionomics

Another group of investigations that seems to play an important part in the future development of the theory of evolution relates to the study of what is known as organic symmetry. The differentiations of structure that characterize animals and plants are being shown to be orderly and definite in many respects; the relations of the various parts to one another and to the whole, the modes of repetition of parts, and the series of changes that occur in groups of repeated parts appear to be to a certain extent inevitable, to depend on the nature of the living material itself and on the necessary conditions of its growth. Closely allied to the study of symmetry is the study of the direct effect of the circumambient media on embryonic young and adult stages of living beings (see EMBRYOLOGY, PHYSIOLOGY OF; HEREDITY; and VARIATION), and a still larger number of observers have added to our knowledge of these. It is impossible here to give even a list of the names of the many observers who in recent times have made empirical study of the effects of growth-forces and of the symmetrical limitations and definitions of growth. It is to be noticed, however, that, even after such phenomena have been properly grouped and designated under Greek names as laws of organic growth, they have not become explanations of the series of facts they correlate. Their importance in the theory of evolution is none the less very great. In the first place, they lessen the number of separate facts to be explained; in the second, they limit the field within which explanation must be sought, since, for instance, if a particular mode of repetition of parts occur in mosses, in flowering-plants, in beetles, and in elephants, the seeker of ultimate explanations may exclude from the field of his inquiry all the conditions individual to these different organic forms, and confine himself only to what is common to all of them; that is to say, practically only the living material and its environment. The prosecution of such inquiries is beginning to make unnecessary much ingenious speculation of a kind that was prominent from 1880 to 1900; much futile effort has been wasted in the endeavour to find on Darwinian principles special "selection-values" for phenomena the universality of which places them outside the possibility of having relations with the particular conditions of particular organisms. On the other hand, many of those who have been specially successful in grouping diverse phenomena under empirical generalizations have erred logically in posing their generalizations against such a *vera causa* as the preservation of favoured individuals and races. The period between the publication of the *Origin of Species* and the writing of the article EVOLUTION in the ninth edition of this Encyclopædia was characterized chiefly by anatomical and embryological work; the period to which this supplementary article refers has been marked by no diminution in anatomical and embryological enthusiasm, but by the fact that a large number of the continually increasing body of investigators have turned again to bionomical work. Inasmuch as Lamarck attempted to frame a theory of evolution in which the principle of natural selection had no part, the interpretation placed on their work by many bionomical investigators recalls the theories of Lamarck, and the name *Neo-Lamarckism* has been used of such a school of biologists, particularly active in America. The weakness of the Neo-Lamarckian view lies in its interpretation of heredity; its strength lies in its zealous study of the living world and the detection therein of proximate empirical laws, a strength shared by very many bionomical investigations, the authors of which would prefer to call themselves Darwinians, or to leave themselves without sectarian designation.

Biometrics. Statistical inquiry into the facts of life has long been employed, and in particular Galton, within the Darwinian period, has advocated its employment and developed its methods. Within quite recent years, however, a special school has arisen with the main object of treating the processes of evolution quantitatively. It has been the habit of biologists to use the terms variation, selection, elimination, correlation, and so forth, vaguely; the new school, which has been strongly reinforced from the side of physical science, insists on quantitative measurements of the terms. When the anatomist says that one race is characterized by long heads, another by round heads, the biometricist demands numbers and percentages. When an organ is stated to be variable, the biometricist demands statistics to show the range of the variations and the mode of their distribution. When a character is said to be favoured by natural selection, the biometricist demands investigation of the death-rate of individuals with or without the character. When a character is said to be transmitted, or to be correlated with another character, the biometricist declares the statement valueless without numerical estimations of the inheritance or correlation. The subject is still so new, and its technical methods (see VARIATION) have as yet spread so little beyond the group which is formulating and defining them, that it is difficult to do more than guess at the importance of the results likely to be gained. Enough, however, has already been done to show the vast importance of the method in grouping and codifying the empirical facts of life, and in so preparing the way for the investigation of ultimate "causes." The chief pitfall appears to be the tendency to attach more meaning to the results than from their nature they can bear. The ultimate value of numerical inquiries must depend on the equivalence of the units on which they are based. Many of the characters that up to the present have been dealt with by biometrical inquiry are obviously composite. The height or length of arm of a human being, for instance, is the result of many factors, some inherent, some due to environment, and until these have been sifted out, numerical laws of inheritance or of correlation can have no more than an empirical value. The analysis of composite characters into their indivisible units and statistical inquiry into the behaviour of the units would seem to be a necessary part of biometric investigation, and one to which much further attention will have to be paid.

Segregation. It is well known that Darwin was deeply impressed by differences in flora and fauna, which seemed to be functions of locality, and not the result of obvious dissimilarities of environment. Wallace's studies of island life, and the work of many different observers on local races of animals and plants, marine, fluviatile, and terrestrial, have brought about a conception of segregation as apart from differences of environment as being one of the factors in the differentiation of living forms. The segregation may be geographical, or may be the result of preferential mating, or of seasonal mating, and its effects plainly can be made no more of than proximate or empirical laws of differentiation, of great importance in codifying and simplifying the facts to be explained.

Bathmism. Consideration of phylogenetic series, especially from the palæontological side, has led many writers to the conception that there is something of the nature of a growth-force inherent in organisms and tending inevitably towards divergent evolution. It is suggested that even in the absence of modification produced by any possible Darwinian or Lamarckian factors, that even in a neutral environment, divergent evolution of some kind would have occurred. The conception is necessarily somewhat hazy, but the words *Bathmism* and *Bathmic Evolution* have been employed by a number of writers for some such conception. Closely connected with it, and probably underlying many of the facts which have led to it, is a more definite group of ideas that may be brought together under the phrase "phylogenetic limitation of variation." In its simplest form, this phrase implies such an obvious fact as that whatever be the future development of, say, existing cockroaches, it will be on lines determined by the present structure of these creatures. In a more general way, the phrase implies that at each successive branching of the tree of life, the branches become more specialized, more defined, and, in a sense, more limited. The full implications of the group of ideas require, and are likely to receive, much attention in the immediate future of biological investigation, but it is enough at present to point out that until the more obvious lines of inquiry have been opened out much more fully, we cannot be in a position to guess at the existence of a residuum, for which such a metaphysical conception as Bathmism would serve even as a convenient disguise for ignorance.

Contributions to the theory of evolution have been extremely numerous since 1879. It has been a feature of great promise that such contributions have received attention almost directly in proportion to the new methods of observation and the new series of facts with which they have come. Those have found little favour who brought to the debate only formal criticisms or amplifications of the Darwinian arguments, or re-marshallings of the Darwinian facts, however ably conducted. The time has not yet come for the attempt to synthesize the results of the many different and often apparently antagonistic groups of workers, however plainly it may appear that they are pressing towards similar conclusions under different banners. The great work that is going on is the simplification of the facts to be explained by grouping them under empirical laws; and the most general statement relating to these that can yet be made is that no single one of these laws has as yet shown signs of taking rank as a *vera causa* comparable with the Darwinian principle of natural selection.

REFERENCES. — Practically, every botanical and zoological publication of recent date has its bearing on evolution. The following are a few of the more general works :—BATESON. *Materials for the Study of Variation.*—BUNGE. *Vitalismus und Mechanismus.*—COPE. *Origin of the Fittest; Primary Factors of Organic Evolution; Darwin's Life and Letters.*—EIMER. *Organic Evolution.*—GULICK. "Divergent Evolution through Cumulative Segregation," *Jour. Linn. Soc.* xx.—HAACKE. *Schöpfung des Menschens.*—MITCHELL. "Valuation of Zoological Characters," *Trans. Linn. Soc.* viii. pt. 7. —PEARSON. *Grammar of Science.*—ROMANES. *Darwin and after Darwin.*—SEDGWICK. Presidential Address to Section Zoology, *Brit. Ass. Rep. 1899.*—WALLACE. *Darwinism.*—WEISMANN. *The Germ-Plasm.* Further references of great value will be found in the works of Bateson and Pearson referred to above, and in the annual volumes of the *Zoological Record*, particularly under the head "General Subject." (P. C. M.)

Evora, a city and archiepiscopal see of Portugal, capital of district Evora, about 60 miles east by south from Lisbon, at an altitude of 909 feet. Here is held, in June, one of the largest fairs in the country. The "Temple of Diana" is now used as a library. Good marble is quarried. Population, 15,134. The district of Evora has an area of 2736 square miles, and population 118,408, giving 43 inhabitants to the square mile. A great part of its surface is uncultivated. The district is famous for its mules, and abounds in cork-woods; there are mines of iron, copper, and asbestos, and marble quarries.

Evreux, chief town of department Eure, France, 67 miles west-north-west of Paris by rail. The cathedral has been entirely restored (finished 1896). The Hôtel de Ville is a handsome edifice, completed 1895; in front of it is a sculptured fountain with allegorical figures. The manufacture of ticking is the principal textile industry, and there are important iron and copper works. Population (1881), 9286; (1891), 10,825; (1901), 18,322.

Ewell, Richard Stoddert (1817–1872), American soldier, was born in Georgetown, D.C., 8th February 1817, and graduated at the U.S. Military Academy in 1840. He resigned his captain's commission in 1861, and entering the Confederate army, rose by successive grades (1861–65) from lieutenant-colonel to lieutenant-general. He lost a leg during the second Bull Run engagement in August 1862. General "Stonewall" Jackson trusted him greatly, and when fatally wounded nominated him as his successor. At the head of Jackson's veterans he fought at Winchester, Gettysburg, and the Wilderness, but was captured with his entire force by Sheridan on 6th April 1865. He died in Springfield, Tenn., on 25th January 1872.

Ewing, Juliana Horatia Orr (1842–1885), English writer of books for children, daughter of the Rev. Alfred Scott Gatty and of Margaret Gatty (see *Ency. Brit.* 9th ed. vol. x. p. 109), was born at Ecclesfield, Yorkshire, in 1842. One of a large family, she was accustomed to act as nursery story-teller to her brothers and sisters, and her brother Alfred Scott Gatty provided music to accompany her plays. She was well educated in classics and modern languages, and at an early age began to publish verses, being a contributor to *Aunt Judy's Magazine*, which her mother started in 1866. In 1867 she married Major Alexander Ewing, himself an author, and the composer of the well-known hymn "Jerusalem the Golden." From this time until her death (13th May 1885), previously to which she had been a constant invalid, Mrs Ewing produced a number of charming children's stories. The best of these are: *The Brownies* (1870), *A Flat-Iron for a Farthing* (1873), *Lob-lie-by the Fire* (1874), and *Jackanapes* (1884), the last-named, in particular, obtaining a great success; among others may be mentioned *Mrs Over-the-Way's Remembrances* (1869), *Six to Sixteen*, *Jan of the Windmill* (1876), *A Great Emergency* (1877), *We and the World* (1881), *Old-Fashioned Fairy Tales*, *Brothers of Pity* (1882), *The Doll's Wash*, *Master Fritz*, *Our Garden*, *A Soldier's Children*, *Three Little Nest-Birds*, *A Week Spent in a Glass-House*, *A Sweet Little Dear*, and *Blue-Red* (1883). Many of these were published by the S.P.C.K. Simple and unaffected in style, and sound and wholesome in matter, with quiet touches of humour and bright sketches of scenery and character, Mrs Ewing's stories have never been surpassed in the style of literature to which they belong.

Exchequer.—The ancient term "Exchequer" has survived mainly as the official title of the national banking account of the United Kingdom. For the conduct of the complicated business of a modern state many subsidiary accounts are necessary; but it is an essential part of the financial system of Great Britain that there should be one central account into which all sources of revenue flow, out of which all expenditure is provided, and on the operations of which the principal statements of national finance are based. This central account is commonly called the Exchequer, and its statutory title is "His Majesty's Exchequer." It may also be described with statutory authority as "The Account of the Consolidated Fund of Great Britain and Ireland." This account is, in fact, divided between the Banks of England and Ireland. At the head office of each of these institutions receipts are accepted and payments made on account of the Exchequer; but in published documents the two accounts are consolidated into one, the balances only at the two banks being shown separately.

Operations affecting the Exchequer are regulated by the Exchequer and Audit Departments Act, 1866. Section 10 prescribes that the gross revenue of the United Kingdom (less drawbacks and repayments, which are not really revenue) is payable, and must sooner or later be paid into the Exchequer. Section 11 directs that payments should be made from the fund so formed to meet the current requirements of spending departments. Sections 13, 14, 15 lay down the conditions under which money can be drawn from the Exchequer. Drafts on the Exchequer require the approval of an officer independent of the executive Government, the Comptroller and Auditor-General. But the description of the formal procedure required by statute cannot adequately express the actual working of the system, or the part it plays in the national finance. The simplicity of the system laid down by the Act of 1866 has been disturbed by the diversion of certain branches or portions of revenue from the Exchequer to "Local Taxation Accounts," under a system initiated by the Local Government Act, 1888, and much extended since.

While the Exchequer is, as already stated, the central account, it is not directly in contact with the details of either revenue or expenditure. As regards revenue, the produce of taxes and other sources of income passes, in the first instance, into the separate accounts of the respective receiving departments—mainly, of course, those of the Customs, Inland Revenue, and Post Office. A not inconsiderable portion is received in the provinces, and remitted to London or Dublin by bills or otherwise, and the ultimate transfers to the Exchequer are made (in round sums) from the accounts of the receiving departments in London or in Dublin. Thus, there are always considerable sums due to the Exchequer by the revenue departments; on the other hand, as floating balances are (for the sake of economy) used temporarily for current expenses, there are generally amounts due by the Exchequer to the receiving departments; such cross claims are adjusted periodically, generally once a month. Pages 16 and 17 of the "Finance Accounts of the United Kingdom for 1898–99" (House of Commons paper No. 258 of 1899), or the corresponding pages of the volume for any other year, show the gross amounts due to the Exchequer from the departments, and likewise the amounts payable out of the gross revenue in priority to the claim of the Exchequer. On the expenditure side a similar system prevails. No detailed payments are made direct from the Exchequer, but round sums are issued from it to subsidiary accounts, from which the actual drafts for the public services are met. For instance, the interest on the national debt is paid by the Bank of England from a separate account fed by transfers of round sums from the Exchequer as required. Similarly, payments for army, navy, and most civil services are met by the Paymaster-General out of an account of his own, fed by daily transfers from the Exchequer.

This system has two noticeable effects. Firstly, it secures the simplicity and finality of the Exchequer accounts, and therefore of all ordinary statements of national finance. Every evening the Chancellor of the Exchequer can tell his position so far as the Exchequer is concerned; on the first day of every quarter the Press is able to comment on the national income and expenditure up to the evening before. The annual account is closed on the evening of 31st March, and there can be no reopening of the budget of a past year such as may occur under other financial systems. The second effect of the system is to introduce a certain artificiality into the financial statements. Actual facts cannot be reduced to the simplicity of Exchequer figures; there is always (as already explained) revenue received by Government which has not yet reached the Exchequer; and there must always be a considerable outstanding liability in the form of cheques issued but not yet cashed. The suggested criticism is, however, met if it can be shown that, on the whole, the differences between the true revenue and the Exchequer receipts, or between the true (or audited) expenditure and the Exchequer issues, are not, taking one year with another, relatively considerable. The following figures illustrate this point:—

Expenditure (000s omitted)

	Exchequer Issues.	Audited Expenditure.	Difference.
	£	£	£
1888–89	85,674	86,070	+396
1889–90	86,083	86,033	− 50
1890–91	87,732	87,638	− 94
1891–92	89,928	90,125	+197
1892–93	90,375	90,164	−211
1893–94	91,303	91,530	+227
1894–95	93,919	93,818	−101
1895–96	97,764	97,667	− 97
1896–97	101,477	101,543	+ 66
1897–98	102,936	103,010	+ 74
Total for 10 years	927,191	927,598	+407

Revenue (000s omitted)

	Exchequer Receipts.	Actual Revenue.	Difference.
	£	£	£
1888–89	88,473	88,038	−435
1889–90	89,304	89,416	+112
1890–91	89,489	89,282	−207
1891–92	90,995	91,428	+433
1892–93	90,395	90,181	−214
1893–94	91,133	91,265	+132
1894–95	94,684	94,873	+189
1895–96	101,974	102,031	+ 57
1896–97	103,960	104,089	+129
1897–98	106,614	106,691	+ 77
Total for 10 years	947,011	947,294	+273

Surplus (000s omitted)

	Exchequer Accounts.	Diff. between Actual Rev. and Aud. Exp.	Difference.
	£	£	£
1888–89	2799	1968	−831
1889–90	3221	3383	+162
1890–91	1757	1644	−113
1891–92	1067	1303	+236
1892–93	20	17	− 3
1893–94	*−170*	*−265*	− 95
1894–95	765	1055	+290
1895–96	4210	4364	+154
1896–97	2473	2546	+ 73
1897–98	3678	3681	+ 3
Total for 10 years	19,820	19,696	−124

The third column in the above shows the price which has to be paid (in the form of discrepancies between facts and figures) for the simplicity secured to statements and records of the national finance by the present system embodied in the term Exchequer. Probably few will think the price too high in consideration of the advantages secured.

The principal official who derives a title from the Exchequer in its living sense is, of course, the Chancellor of the Exchequer. He is the person named second in the patent appointing commissions for executing the office of Lord High Treasurer of Great Britain and Ireland; but he is appointed Chancellor of the Exchequer for Great Britain and Chancellor of the Exchequer for Ireland by two additional patents. Although, in fact, the finance minister of the United Kingdom, he has no *statutory* power over the Exchequer apart from his position as second commissioner of the Treasury; but in virtue of his office he is by statute master of the Mint, senior commissioner for the reduction of the national debt, a trustee of the British Museum, an ecclesiastical commissioner, a member of the Board of Agriculture, a commissioner of Public Works and Buildings, Local Government, and Education, a commissioner for regulating the offices of the House of Commons, and has certain functions connected with the office of the Secretary of State for India. The only other Exchequer officer requiring mention is the Comptroller and Auditor-General, whose functions as Comptroller-General of the Exchequer have been already described.

The ancient name of the national banking account is still attached to one (until recently two) of the forms of unfunded national debt. Exchequer bills, which date from the reign of William and Mary, became extinct in 1897, and are not likely to be revived, but Exchequer bonds still possess a practical importance. An Exchequer bond is a promise by Government to pay a specified sum after a specified period, generally three or five years, and meanwhile to pay interest half-yearly at a specified rate on that sum. Government possesses no general power to issue Exchequer bonds; such power is only conferred by a special Act, and for specified purposes; but when the power has been created, Exchequer bonds issued in pursuance of it are governed by general statutory provisions contained in the Exchequer Bills and Bonds Act, 1866, and amending Acts. These Acts create machinery for the issue of Exchequer bonds and for the payment of interest thereon, and protect them against forgery.

Some traces may be mentioned of the ancient uses of the name Exchequer which still remain. The Chancellor of the Exchequer still presides at the ceremony of "pricking the list of sheriffs," which is a quasi-judicial function; and on that occasion he wears a robe of black silk with gold embroidery, which suggests a judicial costume. In England the last judge who was styled Baron of the Exchequer (Baron Pollock) died in 1897. In Scotland the jurisdiction of the Barons of the Exchequer was transferred to the Court of Session in 1856, but the same Act requires the appointment of one of the judges as "Lord Ordinary in Exchequer causes," which office still exists. In Ireland there remains a Lord Chief Baron of the Exchequer (Palles) who, however, is now a member of the King's Bench Division, and will be replaced by an ordinary judge of the division. A street near Dublin Castle is called Exchequer Street, recalling the separate Irish Exchequer, which ceased in 1817. The old term also survives in the full title of the Treasury representative in Scotland, which is "The King's and the Lord Treasurer's Remembrancer in Exchequer," while his office in the historic Parliament Square is styled "Exchequer Chambers." (S. E. S.-R.)

Excise Revenue.—The duties of excise in the United Kingdom are under the control of the Commissioners of Inland Revenue; the amount raised, apart from changes in the rate, shows a fairly constant tendency to increase, and is usually regarded as one of the best tests of the prosperity of the working classes. In the year 1900–1 the amount raised under the several heads of duty was as follows:—Spirit duty, £20,124,003; beer duty, £13,940,536; excise licences, £4,136,526; railway passenger duty, £331,214; miscellaneous, £7808; total, £38,540,087. Of this total about £33,200,000 was paid into the Exchequer, and about £5,200,000 to the Local Taxation Account in aid of the expenditure of local authorities. More than 88 per cent. of the whole revenue was derived from the taxation of two articles—spirits and beer.

The *spirit duty* is levied according to the quantity of "proof spirit" contained in the product of distillation, and the charge is taken at three different points in the process of manufacture, the trader being liable for the result of the highest of the three calculations. What is known as "proof spirit" is obtained by mixing nearly equal weights of pure alcohol and water, the quantity of pure alcohol being in bulk about 57 per cent. of the whole. The rate of duty in the year 1900 was 11s. per proof gallon, of which 6d. per gallon was paid to the Local Taxation Account. Owing to the high rate of duty as compared with the volume and intrinsic value of the spirits, the whole process of manufacture is carried on under the close supervision of revenue officials. All the vessels used are measured by them and are secured with revenue locks; the premises are under constant survey; and notice has to be given by the distiller of the materials used and of the several stages of his operations. Though the charge for duty is raised at the time when the process of distillation is completed, the duty is not actually paid until the spirits are required for consumption. In the meanwhile they may be retained in an approved "warehouse," which is also subject to close supervision.

The *beer duty* dates from 1880, in which year it was substituted for the duty on malt. In the first complete year after its imposition it produced £8,500,000. The rate of duty in 1900 was 7s. 9d. for every 36 gallons of worts at the standard gravity of 1055°. Out of this sum 3d. was paid to the Local Taxation Account and the remainder to the Exchequer. The specific gravity of the worts depends chiefly on the amount of sugar which they contain, and is ascertained by the saccharometer.

Excise *licences* may be divided into—(*a*) licences for the sale or manufacture of excisable liquors (about £2,180,000), (*b*) licences for other trades, such as tobacco dealers or manufacturers, auctioneers, pawnbrokers, &c. (about £330,000), (*c*) licences for male servants, carriages, and armorial bearings (about £749,000), and (*d*) gun, game, and dog licences (about £868,000). Nearly the whole of the licence duties (with the exception of about £250,000) is paid over to the Local Taxation Account.

The *railway passenger duty*, which was made an excise duty by 10 and 11 Vict. cap. 42, applies only to Great Britain. It is levied on all passenger fares exceeding 1d. per mile, the rate being 2 per cent. on urban, and 5 per cent. on other traffic.

The other items which go to make up the excise revenue are the charges on deliveries from bonded warehouses (£5168), and the duties on coffee mixture labels (£1573), and on chicory (£1067). For more detailed information reference should be made to Highmore's *Excise Laws*, and the annual reports of the Commissioners of Inland Revenue, especially those issued in 1870 and 1885. (G. H. M.)

Execution, Civil.—Execution may be defined as the process by which the judgments or orders of courts of law are made effectual. The English law of execution is very complicated, and only a statement of the principal forms can here be attempted. To begin with the High Court of Justice: A judgment for the recovery of money or costs is enforced, as a rule, by a writ of *fieri facias* addressed to the sheriff, and directing him to cause to be made (*fieri facias*) of the goods and chattels of the debtor a levy of a sufficient sum to satisfy the judgment. The wearing apparel, bedding, tools, &c., of the debtor to the value of £5 are protected. Competing claims are brought before the courts by the procedure of "interpleader." Where it is necessary to have recourse to the debtor's land for the purpose of getting payment of a judgment debt, a writ of *elegit* is issued to the sheriff, and the value of the land is assessed by an inquisition before a jury. Where a judgment directing the payment of money into court, or the performance by the defendant of any act within a limited time, has not been complied with, or where a corporation has wilfully disobeyed a judgment, a writ of sequestration is issued, to not less than four sequestrators, ordering them to enter upon the real estate of the party in default, and "sequester" the rents and profits until the judgment has been obeyed. Judgments for the recovery or for the delivery of the possession of land are enforceable by writ of possession. The recovery of specific chattels is obtained by writ of delivery. A judgment creditor may "attach" debts due by third parties to his debtor by what are known as garnishee proceedings. Stock and shares belonging to a judgment debtor may be charged by a charging order, so as, in the first instance, to prevent transfer of the stock or payment of the dividends, and ultimately to enable the judgment creditor to realise his charge. Under the Judgments Act, 1864, a debtor's interest in land may be sold. Where a judgment creditor is otherwise unable to reach the property of his debtor he may obtain equitable execution, usually by the appointment of a receiver, who collects the rents and profits of the debtor's land for the benefit of the creditor. A writ of attachment of the person of a defaulting debtor or party may be obtained in a variety of cases akin to contempt (*e.g.*, against a person failing to comply with an order to answer interrogatories, or against a solicitor not entering an appearance in an action, in spite of his written undertaking to do so), and in the cases where imprisonment for debt is still preserved by the Debtors Act, 1869. Contempt of court (*q.v.*) in its ordinary forms is also punishable by summary committal. In the county courts the chief modes of execution are "warrant of execution in the nature of a writ of *fieri facias*"; garnishee proceedings; equitable execution; warrants of possession and delivery, corresponding to the writs of possession and delivery above mentioned; committal, where a judgment debtor has, or, since the date of the judgment has had, means to pay his debt; and attachment of the person for contempt.

The principal modes of execution or "diligence" in Scots law are (i.) Arrestment and furthcoming, which corresponds to the English garnishee proceedings; (ii.) Arrestment *jurisdictionis fundandæ causâ*, *i.e.*, the seizure of movables within the jurisdiction to found jurisdiction against their owner, being a foreigner; this procedure, which is not, however, strictly a "diligence," as it does not bind the goods, is analogous to the French *saisie-arrêt*, and to the obsolete practice in the Mayor's Court of London known as "foreign attachment" (see Glyn and Jackson, *Mayor's Court Practice*, 2nd ed., vii. 260); (iii.) Arrestment under *meditatione fugæ* warrant, corresponding to the old English writ of *ne exeat regno*, and applicable in the case of a debtor who intends to leave Scotland to evade an action; (iv.) Arrestment on dependence, *i.e.*, of funds in security; (v.) Poinding, *i.e.*, valuation and sale of the debtor's goods; (vi.) Sequestration, *e.g.*, of tenant's effects under a landlord's hypothec for rent; (vii.) Action of adjudication, by which a debtor's "heritable" (*i.e.*, real) estate is transferred to his judgment creditor in satisfaction of his debt or security therefor. In Scots law "multiplepoinding" is the equivalent of "interpleader."

Execution in the *United States* is founded upon English law, which it closely resembles. See Bouvier, *Law. Dict.* (ed. Rawle, 1897, *s.v.* "Execution"). The "homestead laws" of various states exempt a certain amount or value of real estate occupied by a debtor as his homestead from a forced sale for the payment of his debts. This homestead legislation has been copied in some British Colonies (see *Journn. Soc. Comp. Leg.* N.S. No. III. pp. 441–48).

Authorities.—Anderson. *Execution.* London, 1889.—Johnston. *Annual Practice.* London, 1900.—Edwards. *Execution.* London, 1888.—Mackay. *Manual of Practice.* Edinburgh, 1893.

(A. W. R.)

Exeter, a city and county of itself, municipal, county (1888), and parliamentary borough, port and county town of Devonshire, England, on the Exe, 194 miles by rail west-south-west of London. In 1885 the parliamentary representation was reduced to one. In 1877 the grammar school was reorganized, the present buildings being erected on a new site in 1886. There are also a technical university extension college, an industrial, and a reformatory school. Among recent erections are four Established churches, a Roman Catholic church, a public hall, a volunteer drill hall, and an additional wing to the Technical and University Extension College. Belmont Pleasure Ground and the city asylum, costing £80,000, were both opened in 1886. There are four daily newspapers. Exeter has several large foundries. The imports of foreign and colonial merchandise in 1898 amounted to the value of £117,665, against £173,069 in 1888. In 1898, 24 vessels of 1514 tons were registered at the port. Showing a slight increase on 1888 were: entrances, 981 vessels of 79,333 tons; clearances, 979 of 78,193. Area of municipal and county borough and city prior to extension in 1900, 1883 acres. Population (1881), 37,447; (1891), 37,404. Extended area, 3158 acres. Population (1891), 45,588; (1901), 47,180.

Exhibitions.—The first exhibition of which there is any account, in either sacred or profane history, was that held by King Ahasuerus, who, according to the Book of Esther, showed in the third year of his reign "the riches of his glorious kingdom, and the honour of his excellent majesty, many days, even a hundred and fourscore days." The locale of this function was Shushan, the palace and the exhibits consisted of "white, green, and blue hangings, fastened with cords of fine linen and purple to silver rings and pillars of marble: the beds were of gold and silver, upon a pavement of red, and blue, and white, and black marble. And they gave them drink in vessels of gold, the vessels being diverse one from another." The first exhibition since the Christian era was at Venice during the dogeship of Lorenzo Tiepolo, in 1268. On that occasion there was a grand display, consisting of a water fête, a procession of the trades, and an industrial exhibition. The various guilds of the Queen City of the Seas marched through the narrow streets to the great square of St Mark, and their leaders asked the Dogaressa to inspect the products of their industry. Other mediæval exhibitions were the fairs held at Leipzig and Nijni-Novgorod in Europe, at Tantah in Egypt, and in 1689 that by the Dutch at Leyden.

The first modern exhibition was held at London in 1756 by the Society of Arts, which offered prizes for improvements in the manufacture of tapestry, carpets, and porcelain, the exhibits being placed side by side. Five years afterwards, in 1761, the same society gave an exhibition of agricultural machinery. In 1797 a collective display of the art factories of France, including those of Sèvres, the Gobelins, and the Savonnerie, was made in the Palace of St Cloud, and the exhibition was repeated during the following year in the Rue de Varennes, Paris. This experiment was so successful that in the last three days of the same year an exhibition under official auspices, at which private exhibitors were allowed to compete, was held in the Champ de Mars. Four years later, in 1801, there was a second official exhibition in the Grand Court of the Louvre. Upon that occasion juries of practical men examined the objects shown, and the winners of a gold medal were invited to dine with Napoleon, who was at that time First Consul. In the report of the jury the following remarkable sentence appeared:—"There is not an artist or inventor who, once obtaining thus a public recognition of his ability, has not found his reputation and his business largely increased." The third Paris Exhibition, held in 1802, was the first to publish an official catalogue. There were 540 exhibitors, including Montgolfier, the first aëronaut, and Jacquard, the inventor of the loom which bears his name. The fourth exhibition was held in 1806 in the esplanade in front of the Hotel des Invalides, and attracted 1422 exhibitors. There were no more exhibitions till after the fall of the empire, but in 1819 the fifth was held during the reign of Louis XVIII., with 1622 exhibitors. Others were held at Paris at various intervals, that in 1849 having 4500 exhibitors.

Other exhibitions, though on a smaller scale, were held in Dublin, London, and in various parts of Germany and Austria during the first half of the 19th century—that in 1844, held at Berlin, having 3040 exhibitors. Switzerland, Holland, Belgium, Sweden, Russia, Poland, Italy, Spain, and Portugal all held exhibitions, and there was a Free Trade Bazaar of British Manufactures at Covent Garden Theatre in 1845, which at the time created a great deal of interest. But all these exhibitions were confined to the products of the country in which they took place, and the first great International Exhibition was held in London in 1851 by the Society of Arts, under the Presidency of the Prince Consort All nations were invited to compete; a site was obtained in Hyde Park, and a building 20 acres in extent was erected, after the design of Sir Joseph Paxton, at a cost of £193,168. The exhibition was open for five months and fifteen days. The receipts amounted to £506,100, and the surplus was £186,000. The number of visitors was 6,039,195, and the money taken at the doors was £423,792. The total number of exhibitors was 13,937, of which Great Britain contributed 6861, the British Colonies 520, and foreign countries 6556. The International Exhibition of 1851 was followed by those of New York and Dublin in 1853, Melbourne and Munich in 1854, and Paris in 1855,—this latter was held in the Palais d'Industrie, which remained in existence until pulled down to make room for the two Palais des Beaux Arts, which formed one of the attractions of the 1900 exhibition. The exhibitors numbered 20,839, and the visitors 5,162,330. There were national exhibitions during the following years in several European countries, but the next great world's fair was held at London in 1862. The total space roofed in amounted to 988,000 square feet, 22·65 acres, the number of visitors was 6,211,103, and the amount received at the doors £408,530. The death of the Prince Consort had a depressing effect upon the enterprise. In 1865 an exhibition was held at Dublin, the greater proportion of the funds being supplied by Sir Benjamin Lee Guinness. The number of attendances during six months was 900,000, and the exhibition was opened at night. An Italian exhibition was held at Rome in 1862.

The Paris Exhibition of 1867 was upon a far larger scale than that of 1855. It was held, like those that preceded and succeeded it, at the Champ de Mars, and covered 41 acres. The building resembled an exaggerated gasometer. The external ring was devoted to machinery, the internal to the gradual development of civilisation, commencing with the stone age and continuing to the present era. A great feature of the exhibition was the park, which was studded with specimens of every style of modern architecture—Turkish mosques, Swedish cottages, English lighthouses, Egyptian palaces, and Swiss châlets. The number of attendances was 6,805,969. The exhibitors numbered 43,217, and the total amount received for entrances, concessions, &c., was £420,735. This was the first exhibition at which there were international restaurants. The cost of the exhibition was defrayed partly by the State and partly by private subscriptions.

Small exhibitions were held in various parts of Europe between 1867 and 1870, and in the latter year a series of international exhibitions, confined to one or two special descriptions of produce or manufactures, was inaugurated in London at South Kensington. These continued till 1874, but they failed to attract any very large attendance of the public, and were abandoned. A medal was given to each exhibitor, and reports on the various exhibits were published, but there was no examination of the exhibits by jurors. In 1873 there was an International Exhibition at Vienna. The main building, a rotunda, was erected in the beautiful park of the Austrian capital. There were halls for machinery and agricultural products, and hundreds of buildings, erected by different nations, were scattered amongst the woodlands of the Prater. Unfortunately, an outbreak of cholera diminished the attendance of visitors, and the receipts were only £206,477, although the visitors were said to have reached 6,740,500, and the number of exhibitors was 25,760.

None of the International Exhibitions held between 1857 and 1873 had attracted as many as 7,000,000 visitors, but the gradual extension of education amongst the masses, and the greater facilities for locomotion, brought about by the growth of the railway system in all portions of the civilized world, largely increased the attendances at subsequent World's Fairs. The Centennial Exhibition of 1876, to celebrate the one-hundredth anniversary of American Independence, was held at Fairmount Park, Philadelphia. The funds were raised partly by private subscriptions, and partly by donations from the city of Philadelphia, from Pennsylvania, and some of the neighbouring states. The Central Government at Washington made a large loan, which was subsequently repaid. The principal buildings, five in number, occupied an area of 48½ acres, and there were several smaller structures, which in the aggregate must have filled half as much space more, the largest being that devoted to the exhibits of the various departments of the United States Government, which covered 7 acres. Several novelties in exhibition management were introduced at Philadelphia. Instead of gold, silver, and bronze medals, only one description, bronze, was issued, the difference between the merits of the different exhibits being shown by the reports. Season tickets were not issued, and the price of admission, the same on all occasions, was half a dollar, or about 2s. 1d. The exhibition was not open at night or on Sundays, thus following the British, and not the continental, precedent. The number of visitors was 9,892,625, of whom 8,004,214 paid for admission, the balance being exhibitors, officials, and attendants. The total receipts amounted to £763,899. Upon one occasion, the Pennsylvania day, 274,919 persons—the largest number that had visited any exhibition up to that date—passed through the turnstiles. The display of machinery was the finest ever made, that of the United States occupying 480,000 square feet. The motive-power was obtained from a Corliss engine of 1600 horse-power. At this exhibition the United Kingdom and the British Colonies of Canada, Victoria, New South Wales, New Zealand, Cape Colony, and Tasmania made a very fine display, which was only excelled by that of the United States.

The Paris Exhibition of 1878 was upon a far larger scale in every respect than any which had been previously held in any part of the world. The total area covered not less than 66 acres, the main building in the

Champ de Mars occupying 54 acres. The French exhibits filled one-half the entire space, the remaining moiety being occupied by the other nations of the world. The United Kingdom, British India, Canada, Victoria, New South Wales, Queensland, South Australia, Cape Colony, and some of the British Crown Colonies occupied nearly one-third of the space set aside for nations outside France. Germany was the only great country which was not represented, but there were a few German paintings. The display of fine arts and machinery was upon a very large and comprehensive scale, and the Avenue des Nations, a street 2400 feet in length, was devoted to specimens of the domestic architecture of nearly every country in Europe, and to several in Asia, Africa, and America. The palace of the Trocadero, on the northern bank of the Seine, was erected for the exhibition. It was a handsome structure, with towers 250 feet in height, and flanked by two galleries. The rules for admission were the same as those at Philadelphia, and every person—exhibitor, journalist, or official—who had the right of entrance was compelled to forward two copies of his or her photograph, one of which was attached to the card of entry. The ordinary tickets were not sold at the doors, but were obtainable at various Government offices and shops, and from numerous pedlars in all parts of the city and suburbs. The buildings were somewhat unfinished upon the opening day, political complications having prevented the French Government and the French people from paying much attention to the exhibition till about six months before it was opened; but the efforts made in April were prodigious, and by June 1st, a month after the opening, the exhibition was complete, and afforded an object-lesson of the recovery of France from the calamities of 1870–71. The decisions arrived at by the international juries were accompanied by medals of gold, silver, and bronze. The expenditure by the United Kingdom was defrayed out of the consolidated revenue, each British colony defraying its own expenses. The display of the United Kingdom was under the control of a Royal Commission, of which the Prince of Wales was President. The number of paying visitors to the exhibition was 13,000,000, and the cost of the enterprise to the French Government, which supplied all the funds, was a little less than a million sterling, after allowing for the value of the permanent buildings and the Trocadero Palace, which were sold to the city of Paris. The total number of persons who visited Paris during the time the exhibition was open was 571,792, or 308,974 more than came to the French metropolis during the year 1877, and 46,021 in excess of the visitors during the previous exhibition of 1867. It was stated at the time that, in addition to the impetus given to the trade of France, the revenue of the Republic and of the city of Paris from customs and octroi duties was increased by nearly three millions sterling as compared with the previous year.

Exhibitions on a scale of considerable magnitude were held at Sydney and Melbourne in 1879 and 1880, and many Continental and American manufacturers took advantage of them in order to bring the products of their industry directly under the notice of Australian consumers, who had previously purchased their supplies through the instrumentality of British merchants. The United Kingdom and India made an excellent display at both cities, but the effect of the two great Australian exhibitions was to give a decided impetus to German, American, French, and Belgian trade. One of the immediate results was that lines of steamers to Melbourne and Sydney commenced to run from Marseilles and Bremen; another, that for the first time in the history of the Australian Colonies, branches of French banks were opened in the two principal cities. The whole cost of these exhibitions was defrayed by the local Governments.

Exhibitions were held at Turin and Brussels during 1880, and smaller ones at Newcastle, Milan, Lahore, Adelaide, Perth, Moscow, Ghent, and Lille during 1881 and 1882, and at Zurich, Bordeaux, and Caraccas in Venezuela during 1883. The next of any importance was held at Amsterdam in the latter year. On that occasion a new departure in Exhibition management was made. The Government of the Netherlands was to a certain extent responsible for the administration of the exhibition, but the funds were obtained from private sources, and a charge was made to each nation represented for the space it occupied. The United Kingdom, India, Victoria, and New South Wales took part in the exhibition, but there was no official representation of the mother country. Exhibitions on somewhat similar lines were held at Nice and Calcutta in the winter of 1883 and 1884, and at Antwerp in 1895.

A series of exhibitions, under the Presidency of the Prince of Wales, and managed by the late Sir Cunliffe Owen, was commenced at South Kensington in 1883. The first was devoted to a display of the various industries connected with Fishing; the second, in 1884, to objects connected with Hygiene; the third, in 1885, to Inventions; and the fourth, in 1886, to the British Colonies and India. These exhibitions attracted a large number of visitors, and realized a substantial profit. They might have been continued indefinitely if it had not been that the buildings in which they were held had become very dilapidated, and that the ground covered by them was required for other purposes. There was no examination of the exhibits by juries, but a tolerably liberal supply of instrumental music was supplied by military and civil bands. The Crystal Palace held a successful International Exhibition in 1884, and there was an Italian Exhibition at Turin, and a Forestry Exhibition at Edinburgh, during the same year. A World's Industrial Fair was held at New Orleans in 1884–85, and there were Universal Exhibitions at Montenegro and Antwerp in 1885, at Edinburgh in 1886, Liverpool, Adelaide, Newcastle, and Manchester in 1887, and at Glasgow, Barcelona, and Brussels in 1888. Melbourne held an International Exhibition in 1888–89 to celebrate the Centenary of Australia. Great Britain, Germany, France, Austria, and the United States were officially represented, and an expenditure of £237,784 was incurred by the local Government.

The Paris Exhibition of 1889 marked an important change in the policy which had previously characterized the management of these gatherings. The funds were contributed partly by the State, which voted 17,000,000 francs, and by the municipality of Paris, which gave 8,000,000. A guarantee fund amounting to 23,124,000 francs was raised, and on this security a sum of 18,000,000 francs was obtained and paid into the coffers of the administration. The bankers who advanced this sum recouped themselves by the issue of 1,200,000 "bons," each of 25 francs. Every bon contained 25 admissions, valued at 1 franc, and certain privileges in the shape of participation in a lottery, the grand prix being £20,000. The calculations of the promoters were tolerably accurate. The attendances reached the then unprecedented number of 32,350,297, of whom 25,398,609 paid in entrance tickets, and 2,723,366 entered by season tickets. A sum of 2,307,999 francs was obtained by concessions for restaurants and "side-shows," upon which the administration relied for much of the attractiveness of the exhibition. The total expenditure was 44,000,000 francs, and there was a small surplus. The space covered in the Champ de Mars, the Trocadero, the Palais d'Industrie, the Invalides, and the Quai d'Orsay was 72 acres, as compared with 66 acres in 1878, and 41 acres in 1867. Amongst the novelties was the Eiffel Tower, 1000 feet in height, and a faithful reproduction of a street in Cairo. The system of international juries was continued, but instead of gold, silver, and copper medals, diplomas of various merits were granted, each entitling the holder to a uniform medal of bronze. Some of the "side-shows" did not add to the dignity, although perhaps to the pecuniary success, of the exhibition. The date at which it was held, the Centenary of the French Revolution, did not commend it to several European Governments. Austria, Hungary, Belgium, China, Egypt, Spain, Great Britain, Italy, Luxembourg, Holland, Peru, Portugal, Rumania, and Russia took part, but not officially, while Germany, Sweden, Turkey, and Montenegro were conspicuous by their absence. On the other hand, Argentina, Bolivia, Chili, the United States, Greece, Guatamala, Morocco, Mexico, Nicaragua, Norway, Paraguay, Salvador, the South African Republic, Switzerland, Uruguay, and Venezuela sent Commissioners, who were accredited to the Government of the French Republic. The total number of exhibitors was 61,722, of which France contributed 33,937, and the rest of the world 27,785. The British and Colonial section was under the management of the Society of Arts, which obtained a guarantee fund of £16,800, and, in order to recoup itself for its expenditure, made a charge to exhibitors of 5s. per square foot for the space occupied. There were altogether 1149 British exhibitors, of whom 429 were in the Fine Arts section. One of the features of the exhibition was the number of congresses and conferences held in connexion with it.

During the year 1890 there was a Mining Exhibition at the Crystal Palace, and a Military Exhibition in the grounds of Chelsea Hospital; in 1891, a Naval Exhibition at Chelsea, and an International at Jamaica. In 1891–92 there were exhibitions at Palermo and at Launceston in Tasmania; in 1892, a Naval Exhibition at Liverpool, and one of Electrical Appliances at the Crystal Palace. A series of small national exhibitions under private management were held at Earl's Court between 1887 and 1891. The first of the series was that of the United States—Italy followed in 1888, Spain in 1889, France in 1890, and Germany in 1891.

The next Exhibition of the first order of magnitude was at Chicago in 1893, and was held in celebration of the 400th anniversary of the discovery of America by Columbus. The financial arrangements were undertaken by a company, with a capital of £2,000,000. The Central Government at Washington allotted £20,000 for the purposes of foreign exhibits, and £300,000 for the erection and administration of a building to contain exhibits from the various Departments of State. The exhibition was held at Jackson Park, a place for public recreation, 580 acres in extent, situated on the shore of Lake Michigan, on the southern side of the city, with which it was connected by railways and tramways. Special provision was made for locomotion in the grounds themselves by a continuous travelling platform and an elevated electric railway. The proximity of the lake, and of some artificial canals which had been constructed, rendered possible the service of electric and steam launches. The exhibition remained open from May 1st to October 30th, and was visited by 21,477,212 persons, each of whom paid half a dollar (about 2s. 1d.) for admission. The largest number of visitors on any one day was 716,881. In addition to its direct vote of £320,000, Congress granted £500,000 to the Exhibition in a special coinage, which sold at an enhanced price. The receipts from admissions were £2,120,000; from concessions, £750,000; and the miscellaneous receipts, £159,000: total, £3,029,000. The total expenses were £5,222,000. Of the sums raised by the Company, £400,000 was returned to the subscribers. Speaking roughly, it may be said that the total outlay on the Chicago Exhibition was six millions sterling, of which three millions were earned by the Fair, two millions subscribed by Chicago, and a million provided by the United States Government. The sums expended by the participating foreign Governments was estimated at £1,440,000. The total area occupied by buildings at Chicago was as nearly as possible 200 acres, the largest building, that devoted to Manufactures, being 1687 feet by 787, and 30·5 acres. The funds for the British Commission, which was under the control of the Society of Arts, were provided by the Imperial Government, which granted £60,000. The number of British exhibitors was 2236, of whom 597 were Industrial, 501 Fine Arts, and 1138 Women's work. In this total was included 18 Indian exhibitors. The space occupied by Great Britain was 306,285 square feet; and, in addition, separate buildings were erected in the grounds. These were Victoria House, the headquarters of the British Commission; the Indian Pavilion, erected by the Indian Tea Association; the Kiosk of the White Star Steamship Company; and the structure set up by the Maxim-Nordenfelt Company. Canada and New South Wales had separate buildings, which covered 100,140 and 50,951 square feet respectively; and Cape Colony occupied 5250, Ceylon 27,574, British Guiana 3367, Jamaica 4250, Trinidad 3400, and India 3584 square feet in the several buildings. The total space occupied by the British Colonies was therefore 193,660 square feet. The system of awards was considered extremely unsatisfactory. Instead of international juries, a single judge was appointed for each class, and the recompenses were all of one grade, a bronze medal and a diploma, on which was stated the reasons which induced the judge to make his decision. Some judges took a high standard, and refused to make awards except to a small proportion of selected exhibits; others took a low one, and gave awards indiscriminately. About 1183 awards were made to British exhibitors. The French refused to accept any awards. The value of the British goods exhibited was estimated, exclusive of Fine Arts, at £430,000, and the expenses of showing them at £200,000. A large expenditure was incurred in the erection of buildings, which were more remarkable for their beauty and grandeur than for their suitableness to the purposes for which they were intended. Considerable areas were devoted to "side-shows," and the midway Plaisaunce, as it was termed, resembled a gigantic fair. Every country in the world contributed something. There were sights and shows of every sort from everywhere. The foreign countries represented were Argentina, Austria, Belgium, Bolivia, Brazil, Bulgaria, Chili, Columbia, Costa Rica, Cuba, Curaçoa, Denmark, Danish West Indies, Ecuador, France, Germany, Greece, Guatamala, Honduras, Hayti, Japan, Johore, Korea, Liberia, Mexico, Monaco, Netherlands, Norway, Orange Free State, Paraguay, Persia, Portugal, Russia, Siam, Spain, Sweden, Turkey, United Kingdom and Colonies, Uruguay, and Venezuela.

Exhibitions were held at Antwerp, Madrid, and Bucharest in 1894; Hobart in 1894–95; Bordeaux, 1895; Niji Novgorod, Berlin, and Buda-Pest in 1896; Brussels and Brisbane in 1897. A series of exhibitions, under the management of the London Exhibitions Company, commenced at Earls Court in 1895 with that of India. India and Ceylon followed in 1896, the Victorian Era in 1897, the Universal in 1898, the Greater Britain (at which Victoria, Queensland, West Australia, Rhodesia, West

Africa, and the West Indies were represented) in 1899, Woman's Work in 1900, and a Military Exhibition in 1901.

The Paris Exhibition of 1900 was larger than any which had been previously held in Europe. The buildings did not cover so much ground as those at Chicago, but many of those at Paris had two or more floors. In addition to the localities occupied in 1889, additional space was obtained at the Champs Elysées, the Park of Vincennes, on the north bank of the Seine between the Place de la Concorde, and at the Trocadero. The total superficial area occupied was as follows:—Champs de Mars, 124 acres; Esplanade des Invalides, 30 acres; Trocadero Gardens, 40 acres; Champs Elysées, 37 acres; quays on left bank of Seine, 23 acres; quays on right bank of Seine, 23 acres; Park at Vincennes, 270 acres: total, 549 acres. The space occupied by buildings and covered in amounted to 4,865,328 square feet, $111\frac{1}{2}$ acres. The French section covered 2,691,000 square feet, the Foreign 1,829,880, and those at the Park of Vincennes 344,448 square feet. About one hundred French and seventy-five Foreign pavilions and detached buildings were erected in the grounds in addition to the thirty-six official pavilions, which were for the most part along the Quai d'Orsay. Funds were raised upon the same system as was adopted in 1889. The French Government granted £800,000, and a similar sum was contributed by the municipality of Paris. £2,400,000 was raised by the issue of 3,250,000 "bons," each of the value of 20 francs, and containing 20 tickets of admission to the Exhibition of the face value of one franc each, and a document which gave its holder a right either to a reduced rate for admission to the different "side-shows" or else to a diminution in the railway fare to and from Paris, together with a participation in the prizes, amounting to six million francs, drawn at a series of lotteries. Permission to erect restaurants, and to open places of amusement in buildings erected for that purpose, were sold at high prices, and for these privileges, which only realised 2,307,999 francs in 1889, the concessionaires agreed to pay 8,864,442 francs in 1900. The results did not justify the expectations which had been formed, and the administration finally consented to receive a much smaller sum. The administration calculated that they would have 65,000,000 paying visitors, though there were only 13,000,000 in 1878 and 25,398,609 in 1889. A very few weeks after the opening day, April 15th, it became evident that the estimated figures would not be reached, and as a large number of holders of "bons" threw them on the market, and the selling price of an admission ticket declined from the par value of one franc to less than half that amount, or from 30 to 50 centimes. The proprietors of the restaurants and "side-shows" discovered that they had paid too much for their concessions, that the buildings they had erected were far too handsome and costly to be profitable, and that the public preferred the Exhibition itself to the so-called attractions. The Exhibition was largely visited by foreigners, but various causes kept away many persons of wealth and position. Although many speculators were ruined, the Exhibition itself was successful. The attendance was unprecedentedly large, and during the seven months the Exhibition was open, 39,000,000 persons paid for admission with 47,000,000 tickets, since from two to five tickets were demanded at certain times of the day and on certain occasions. The entries of exhibitors, attendants, and officials totalled 9,000,000. The receipts were 114,456,213 francs (£4,578,249), and the expenditure 116,500,000 (£4,660,000), leaving a deficiency of rather more than two millions of francs (£80,000). It was calculated that the expenditure of the foreign nations which took part in the Exhibition was six millions sterling, and of the French exhibitors and concessionaires three millions sterling.

A new plan of classifying exhibits was adopted at Paris, all being displayed according to their nature, and not according to their country of origin, as had been the system at previous Exhibitions. One-half the space in each group was allotted to France, so that the exhibitors of that nation were enabled to overwhelm their rivals by the number and magnitude of the objects displayed by them. All the agricultural implements, whatever their nationality, were in one place, all the ceramics in another, so that there was no exclusively British and no exclusively German court. The only exceptions to this rule was in the Trocadero, where the French, British, Dutch, and Portuguese Colonies, Algeria, Tunis, Siberia, the South African Republic, China, and Japan were allowed to erect at their own cost separate pavilions. The greater number of the nationalities represented had palaces of their own in the Rue des Nations along the Quai d'Orsay, in which thoroughfare were to be seen the buildings erected by Italy, Turkey, the United States, Denmark, Portugal, Austria, Bosnia, Herzegovina, Peru, Hungary, the United Kingdom, Persia, Belgium, Norway, Luxemburg, Finland, Germany, Spain, Bulgaria, Monaco, Sweden, Rumania, Greece, Servia, and Mexico. Scattered about the grounds, in addition to those in the Trocadero, were the buildings of San Marino, Morocco, Ecuador, and Corea. Nearly every civilized country in the world was represented at the Exhibition, the most conspicuous absentees being Argentina, Brazil, Chili, and some other South and Central American Republics, and a number of the British Colonies. The most noteworthy attractions of the Exhibition were the magnificent effects produced by electricity in the Palace devoted to it in the Chateau d'Eau and in the Hall of Illusions, the two Palaces of the Fine Arts in the Champs Elysées, and the Bridge over the Seine dedicated to the memory of Alexander II. These permanent Fine Art palaces were devoted, the one to modern painting and sculpture, the other to the works of French artists and art workmen who flourished from the dawn of French art up to the end of the 18th century.

The United Kingdom was well but not largely represented both in Fine Arts and Manufactures, the administration of the section being in the hands of a Royal Commission, presided over by the Prince of Wales. The British Pavilion contained an important collection of paintings of the British school, chiefly by Reynolds, Gainsborough, and their contemporaries, and by Turner and Burne-Jones. Special buildings had been erected by the British Colonies and by British India. Canada, West Australia, and Mauritius occupied the former, India and Ceylon the latter. For the first time since the war of 1870 Germany took part in a French International Exhibition, and the exhibits showed the great industrial progress which had been made since the foundation of the empire in 1870. The United States made a fine display, and fairly divided the honours with Germany. Remarkable progress was manifested in the exhibits of Canada and Hungary. France maintained her superiority in all the objects in which good taste was the first consideration, but the more utilitarian exhibits were more remarkable for their number than their quality, except those connected with electrical work and display, automobiles, and iron-work. The number of exhibitors in the Industrial Section from the British Empire, including India and the Colonies, was 1250, who obtained 1647 awards, as many persons exhibited in several classes. There were, in addition, 465 awards for "collaborateurs," that is, assistants, engineers, foremen, craftsmen, and workmen who have co-operated in the production of the exhibits. In the British Fine Arts section there were 429 exhibits by 282 exhibitors, and 175 awards.

Important International Exhibitions were held at Glasgow, and at Buffalo, New York, during 1901. (G. C. L.)

Exmouth, a market-town, seaport, and watering-place in the Honiton parliamentary division of Devonshire, England, 10 miles south-east by south of Exeter by rail. The scenery of the neighbourhood is unrivalled, and the drives over Black Hill and Woodbury Common are very beautiful. Recent erections are two district churches, a mission church, a Catholic chapel, a Reformed Church of England, a Congregational chapel, a Wesleyan chapel, a public hall, yacht clubhouse, and the Maud Hospital. A pleasure ground and public garden has been opened. A new system of sewerage is nearly completed, at a cost of £35,000. There is an excellent supply of pure water. Two commodious excursion steamers run to different places on the coast daily during the summer. A new dispensary has lately been built, and it is proposed to erect a new hospital to take the place of the Maud Hospital. Area of urban district (two parishes), 4800 acres. Population (1881), 7265; (1901), 10,442.

Experiments on Animals.—The purpose of this article is to give some account of the present method of experiments on animals in the United Kingdom, and to set forth the chief discoveries that have been made by the help of such experiments.

I. Methods Employed.—The Act relating to experiments on animals was passed in 1876. At that time the majority of these experiments were physiological. There was, it may be fairly said, no such thing as bacteriology, and the doctrine of spontaneous generation was still held by one, at least, among men eminent in science. A few experiments were made in pathology, for instance in tubercle; and a few in surgery, in pharmacology, and in the action of poisons, especially snake-venom. But the chief use of experiments on animals was for the advancement of physiology. The evidence given before the Royal Commission (1875) was, almost entirely, on physiological matters, on the discoveries of Harvey, Bell, Magendie, and Claude Bernard, on the *Handbook for the Physiological Laboratory*, and so forth. The Act, therefore, was drafted with a view to physiology, without much concern for pathology, and without foreknowledge of bacteriology. At the present time, about 80 per cent. of the experiments are inoculations.

The chief conditions of the Act must be mentioned here, though they are also referred to under Vivisection. Every experiment must be made in a registered place open to Government inspection. As the Home Secretary said in 1898, "The only experiments performed elsewhere than at registered places are inoculation operations in connexion with the diseases of cattle; and inspection in such cases is deemed unnecessary and does not take place." Every experiment must be made under a licence; and every application for a licence must be recommended by the signatures of two out of a small body of authorities specified in the Act—presidents of certain learned societies, and professors of certain universities and colleges. The word "experiment" is not allowed to cover the use of more than one animal.

Most experiments are made not under a licence alone, but under a licence *plus* one or more certificates, and the wording and working of these certificates must be clearly understood, because it is over them that the question arises as to the amount of pain inflicted by these experiments. Under the licence alone the animal must be kept under an anæsthetic during the whole of the experiment; and "if the pain is likely to continue after the effect of the anæsthetic has ceased, or if any serious injury has been inflicted on the animal," it must be killed forthwith under the anæsthetic. Thus, under the licence alone, it is impossible to make an inoculation; for the experiment consists not in the introduction of the needle under the skin, but in the observation of the results of the inoculation. A guinea-pig inoculated with tubercle cannot be kept under an anæsthetic till it dies of the disease. The disease is the experiment, and it is therefore an experiment made without an anæsthetic, and not authorized by the licence alone. Again, under the licence alone it would have been impossible to work out the thyroid treatment of myxœdema, or the facts of cerebral localization. For to remove the thyroid gland, or to remove a portion of the surface of the brain, is to inflict a serious injury on the animal. The operation is done under profound anæsthesia—it would be impracticable otherwise: the wound is treated and dressed by the antiseptic method—suppuration would invalidate the result. But a serious injury has been inflicted. Nevertheless, the animal must not be killed forthwith: the result must be watched. These and the like experiments cannot therefore be made under the licence alone. For the removal of such disabilities as these, the Act empowers the Home Secretary to grant certain certificates, to be held with the licence. They must be recommended by two signatures, and various restrictions are put upon them by the Home Secretary. On July 11, 1898, the Home Secretary was asked, in the House of Commons, what were the conditions and regulations attached by the Home Office to licences and certificates; and he answered—

"The conditions are not always the same, but may vary according to the nature of the investigation. It is hardly possible, therefore, for me to state all the conditions attached to licences and certificates. The most important conditions, however (besides the limitations as to place, time, and number of experiments), and the conditions most frequently imposed, are those as to reporting and the use of antiseptics. The latter condition is that the animals are to be treated with strict antiseptic precautions, and if these fail and pain results, they are to be killed immediately under anæsthetics. The reporting conditions are, in brief, that a written record, in a prescribed form, is to be kept of every experiment, and is to be open for examination by the inspector; that a report of all experiments is to be forwarded to the inspector; and that any published account of an experiment is to be transmitted to the Secretary of State. Another condition requires the immediate destruction under anæsthetics of an animal in which severe pain has been induced, after the main result of the experiment has been attained."

The certificates are distinguished as A, B, C, E, EE, and F. Certificate D, which permitted the testing, by experiments, of "former discoveries alleged to have been made," has fallen into disuse. Certificate C permits experiments to be made by way of illustration of lectures. They must be made under the provisions contained in the Act as to the use of anæsthetics. Certificates E, EE, and F permit experiments to be made on the dog, cat, horse, ass, or mule. These certificates are linked with Certificate A or Certificate B. It is round these two certificates, A and B, that the controversy as to the pain caused by experiments on animals is centred.

Certificate A permits experiments to be made without anæsthesia. It is worded as follows:—"Whereas A. B. of [*here insert address and profession*] has represented to us (*i.e.*, two authorities) that he proposes, if duly authorized under the above-mentioned Act, to perform on living animals certain experiments described below: We hereby certify that, in our opinion, insensibility in the animal on which any such experiment may be performed cannot be produced by anæsthetics without necessarily frustrating the object of such experiment." All inoculations under the skin, all feeding experiments, and the like, are scheduled under this certificate. They must be scheduled somehow: they cannot legally be made under a licence alone. Though the only instrument used is a hypodermic needle, yet every inoculation is officially returned as an experiment, calculated to give pain, performed without an anæsthetic. It is for inoculations and the like experiments, and for them alone, and for nothing else, that Certificate A is allowed (or A linked with E or F). This want of a special certificate for inoculations, and this wresting of Certificate A for the purpose, have led to an erroneous belief that "cutting operations" are permitted by the Act without an anæsthetic. But, as the Home Secretary said in Parliament, in March 1897, "Certificate A is never allowed except for inoculations and similar trivial operations, and in every case a condition is attached to prevent unnecessary pain." And again he wrote in 1898, "Such special certificates (dispensing with anæsthetics) are granted only for inoculations, feeding, and similar procedures involving no cutting. The animal has to be killed under anæsthetics if it be in pain, so soon as the result of the experiment is ascertained."

Certificate B permits the keeping alive of the animal after the initial operation of an experiment. It is worded as follows:—"Whereas A. B. of [*here insert address and profession*] has represented to us (*i.e.*, two authorities) that he proposes, if duly authorized under the above-mentioned Act, to perform on living animals certain experiments described below, such animals being, during the whole of the initial operation of such experiments, under the influence of some anæsthetic of sufficient power to prevent their feeling pain: We hereby certify that, in our opinion, the killing of the animal on which any such experiment is performed before it recovers from the influence of the anæsthetic administered to it would necessarily frustrate the object of such experiment." Certificate B (or B linked with EE or F) is used for those experiments which consist in an operation *plus* subsequent observation of the animal. The section of a nerve, the removal of a secretory organ, the establishment of a fistula, the plastic surgery of the intestine, the transplantation of particles of a tumour, the sub-dural method of inoculation—these and the like experiments are made under this certificate. We may take, to illustrate the use of Certificate B, Mr. Horsley's observations on the thyroid gland. The removal of the gland was the initial operation; and this was performed under an anæsthetic, and with the antiseptic method. Then the animal was kept under observation. The experiment is neither the operation alone nor the observation alone, but the two together.

It has been said that Certificate B allows a licensee to make an incision under an anæsthetic, and then, when the anæsthetic has passed off, to keep the animal under curare, and make painful experiments on it through the incision. Curare, however, is not an anæsthetic under the Act; and Certificate B is granted "on condition that antiseptic precautions are used; and if these fail and pain continues after the anæsthetics have ceased to operate, the animal is immediately killed painlessly" (Letter from the Home Secretary, 1898). The purpose of this certificate is set forth in the Inspector's report for 1899:—"In experiments performed under Certificate B (or EE or F linked with B) the animal is anæsthetized during the operation, but is allowed to recover. These operations, in order to ensure success, are necessarily done with as much care as are similar operations upon the human subject, and the operations being performed aseptically, the process of healing takes place without pain."

From this brief account of the chief provisions of the Act, we come to consider the general method of experiments on animals in the United Kingdom, and the question of the infliction of pain on them. The total number of licensees in Great Britain and Ireland in 1899 was 259, of whom 74 (or 30 per cent.) performed no experiments. The total number of experiments was 8696. Of these, only 227 were made in Ireland; and since the report of the Inspector for Ireland is separate from that of the Chief Inspector for England and Scotland, we may take separately the experiments made in Great Britain. These are 8469 in number. They are tabulated in two divisions, called iii. A and iii. B:—

Table iii. is divided into two parts, A and B, for the purpose of separating experiments which are performed without anæsthetics from experiments in which anæsthetics are used. The only experiments performed without anæsthetics are inoculations, hypodermic injections, vaccinations, and similar proceedings, in which the pain inflicted is not greater than the prick of a needle. *No experiments requiring anything of the nature of a surgical operation, or that would cause the infliction of an appreciable amount of pain, are allowed to be performed without an anæsthetic.*

The total number of experiments included in Table iii. (A) is 1656. Of these there were performed—

Under licence alone	820
,, Certificate C	182
,, Certificate B	449
,, Certificate B and EE	205

In experiments performed under the licence alone, or under Certificate C, the animal suffers no pain, because it is kept under the influence of an anæsthetic from the beginning of the experiment until it is killed.

In experiments performed under Certificate B (or EE or F linked with B) the animal is anæsthetized during the operation, but is allowed to recover. These operations, in order to ensure success, are necessarily done with as much care as are similar operations upon the human subject, and the operations being performed aseptically, the process of healing takes place without pain. Inoculations made (upon rodents) with the object of diagnosing rabies in dogs have been placed, together with other inoculations requiring a preliminary incision in order to expose the part into which the injection is made, in Table iii. (A). In all these cases the whole operation is performed under an anæsthetic.

Table iii. (B) is devoted entirely to inoculations, hypodermic injections, and some few other proceedings, performed without anæsthetics. It includes 6813 experiments, whereof there were performed—

Under Certificate A	6689
,, Certificate A and E	83
,, Certificate A and F	41

A large number of these experiments were performed as a matter of professional duty for the diagnosis and prevention of disease, for the standardization of remedies, and for the testing of articles of food, such as water, milk, and butter, many of them on behalf of Government Departments, County Councils, and Municipal Corporations. The demand for antitoxins continues to increase, and during the past year 54,569 doses of diphtheria antitoxin have been sent out from two institutions.

It may be well to consider first the 6813 experiments included in Table iii. B. All, except 124, were performed on animals not especially protected by the Act. The animals most used for inoculations are mice, rats, guinea-pigs, and rabbits. The act of inoculation is not in itself painful. A small area of the skin is carefully shaved and cleansed, that it may be aseptic, the hypodermic needle is sterilized, and the method of hypodermic injection or of vaccination is the same as it is in medical practice. "A guinea-pig that will rest quietly in your hands before you commence to inject it, will remain perfectly quiet during the introduction of the needle under the skin; and the moment it is returned to the cage it resumes its interrupted feeding. Arteries, veins, and most of the parts of the viscera are without the sense of touch. We have actual proof of this in what takes place when a horse is bled for the purpose of obtaining curative serum. With a sharp lance a cut may be made in the skin so quickly and easily that the animal does nothing more than twitch the skin-muscle of the neck, or give his head a shake, while of the further proceeding of introducing a hollow needle into the vein, the animal takes not the slightest notice. Some horses, indeed, will stand perfectly quiet during the whole operation, munching a carrot, nibbling at a wisp of hay, or playing with a button on the vest of the groom standing at its head." These sentences, written in the *Medical Magazine* (June 1898) by Dr Woodhead, Professor of Pathology at Cambridge, are sufficient evidence that inoculations and the like experiments are not painful in the act. In a few instances cultures of micro-organisms have been made in the anterior chamber of the eye, by the introduction of a needle behind the cornea. This might be thought painful, but cocain renders the surface of the eye wholly insensitive. Many operations of ophthalmic surgery are done under cocain alone, and the anterior chamber of the eye is so far insensitive that a man may have blood or pus (*hypopyon*) in it, and hardly be conscious of the fact. The results of inoculation are in some cases negative, in others positive: the positive results are, in the great majority of cases, not a local change, but a general infection which may end in recovery, or in death. The diseases thus induced may, in many cases, fairly be called painless — such are septicæmia in a mouse, snake-venom in a rat, and malaria in a sparrow. Rabbits affected with rabies do not suffer in the same way as dogs and some other animals, but become subject to a painless kind of paralysis. It is probable that animals kept for inoculation have, on the whole, less pain than falls to the lot of a like number of animals in a state of nature or in the service of man: they are well fed and sheltered, and escape the rapacity of larger animals, the inevitable cruelties of sport, and the drudgery and sexual mutilation that man inflicts on the higher domestic animals.

The Inspector's report for 1899 says:—"The animals being experimented on under Certificates A and B have been carefully examined, and among the large number that I have seen there have been none showing any signs of pain. The guinea-pigs and rabbits, for example, which have been inoculated under Certificate A for the testing of antitoxins, for the diagnosis of disease, and so forth, are generally indistinguishable from the untouched animals in stock; and in most cases that have come under my notice of animals operated on under Certificate B, it would be quite impossible, apart from the scar or healing wound, to recognize that anything had been done to them."

We have now to consider Table iii. A, which includes all experiments other than inoculations and the like. In all of them (1656) anæsthetics were used. Those that were made under the licence alone, or under Certificate C, may be excluded, so far as the question of pain is concerned; for the animals were killed under the anæsthetic. There remain 654 experiments, made under Certificate B, or B linked with EE, in which the animal was anæsthetized during the operation, but was allowed to recover.

If it were lawful, under Certificate B, to make an incision under an anæsthetic, to call this the "initial operation," and then, without an anæsthetic, to make painful experiments through the incision on the deeper structures, doubtless much pain might be inflicted under this certificate. But experiments of this kind can be, and are, made under the licence alone, the animal being kept under an anæsthetic all the time, and killed under it. "No experiments requiring anything of the nature of a surgical operation, or that would cause the infliction of an appreciable amount of pain, are allowed to be performed without an anæsthetic" (Inspector's Report for 1899). "These certificates (B) are granted on condition that antiseptic precautions are used; and if these fail and pain continues after the anæsthetics have ceased to operate, the animal is immediately killed painlessly" (Letter from the Home Secretary, 1898). Of the 654 experiments made in 1899 under Certificate B, more than a fourth part were of the nature of inoculations only; but an anæsthetic was given, because the inoculation was made not under the skin, but by incision into the deeper structures.

Of other experiments such as are made under this certificate (which must be linked with Certificate EE for any experiment on a dog or a cat), three instances may be given here: an operation on the brain, a removal of part or the whole of a secreting gland, and the establishment of a fistula. It is to be noted that, for these and the like operations, profound anæsthesia and the strict observance of the aseptic method are matters of absolute necessity for the success of the experiment: the operation could not be performed without anæsthesia; and the experiment would come to nothing if the wound suppurated. It is to be noted, also, that these operations are such as are performed in surgery for the saving of life or for the relief of pain.

As to operations on the brain, it must be remembered that the surface of the brain is not sensitive. Therefore the removal or destruction of a portion of the surface of the brain, or the division of some tract of central nervous tissue, though it might entail some loss of power or of control, do not cause pain: a wound of the brain is painless. Tension within the cranial cavity, as in cases of cerebral tumour or cerebral abscess, may indeed cause great pain; and if the aseptic method failed in an experiment, inflammation and tension would ensue: in that case the animal must be killed.

The removal of part or the whole of a secreting gland (*e.g.*, the thyroid, the spleen, the kidney) is performed by the same methods, and with the same precautions, as in human surgery. Profound anæsthesia, and the use of a strict antiseptic or aseptic procedure, are of absolute necessity. The skin over the part to be removed must be shaved and carefully cleansed for the operation; the instruments, sponges, and ligatures must be sterile, not capable of infecting the wound; and when the operation is over, the wound must be carefully closed with sutures, and left to heal under a proper surgical dressing.

The establishment of a fistula, again, is an operation practised, as a matter of course, in large numbers of surgical cases. The stomach, the gall-bladder, the large intestine, are opened for the relief of obstruction, and kept open either for a time or permanently, according to the nature of the case. Under anæsthesia, the organ that is to be opened is exposed through an incision made through the structures overlying it, and is secured in the wound by means of fine sutures. Then, when it has become adherent there, it is opened by an incision made into it; no anæsthetic is needed for this purpose, because these internal organs are so unlike the skin in sensitiveness that an incision is hardly felt: the patient may say that he "felt a prick," or he may be wholly unconscious that anything has been done. A fistula thus established is not afterward painful, though there may be some discomfort now and again.

The classical instance is the case of Alexis St Martin, who was shot in the stomach in 1822, and recovered, but with a fistula. He let Dr Beaumont make experiments on him for nine years:—"During the whole of these periods, from the spring of 1824 to the present time (1833), he has enjoyed general good health . . . active, athletic, and vigorous; exercising, eating, and drinking like other healthy and active people. For the last four months he has been unusually plethoric and robust, though constantly subjected to a continuous series of experiments on the interior of the stomach; allowing to be introduced or taken out at the aperture different kinds of food, drinks, elastic catheters, thermometer tubes, gastric juice, chyme, &c., almost daily, and sometimes hourly. Such have been this man's condition and circumstances for several years past; and he now enjoys the most perfect health and constitutional soundness, with every function of the system in full force and vigour" (Beaumont, *Experiments and Observations on the Gastric Juice*, 1838).

We come now to the question, What anæsthetics are used in these experiments, and are they properly administered? In almost every case the anæsthetic used is chloroform or ether, sometimes combined with and followed by morphia or chloral. The anæsthetic given in each case must be stated in the returns sent to the Home Office. Animals take ether well, and there is no difficulty in rendering them unconscious with it. With some animals, chloroform is equally good; with others, it is dangerous to life; but Professor Hobday, of the Royal Veterinary College, published in 1898 an account of five hundred administrations of chloroform to dogs, in veterinary surgery, with only one death (*Lancet*, September 1898). Still, for dogs and cats ether is generally used. Morphia is seldom used alone, but in some cases it is used after chloroform or ether. It is certain that an animal, so far under the influence of morphia that it lies still, cannot be suffering, for the drug does not act directly on the muscles, but on the higher nervous centres. It happens now and again that a dog is excited, not narcotized, by morphia (see Professor Lugaro's paper, *Brit. Med. Journ.*, January 14, 1899). But this is altogether exceptional; an animal in such a condition could not be used for experiment; and the physiologist has other anæsthetics. Except in these rare cases, animals take morphia well, and are profoundly influenced by it. Curare is not an anæsthetic under the Act. Its use was thus defined in 1899 by the Home Secretary: "It is illegal to use curare as an anæsthetic. It is often used in addition to anæsthetics, for very good reasons; and as it does not render an anæsthetized animal sensitive, it would be absurd to forbid its use."

The following accounts of the action of curare are by Professor Rüffer, some time Hon. Secretary of the Institute of Preventive Medicine, and by a writer in the *Edinburgh Review*, who seems to speak from experience:—

1. "It is quite true that curare in small doses has the effect of paralyzing the motor nerves without affecting the nerves of sense; but in such doses as are used in the laboratory it paralyzes both sets of nerves, and this has actually been proved on man, as there have been cases of accidental curare poisoning in men who recovered, and in whom sensation has been totally abolished, while the action of the drug was apparent. Moreover, curare is nowadays not used alone, but is always used in combination with morphia, ether, chloroform, or other anæsthetics" (Professor Rüffer, *Liberty Review*, October 1893).

2. "It is pretty certainly known now that Claude Bernard was wrong, and that though curare acts first upon the motor nerves, it also, though less rapidly, paralyzes the sensory nerves, always supposing that by artificial respiration the animal is kept alive long enough for the less rapid effect to be produced. It would be out of place here to give the experimental evidence which satisfies physiologists upon this point. . . . Probably the truth is that, like all other nerve-poisons, the effect of curare varies with the dose. The muscular nerves are the first affected, then the sensory, and finally the central nervous system. As a matter of fact, however, morphia or some other narcotic is always given in addition to curare when it is used in laboratory work in England" (*Edinburgh Review*, July 1899).

The administration of chloroform or ether is performed by the ordinary methods of surgery; and the drug is given freely, if only for the reason that the absolute unconsciousness of the animal makes the accuracy and success of the experiment more certain. Lately, in an account of some experiments, it was stated that in two or three cases the anæsthesia was "incomplete." Such use of chloroform or ether may be made sometimes in surgery because of the general condition of the patient, or the special circumstances of the operation. But alike in surgery and in experiments on animals it is altogether exceptional, or something more than exceptional. The administration of morphia or of chloral is pushed beyond the point at which these drugs are "sedatives," almost to the point at which they become fatal.

It may be interesting to compare the pain or death or discomfort of these 8469 animals, used for experiment in Great Britain in 1899, with the fate of an equal number of the same kinds of animals, either wild, or preserved as game, or kept for the service or the amusement of man. Of the 8469 animals, the vast majority, no less than 6813, were used for inoculation only; and these were, most of them, mice, rats, guinea-pigs, or rabbits. Those which died may fairly be said to have suffered neither more nor less than the like number of domestic animals dying in the ordinary course of nature. Of the remaining 1656, the majority, 1002, were put under an anæsthetic, and kept in a condition of profound anæsthesia, and killed under the anæsthetic, there and then. The minority, 654, were subjected under profound anæsthesia to a surgical operation, and were allowed (provided their wounds healed well and they were not in pain) to recover. These 654 may fairly be put against the like number of animals wounded in the course of sport, or mutilated as live stock.

In 1900, in England and Scotland, the total number of licensees was 247, of whom 63 performed no experiments; and the inspector, Mr Thane, reported that licences and certificates had been granted and allowed only upon the recommendation of persons of high scientific standing; that the licensees were persons who, by their training and education, were fitted to undertake experimental work and to profit by it; and that all experimental work had been conducted in suitable places. The total number of experiments was 10,839, being 2370 more than in 1899. This increase is accounted for by 229 under Table III. (A): "experiments other than those of the nature of simple inoculations, hypodermic injections, or similar proceedings"; and 2141 under Table III. (B): "inoculations, hypodermic injections, and some few other proceedings performed without anæsthetics." Few of these experiments had been in any serious degree painful. Taking first those recorded in Table III. (A), 1885 in number, the experiments performed under licence alone or under Certificate C, "permitting experiments in illustration to lectures," together amounting to 1299, were unattended by pain, because the animal was kept under an anæsthetic during the whole of the experiment, and, if the pain was likely to continue after the effect of the anæsthetic had ceased, or if any serious injury had been inflicted on the animal, was killed before it recovered. In the remaining 586 experiments the operations were performed under anæsthetics, from the influence of which the animals were allowed to recover. The operations were performed aseptically, and the healing of the wounds as a rule took place without pain. If the antiseptic precautions failed and suppuration occurred, the animal was required to be killed. Mr. Thane reported that he had seen numerous animals on which serious operations had been performed—removal of organs and the like—and which were clearly not in pain; indeed, they were often to all appearance in perfect health. The experiments included in Table III. (B), 8954 in number, were all performed without anæsthetics. They were mostly inoculations, but a few were feeding experiments or the administration of various substances by the mouth. In no case had a certificate dispensing with the use of anæsthetics been presented for an experiment involving a serious operation.

In a large proportion of the inoculations included in Table III. (B) the result was negative—the animal did not exhibit any ill effects, and therefore did not suffer any pain. This was especially the case with many inoculations for purposes of diagnosis, with the great majority of the inoculations performed for the testing of articles of food, and with many of the inoculations made for the purpose of standardizing antitoxic serum, namely, those cases in which the antitoxin was sufficiently powerful to neutralize the amount of toxin injected, so that the latter had no action. It was only a small proportion of the inoculations practised that were followed by disease or poisoning. In some of these cases, such as the injection of certain drugs or of tetanus toxin, the effect produced was without doubt painful; but in the two most frequently employed proceedings of this kind—namely, inoculation for the diagnosis of tuberculosis and for the standardization of diphtheria antitoxin—there was some difference of opinion, amongst those who had had most experience, as to whether the effects produced were attended by pain or not. There was, however, strong reason for holding that the gradual development of tuberculosis, and the poisoning by diphtheria-toxin, resulting from such inoculations, although they might not be accompanied by acute suffering, were conditions which brought those proceedings within the category of "experiments calculated to give pain." In the event of pain ensuing as the result of an inoculation, a condition attached to the licence required that the animal should be killed under anæsthetics as soon as the main result of the experiment had been attained. Therefore in a very large number of instances, especially in the case of experiments performed without the use of anæsthetics, the experiments were entirely painless. The large increase in the number of inoculation experiments included in Table III. (B) was mainly due to the growing appreciation of their great value as a means of detecting, curing, and preventing disease. Inoculations for the purpose of diagnosis were now part of the routine of medical practice. During the year 1900, 2230 inoculations were made by three licensees for the purpose of standardizing antitoxins, and over 1500 inoculations were made by two licensees for the testing of milk. These experiments were performed in large numbers on behalf of the authorities responsible for the care of the public health. The appearance of the bubonic plague in England had afforded an illustration of the value of the experimental method in diagnosis. "It is," Mr Thane says, "of the greatest importance that this disease should be recognized as early as possible. This can only be done with certainty with the aid of inoculations into animals. Two fresh places were registered and two new licences were granted during 1900 expressly to allow of the necessary experiments being performed in localities where infection was apprehended."

Six licences were in existence in Ireland during 1900. The experiments performed were 135. They had been of a useful character, and were attended by little or no pain. The experiments were chiefly in connexion with the identification of canine rabies and tuberculosis, or the investigation of tetanus and epidemic cerebro-spinal meningitis.

II. Scientific Results.—The advantages that have been obtained by the help of experiments on animals may be arranged under two heads—(A) Physiology, (B) Pathology, Bacteriology, and Therapeutics.

A. Physiology.

1. *The Blood.*—Galen (A.D. 131) confuted the doctrine of Erasistratus, that the arteries contained πνεῦμα, the breath of life, proving by experiment that they contain blood. "Ourselves, having tied the exposed arteries above and below, opened them, and showed that they were indeed full of blood." Realdus Columbus (1559), though he did not discover the general or "systemic" circulation of the blood, yet seems to have discovered, by experiment, the pulmonary circulation. "The blood is carried through the pulmonary artery to the lung, and there is attenuated; thence, mixed with air, it is carried through the pulmonary vein to the left side of the heart. Which thing no man hitherto has noted or left on record, though it is most worthy of the observance of all men. . . . And this is as true as truth itself; for if you will look not only in the dead body but also in the living animal, you will always find this pulmonary vein full of blood, which assuredly it would not be if it were designed only for air and vapours. . . . Verily I pray you, O candid reader, studious of authority, but more studious of truth, to make experiment on animals. You will find the pulmonary vein full of blood, not air or *fuligo*, as these men call it, God help them." Harvey's treatise *De Motu Cordis et Sanguinis in Animalibus* was published at Frankfort in 1621. It begins thus: "When by many dissections of living animals, as they came to hand—*Cum multis vivorum dissectionibus, uti ad manum dabantur*—I first gave myself to observing how I might discover, with my own eyes, and not from books and the writings of other men, the use and purpose of the movement of the heart in animals, forthwith I found the matter hard indeed and full of difficulty; so that I began to think, with Frascatorius, that the movement of the heart was known to God alone. . . . At last, having daily used greater disquisition and diligence, by frequent examination of many and various living animals—*multa frequenter et varia animalia viva introspiciendo*—I came to believe that I had succeeded, and had escaped and got out of this labyrinth, and therewith had discovered what I desired, the movement and use of the heart and the arteries. And from that time, not only to my friends but also in public in my anatomical lectures, after the manner of the Academy, I did not fear to set forth my opinion in this matter." Here, and again at the end of the Preface, and again in the eighth chapter of the *De Motu*, he puts his experiments in the very foreground of the argument. Take the headings of his first four chapters:—1. *Causæ, quibus ad scribendum auctor permotus fuerit.* 2. *Ex vivorum dissectione, qualis fit cordis motus.* 3. *Arteriarum motus qualis, ex vivorum dissectione.* 4. *Motus cordis et auricularum qualis, ex vivorum dissectione.* He had, of course, help from other sources—from anatomy, and from physics; but it is certain, from his own words, that he attributed his discovery, in a very great measure, to experiments on animals. Malpighi (1661), professor of medicine at Bologna, by examining with a microscope the lung and the mesentery of the live frog, made out the capillary vessels. He writes to Borelli, professor of mathematics at Pisa, that he has failed in every attempt to discover them by injecting fluids into the larger vessels, but has succeeded by examining the tissues with the microscope: "Such is the divarication of these little vessels, coming off from the vein and the artery, that the order in which a vessel ramifies is no longer preserved, but it looks like a network woven from the offshoots of both vessels" (*De Pulmonibus*, 1661). Stephen Hales (1733), rector of Farringdon and minister of Teddington, and a Fellow of the Royal Society, made the first exact estimates of the blood-pressure, the real force of the blood, by inserting one end of a vertical glass tube into the crural artery of a mare, and noting the rise of the blood in the tube (*Statical Essays, containing Hæmostaticks, &c., 1733*). John Hunter, born 1738, made many observations on the nature and processes of the blood; and, above all, he discovered the facts of collateral circulation. These facts were fresh in his mind when he first ventured, in December 1785, to tie the femoral artery in "Hunter's canal" for the cure of aneurism in the popliteal space. The experiment that gave him his knowledge of the collateral circulation was made on one of the deer in Richmond Park: he tied its external carotid artery, to see what effect would be produced on the shedding of the antler. Some days later he found that the circulation had returned in the antler. He had the buck killed, and found that the artery had been completely closed by the ligature; but the small branches coming from it, between the heart and the ligature, were enlarged, and were in communication with others of its branches beyond the ligature; and by this collateral circulation the flow of blood to the antler had been restored. Among later observations on the circulation must be mentioned the use of the mercurial manometer by Poiseuille (1828) and Ludwig (1849), the study of the blood-pressure within the heart by Hering (1849), and the permanent tracing of the pressure-curves by Chauveau and Marey (1863). Finally, the study of those more abstruse problems of the circulation that the older physiologists had left alone—the influences of the central nervous system, the relations between blood-pressure and secretion, the automatism of the heart-beat, and the influence of gravitation.

2. *The Lacteals.*—Asellius (1622) by a single experiment demonstrated the flow of chyle along the lacteals. The existence of these minute vessels had been known even to Galen and Erastistratus, but they had made nothing of their knowledge. Asellius says: "I observed that the nerves of the intestines were quite distinct from these white threads, and ran a different course. Struck with this new fact, I was silent for a time, thinking of the bitter warfare of words among anatomists as to the mesenteric veins and their purposes. When I came to myself, to satisfy myself by an experiment I pierced one of the largest cords with a scalpel. I hit the right point, and at once observed a white liquid like milk flowing from the divided vessel." Jehan Pecquet (1647), in the course of an experiment on the heart, observed the flow of chyle into the subclavian vein, and its identity with the chyle in the lacteals; and by further experiment found the thoracic duct, and the chyle flowing up it: "I perceived a white substance, like milk, flowing from the vena cava ascendens into the pericardium, at the place where the right auricle had been. . . . I found these vessels (the thoracic duct) all along the dorsal vertebræ, lying on the spine, beneath the aorta. They swelled below a ligature; and when I relaxed it, I saw the milk carried to the orifices that I had observed in the subclavian vein." The existence of this duct, which is empty and collapsed after death, had been overlooked by Vesalius and all the great anatomists of his time.

3. *The Gastric Juice.*—Our knowledge about digestion dates back to the end of the 17th century, when Valisnieri first observed that the stomach of a dead animal contained a fluid which acted on certain bodies immersed in it—"a kind of *aqua fortis*." In 1752 Réaumur began his observations on this fluid: making birds swallow fine fenestrated tubes containing grain or meat, or sponges with threads attached; and observed that digestion consists in the dissolution of food, not in any sort of mechanical action or trituration. His observations were extended and perfected by Spallanzani (1777). Then came a period of uncertainty, without further advance; until in 1823 the French Academy offered a prize for the best work on the subject, and Tiedemann and Gmelin submitted their observations to them: "The work of Tiedemann and Gmelin is of especial interest to us on account of the great number of their experiments, from which came not only the absolute proof of the existence of the gastric juice, but also the study of the transformation of starch into glucose. Thus the theory of digestion entered a new phase: it was finally recognized, at least for certain substances, that digestion is not simply dissolution, but a true chemical transformation" (Claude Bernard, *Physiologie Opératoire*, 1879.) Beaumont's experiments on Alexis St Martin (*vide supra*) were published in 1838. They were, of course, based on the work of the physiologists: "I make no claim to originality in my opinions as it respects the existence and operation of the gastric juice. My experiments confirm the doctrines (with some modifications) taught by Spallanzani and many of the most enlightened physiological writers" (Preface to Dr Beaumont's book). Eberlé, in 1834, showed how this knowledge of the gastric juice might be turned to a practical use, by extracting it from the mucous membrane of the stomachs of animals after death: hence came the invention of the various preparations of pepsin. Later, Blondlot of Nancy, in 1842, studied the gastric juice by the method of a fistula, like that of St Martin. More recent observations have been made on the movements of the stomach during digestion, and on the influences of the nervous system on the process.

4. *Glycogen.*—The importance of Claude Bernard's discovery of glycogen is not annulled either by the fact that there is still work to be done on the finer issues of this part of physiology, or by the fact that many cases of diabetes are still past cure. It must be measured by the ignorance about the liver, which his work dispelled, and by the far-reaching influence of his discovery. His first experiments on the assimilation and destruction of sugar in the body were made in 1843. His discovery of the glycogenic action of the liver was made by keeping two dogs on different diets, one with sugar, the other without it, then killing them during digestion, and testing the blood in the veins coming from the liver: "What was my surprise when I found a considerable quantity of sugar in the hepatic veins of the dog that had been fed on meat only, and had been kept for eight days without sugar! . . . Finally, after many attempts—*après beaucoup d'essais et plusieurs illusions que je fus obligé de rectifier par des tâtonnements*—I succeeded in showing, that in dogs fed on meat the blood passing through the portal vein (from the stomach) does not contain sugar before it reaches the liver; but when it leaves the liver and comes by the hepatic veins into the inferior vena cava, this same blood contains a considerable quantity of a sugary substance (glucose)" (*Nouvelle Fonction du Foie*, Paris, 1853).

5. *The Pancreas.*—The 17th century was a time of very fanciful theories about the pancreas (Lindanus, Wharton,

Bartholini), which need not be recalled here. But Sylvius (François de Bois) had the wisdom to see that the pancreas must be estimated, not according to its position, but according to its structure, as of the nature of the salivary glands. He urged his pupil, Regnier de Graaf, to study it by experiment, and de Graaf says: "I put my hand to the work; and though many times I despaired of success, yet at last, by the blessing of God on my work and prayers, in the year 1662 I discovered a way of collecting the pancreatic juice." By the method of a fistula he collected and studied the secretion of the pancreas; and by further experiment he refuted Bartholini's theory that the pancreas was a sort of appanage or "biliary vesicle" of the spleen. But he got no help from the chemistry of his time; and could no more discover the amylolytic action of the pancreatic secretion than Galvani could discover wireless telegraphy. Still, he did good work; and Claude Bernard, 180 years later, went back to de Graaf's method of the fistula. His observations, begun in 1846, received a prize from the French Academy in 1850. Sir Michael Foster says of them: "Valentin, it is true, had in 1844 not only inferred that the pancreatic juice had an action on starch, but confirmed his view by actual experiment with the juice expressed from the gland; and Eberlé had suggested that the juice had some action on fat; but Bernard at one stroke made clear its threefold action. He showed that it on the one hand emulsified, and on the other hand split up into fatty acids and glycerine, the neutral fats; he clearly proved that it had a powerful action on starch, converting it into sugar; and lastly, he laid bare its remarkable action on proteid matters." Of late years it has been discovered that the pancreas, beside its work in digestion, has an "internal secretion": that it, like the thyroid gland and the suprarenal capsules, helps to keep the balance of the general chemistry of the whole body. Professor Schäfer, writing in 1894, says on this subject: "It was discovered a few years ago by von Mering and Minkowski that if, instead of merely diverting its secretion, the pancreas is bodily removed, the metabolic processes of the organism, and especially the metabolism of carbo-hydrates, are entirely deranged, the result being the production of permanent diabetes. But if even a very small part of the gland is left within the body, the carbo-hydrate metabolism remains unaltered, and there is no diabetes. The small portion of the organ which has been allowed to remain (and which need not even be left in its proper place, but may be transplanted under the skin or elsewhere) is sufficient, by the exchanges which go on between it and the blood generally, to prevent those serious consequences to the composition of the blood, and the general constitution of the body, which result from the complete removal of this organ." These later facts, not contradicting Bernard's work but adding to it, are of the very highest importance, alike in physiology and in pathology.

6. *The Growth of Bone.*—The experiments made by du Hamel (1739–1843) on the growth of bone by deposit from the periosteum (the thin membrane ensheathing each bone) rose out of Belchier's observation (1735) that the bones take up the stain of madder mixed with their food. Du Hamel studied the whole subject very carefully, and discovered this bone-producing power of the periosteum, that is an important fact in all operations on the bones. As he puts it, in the title of one of his own memoirs, *Les os croissent en grosseur par l'addition de couches osseuses qui tirent leur origine du périoste, comme le corps ligneux des Arbres augmente en grosseur par l'addition de couches ligneuses qui se forment dans l'écorce.* By feeding pigs at one time with dyed food, at another with undyed food, he obtained their bones in concentric layers alternately stained and unstained. His facts were confirmed by Bazan (1746) and Boehmer (1751); but his conclusions, unfortunately, were opposed by Haller. Still, he brought men to study the whole subject of the growth of bones, in length as well as in thickness, and the whole modelling of the bones, in adult life, by deposit and absorption. Bichat, John Hunter, Troja, and Cruveilhier took up his work in physiology and in surgery. Later, from the point of view of surgery, Syme (1837) and Stanley (1849) made experiments on the growth of bone, and on the exfoliation of dead bone; and, after them, Ollier, whose influence on this part of surgical practice has been of the very highest value.

7. *The Nervous System.*—*A.* The Nerve-Roots. Through all the centuries between Galen, who lived in the time of Commodus, and Sir Charles Bell, who lived in the time of George III., no great advance was made in our knowledge of the nervous system. The way of experiment, which had led Galen far ahead of his age, was neglected, and everything was overwhelmed by theories. Bell in London and Magendie in Paris took up the experimental study of the nervous system about where Galen had left it. The question of priority of discovery does not concern us here: we may take Sir Michael Foster's judgment, that Magendie brought exact and full proof of the truth which Bell had divined rather than demonstrated, that the anterior and posterior roots of spinal nerves have essentially different functions—"a truth which is the very foundation of the physiology of the nervous system." The date of Bell's work is 1811, *An Idea of a New Anatomy of the Brain, submitted for the Observation of the Author's Friends.* In it he says: "Considering that the spinal nerves have a double root, and being of opinion that the properties of the nerves are derived from their connexions with the parts of the brain, I thought that I had an opportunity of putting my opinion to the test of experiment, and of proving at the same time that nerves of different endowments were in the same cord (the same nerve-trunk) and held together by the same sheath. On laying bare the roots of the spinal nerves I found that I could cut across the posterior fasciculus of nerves, which took its origin from the spinal marrow, without convulsing the muscles of the back; but that on touching the anterior fasciculus with the point of the knife, the muscles of the back were immediately convulsed. Such were my reasons for concluding that the cerebrum and cerebellum were parts distinct in function, and that every nerve possessing a double function obtained that by having a double root. I now saw the meaning of the double connexion of the nerves with the spinal marrow; and also the cause of that seeming intricacy in the connexions of nerves throughout their course, which were not double at their origins." His other work, on the cranial nerves, which are "not double at their origins," bore fruit at once in surgery. Sir John Erichsen says of it: "Up to the time that Sir Charles Bell made his experiments on the nerves of the face, it was the common custom of surgeons to divide the facial nerve for the relief of neuralgia, *tic douleureux*; whereas it exercises, and was proved by Sir Charles Bell to exercise, no influence over sensation, and its division consequently for the relief of pain was a useless operation." *B.* Reflex Action.—The observations made by Sir Robert Boyle, Redi, Le Gallois, and others on the reflex movements of decapitated vipers, frogs, eels, and butterflies were of no great use from the point of view of physiology; but they led toward the discovery that nerve-power is stored in the spinal cord, and is liberated thence in action independent of the higher cerebral centres. Marshall Hall (1832–1837) discovered, by his experiments, that reflex actions are the work of definite groups of cells, set at certain points or levels in the cord; he proved the segmental structure of the cord, the existence of nerve-centres in it; and thus foreshadowed the discovery of the like centres in the brain. In his earlier writings (1832–1833) he extended the principles of the doctrines of reflex action to the larynx, the pharynx, and the sphincter muscles; later, in 1837, he demonstrated the course of nerve-impulses within the cord, from one level to another, and the effects of direct stimulation of the cord. Also he noted the effects of opium and of strychnine on reflex action; and the reflex character of the convulsions that occur in certain diseases. *C.* The Medulla Oblongata and the Cerebellum.—Flourens, who was among the earliest students of the use of chloroform, is best known for his experiments on the respiratory centre and the cerebellum. He localized the cells in the medulla that govern the reflex movement of respiration. Afterward came the discovery of cardiac and other centres in the neighbourhood of the respiratory centre. He showed also that the cerebellum is concerned with the equilibration and co-ordination of the muscles: that an animal, a few days old, deprived of sensation and consciousness by removal of the cerebral hemispheres, was yet able to stand and to move forward, but when the cerebellum also was removed, lost all power of co-ordination (*Recherches Expérimentales*, Paris, 1842). And from the observations made by him and by others, it was found that the semicircular canals of the internal ears are the terminal organs of this sense of equilibration. *D.* The Vaso-Motor Nerves.—Claude Bernard, studying the sympathetic nervous system, discovered the vaso-motor nerves, that control the calibre of the arteries. The question of priority between him and Brown Séquard need not be considered here. His first account of his work was communicated to the Société de Biologie in December 1851. The following account of it is from his *Leçons de Physiologie Opératoire* (1879):—

"Let me remind you how I was led to discover the vaso-motor nerves. Starting from the clinical observation, made long ago, that in paralyzed limbs you find at one time an increase of cold and at another an increase of heat, I thought that this contradiction might be explained by supposing that, side by side with the general action of the nervous system, the sympathetic nerve might have the function of presiding over the production of heat; that is to say, that in the case where the paralyzed limb was chilled, I supposed the sympathetic nerve to be paralyzed, as well as the motor nerves; while in the paralyzed limbs that were not chilled the sympathetic nerve had retained its function, the systematic nerves alone having been attacked. This was a theory, that is to say, an idea, leading me to make experiments; and for these experiments I must find a sympathetic nerve-trunk of sufficient size, going to some organ that was easy to observe: and must divide the trunk to see what would happen to the heat-supply of the organ. You know that the rabbit's ear, and the cervical sympathetic of this animal, offered us the required conditions. So I divided this nerve; and, at once, the experiment gave the lie direct to my theory—*Je coupai donc ce filet et aussitôt l'expéri-*

ence donna à mon hypothèse le plus éclatant démenti. I had thought that the section of the nerve would suppress the function of nutrition, of calorification, over which the sympathetic system had been supposed to preside, and would cause the hollow of the ear to become chilled; and here was just the opposite, a very warm ear, with great dilatation of its vessels." The experiments of Budge and Waller (1853) and of Schiff (1856) threw light on the action of these vaso-motor nerves, and on the place of the vaso-motor centre in the cord; and in 1858 Claude Bernard, by his experiments on the chorda tympani and the submaxillary gland, demonstrated their twofold influence, either to dilate or to constrict the vessels. "It is almost impossible to exaggerate the importance of these labours of Bernard on the vaso-motor nerves, since it is almost impossible to exaggerate the influence which our knowledge of the vaso-motor system, springing as it does from Bernard's researches as from its fount and origin, has exerted, is exerting, and in widening measure will continue to exert, on all our physiological and pathological conceptions, on medical practice, and on the conduct of human life. There is hardly a physiological discussion of any width in which we do not sooner or later come on vaso-motor questions" (Foster). *E.* Cerebral Localization.—The study of the motor and sensory centres of the cerebral hemispheres began in clinical observation. Observation of cases, and examination of the brain after death (Bouillard, 1825, Dax, 1836, Broca, 1861), led men to believe that a particular area of the left frontal lobe of the brain did indeed govern and permit the use of speech. Physiological experiments had nothing to do with the discovery of the speech centres. "Bouillard in 1825 collected a series of cases to show that the faculty of speech resided in the frontal lobes. In 1861 his views were brought by Aubertin before the notice of the Anthropological Society of Paris. Broca, who was present at the meeting, had a patient under his care who had been aphasic for twenty-one years, and who was in an almost moribund state. The autopsy proved of great interest, as it was found that the lesion was confined to the left side of the brain, and to what we now call the third frontal convolution. . . . In a subsequent series of fifteen typical cases examined, it was found that the lesion had destroyed, among other parts, the posterior part of the third frontal in fourteen" (Hamilton, *Text-Book of Pathology*). From this clinical fact, that the movements of speech depend on the integrity of a special area of the brain's surface, and from the facts of "Jacksonian epilepsy," and similar observations in medicine and surgery, began the experimental work of cerebral localization, by Hitzig, Goltz, Schiff, Ferrier, Yeo, Horsley, Beevor, and many more. It would be hard to find a more striking instance of the familiar truth that science and practice work hand in hand.

[These notes cover a part only of the results that have been obtained in physiology by the help of experiments on animals. The work of Boyle, Hunter, Lavoisier, Despretz, Regnault, and Haldane, on animal heat and on respiration; of Petit, Dupuy, Breschet, and Reid, on the sympathetic system; of Galvani, Volta, Hallex, du Bois-Reymond, and Pflüger, on muscular contraction—all these subjects have been left out, and many more. In his evidence before the Royal Commission (1875), Mr Darwin said: "I am fully convinced that physiology can progress only by the aid of experiments on living animals. I cannot think of any one step which has been made in physiology without that aid."]

B. Pathology, Bacteriology, and Therapeutics.

1. *Inflammation.*—Pathology is so intimately associated with the work of the microscope that it is a new study, in comparison with physiology. Fifty years ago the microscope was not in general use as it is now; nor did men have the lenses, microtomes, and staining-fluids that are essential to modern histology. Bacteriology, again, is even younger than pathology. Five and twenty years ago it had hardly begun to exist. For example, in the evidence before the Royal Commission (1875) one of the witnesses said that they "believed they were beginning to get an idea of the nature of tubercle." Anthrax was the first disease studied by the methods of bacteriology; and in his evidence concerning this disease, Sir John Simon speaks of bacteriology as of a discovery wholly new and unexplored: "We are going through a progressive work that has many stages, and are now getting more precise knowledge of the contagium. By these experiments on sheep it has been made quite clear that the contagium of sheep-pox is *something of which the habits can be studied, as the habits of a fern or a moss can be studied*; and we look forward to opportunities of thus *studying the contagium outside the body which it infects.* This is not a thing to be done in a day, or perhaps in ten years, but must extend over a long period of time." A few years later (1881) came Koch's discovery of the bacillus of tubercle. But a great advance was made in days before 1875 by the more general use of the microscope. Every change in the tissues during inflammation—the slowing of the blood-stream in the capillary vessels, the escape of the leucocytes through their walls into the surrounding tissues, the stagnation of the blood in the affected part—all these were observed in such transparent structures as the web or the mesentery of the frog, the bat's wing, or the tadpole's tail, irritated by a drop of acid, or a crystal of salt, or a scratch with a needle. It was in the course of observations of this kind that Wharton Jones observed the rhythmical contraction of veins, and Waller and Cohnheim observed the escape of the leucocytes, *diapedesis,* through the walls of the capillaries. From these simple experiments under the microscope arose all our present knowledge of the minute processes of inflammation. Later, came the work of Metchnikoff and others, showing the importance of *diapedesis* in relation to the presence of bacteria in the tissues.

2. *Suppuration and Wound-Infection.*—Suppuration may, in exceptional conditions, occur without micro-organisms, but practically every case of suppuration, wound-infection, or "blood-poisoning," all abscesses, boils, carbuncles, and all cases of puerperal fever, septicæmia, or pyæmia, are due to infection, either from without or from within the body, by various forms of *micrococcus.* The same is true of every case of erysipelas, or cellulitis, or acute gangrene—in short, of the whole multitude of "septic" diseases. The work done on these micrococci, and on other pathogenic micro-organisms, involved the study of the phases, antagonisms, and preferences of each kind, their range of variation and of virulence, and their products, and the influences on them of air, light, heat, and chemical agents. To establish a micro-organism as the cause of a disease, Koch postulated that it should be found in the diseased tissues, should be cultivated outside the body *in vitro,* should reproduce the same disease by inoculation in animals, and should be found again in the animals inoculated; and these postulates are but a single instance of the strict methods of bacteriology.

From the study of these organisms of suppuration arose Lister's work on the antiseptic method, as well as the serum-treatment for cases of micrococcic infection.

3. *Anthrax.*—The bacillus of anthrax (charbon, malignant pustule, wool-sorter's disease) was the first specific micro-organism discovered. Rayer and Davaine (1850) observed the *petits bâtonnets* in the blood of sheep dead of the disease; and in 1863, when Pasteur's observations on lactic-acid fermentation were published, Davaine recognized that the *bâtonnets* were not blood-crystals but living organisms. Koch afterward succeeded in cultivating the bacillus, and in reproducing the disease in animals by inoculation from these cultures. Pasteur's discovery of preventive inoculation of animals against the disease was communicated to the Académie des Sciences in February 1881; and in May of that year he gave his public demonstration at Pouilly-le-Fort. Two months later, at the International Medical Congress in London, he spoke as follows of this discovery:—". . . La méthode que je viens de vous exposer pour obtenir des vaccins du charbon était à peine connue qu'elle passait dans la grande pratique pour prévenir l'affection charbonneuse. La France perd chaque année pour une valeur de plus de vingt millions d'animaux frappés du charbon, plus de 30 millions, m'a dit une des personnes autorisées de notre Ministère de l'Agriculture; mais des statistiques exactes font encore défaut. On me demanda de mettre à l'épreuve les résultats qui précèdent par une grande expérience publique, à Pouilly-le-Fort, près de Melun. . . . Je la résume en quelques mots; 50 moutons furent mis à ma disposition, nous en vaccinâmes 25, les 25 autres ne subirent aucun traitement. Quinze jours après environ, les 50 moutons furent inoculés par le microbe charbonneux le plus virulent. Les 25 vaccinés résistèrent; les 25 non-vaccinés moururent, tous charbonneux, en cinquante heures. Depuis lors, dans mon laboratoire, on ne peut plus suffire à préparer assez de vaccin pour les demandes des fermiers. En quinze jours, nous avons vacciné dans les départements voisins de Paris près de 20,000 moutons et un grand nombre de bœufs, de vaches et de chevaux." The extent of this preventive vaccination may be judged from the fact that a single institute, the Sero-Therapeutic Institute of Milan, in a single year (1897–1898) sent out 165,000 tubes of anti-charbon vaccine, enough to inoculate 33,734 cattle and 98,792 sheep. In France, during the years 1882–1893, more than three million sheep and nearly half a million cattle were inoculated. In the *Annales de l'Institut Pasteur,* March 1894, M. Chamberland published the results of these twelve years in a paper entitled *Résultats Pratiques des Vaccinations contre le Charbon et le Rouget en France.* The mortality from charbon, before vaccination, was 10 per cent. among sheep and 5 per cent. among cattle, according to estimates made by veterinary surgeons all over the country. With vaccination, the whole loss of sheep was about 1 per cent.; the average for the twelve years was 0·94. The loss of vaccinated cattle was still less; for the twelve years it was 0·34, or about one-third per cent. The annual reports sent to M. Chamberland by the veterinary surgeons represent not more than half of the work. "A certain number of

veterinary surgeons neglect to send their reports at the end of the year. The number of reports that come to us even tends to become less each year. The fact is, that many veterinary surgeons who perform vaccinations every year content themselves with writing, 'The results are always very good; it is useless to send you reports that are always the same.' We have every reason to believe, as a matter of fact, that those who send no reports are satisfied; for if anything goes wrong with the herds, they do not fail to let us know it at once by special letters."

The following tables, from M. Chamberland's paper, give the results of Pasteur's treatment against *charbon* during 1882–1893, and against *rouget* (swine-measles) during 1886–1892. It is to be noted that the mortality from *rouget* among swine, in years before vaccination, was much higher than that from *charbon* among sheep and cattle: "it was about 20 per cent.; a certain number of reports speak of losses of 60 and even 80 per cent.; so that almost all the veterinary surgeons are loud in their praises of the new vaccination."

Vaccination against Charbon (France).

Years.	Total Number of Animals Vaccinated.	Number of Reports.	Animals Vaccinated according to Reports received.	Mortality. After First Vaccination.	Mortality. After Second Vaccination.	Mortality. During the Rest of the Year.	Total.	Total Loss per 100.	Average Loss before Vaccination.
SHEEP.									
1882	270,040	112	243,199	756	847	1037	2,640	1·08	10 %
1883	268,505	103	193,119	436	272	784	1,492	0·77	,,
1884	316,553	109	231,693	770	444	1033	2,247	0·97	,,
1885	342,040	144	280,107	884	735	990	2,609	0·93	,,
1886	313,288	88	202,064	652	303	514	1,469	0·72	,,
1887	293,572	107	187,811	718	737	968	2,423	1·29	,,
1888	239,574	50	101,834	149	181	300	630	0·62	,,
1889	239,974	43	88,483	238	285	501	1,024	1·16	,,
1890	223,611	69	69,865	331	261	244	836	1·20	,,
1891	218,629	65	53,640	181	102	77	360	0·67	,,
1892	259,696	70	63,125	319	183	126	628	0·99	,,
1893	281,333	30	73,939	234	56	224	514	0·69	,,
Total	3,296,815	990	1,788,879	5668	4406	6798	16,872	0·94	,,
CATTLE.									
1882	35,654	127	22,916	22	12	48	82	0·35	5 %
1883	26,453	130	20,501	17	1	46	64	0·31	,,
1884	33,900	139	22,616	20	13	52	85	0·37	,,
1885	34,000	192	21,073	32	8	67	107	0·50	,,
1886	39,154	135	22,113	18	7	39	64	0·29	,,
1887	48,484	148	28,083	23	18	68	109	0·39	,,
1888	34,464	61	10,920	8	4	35	47	0·43	,,
1889	32,251	68	11,610	14	7	31	52	0·45	,,
1890	33,965	71	11,057	5	4	14	23	0·21	,,
1891	40,736	68	10,476	6	4	4	14	0·13	,,
1892	41,609	71	9,757	8	3	15	26	0·26	,,
1893	38,154	45	9,840	4	1	13	18	0·18	,,
Total	438,824	1255	200,962	177	82	432	691	0·34	,,

Vaccination against Rouget (France).

Years.	Total Number of Animals Vaccinated.	Number of Reports.	Animals Vaccinated according to Reports received.	Mortality. After First Vaccination.	Mortality. After Second Vaccination.	Mortality. During the Rest of the Year.	Total.	Total Loss per 100.	Average Loss before Vaccination.
1886	For these two years France and other countries are put together.	49	7,087	91	24	56	171	2·41	20 %
1887		49	7,467	57	10	23	90	1·21	,,
1888	15,958	31	6,968	31	25	38	94	1·35	,,
1889	19,338	41	11,257	92	12	40	144	1·28	,,
1890	17,658	41	14,992	118	64	72	254	1·70	,,
1891	20,583	47	17,556	102	34	70	206	1·17	,,
1892	37,900	38	10,128	43	19	46	108	1·07	,,
Total	111,437	296	75,455	534	188	345	1067	1·45	,,

4. *Tubercle.*—Laennec, who in 1816 invented the stethoscope, recognized the fact that tubercle is a specific disease, not a simple degeneration of the affected tissues. Villemin, in 1865, communicated to the Académie des Sciences the fact that he had produced the disease in rabbits, by inoculating them with tuberculous matter; and he appealed to these inoculations—*en voici les preuves*—to show that *La tuberculose est une affection spécifique: Sa cause réside dans un agent inoculable: L'inoculation se fait très-bien de l'homme au lapin: La tuberculose appartient donc à la classe des maladies virulentes.* In 1868 Chauveau produced the disease not by inoculation but by admixture of tuberculous matter with the animals' food. In 1880, after a period of some uncertainty and confusion of doctrines, Cohnheim reaffirmed the infectivity of the disease, and even made the proof of tubercle depend on inoculation alone: "everything is tuberculous that can produce tuberculous disease by inoculation in animals that are susceptible to the disease; and nothing is tuberculous that cannot do this." In 1881 Koch discovered the tubercle-bacillus, and, in spite of the tragic failure of his *tuberculin* in 1890–91, a vast amount of practical advantage has already issued out of Koch's discovery, if not by way of cure, yet by way of prevention. It has been proved, by experiment on animals, that the sputa of phthisical patients are infective; and this and the like facts have profoundly influenced the nursing and general care of such cases. Bacteriology has brought about (under the safeguard of modern methods of surgery) a thorough and early surgical treatment of all primary tuberculous sores or deposits—the excision of tuberculous ulcers, the removal of tuberculous glands, and the like. It has helped us to make an early diagnosis, in obscure cases, by finding tubercle-bacilli in the sputa, or in the discharges, or in a particle of the tissues. It has proved, past all reasonable doubt, that *tabes mesenterica*, a disease that kills every year in England alone seven or eight thousand children, may arise from infection of the bowels by the milk of tuberculous cows. It has helped to bring about the present rigorous control of the milk-trade and the meat-trade. Moreover, *tuberculin* is used, because of the reaction that it causes in tuberculous animals, as a test for the detection of latent tuberculosis in cattle. An injection of one to two cubic centimetres under the skin of the neck is followed by a high temperature, if the animal be tuberculous. If it be not, there is no rise of temperature, or only a very slight rise. For example, in 1899 this test was applied to 270 cows on farms in Lancashire: 180 reacted to the test, 85 did not, 5 were "doubtful." Tuberculous disease was actually found in 175 out of the 180. Eber of Dresden used the test on 174 animals, of whom 136 reacted, 32 did not react, and 6 were doubtful. Of the 136, 22 were slaughtered, and were all found to have tubercle; of the 32, 3 were slaughtered, and were found free. The opinion of Professor M'Fadyean, one of the highest authorities on the subject, is as follows:—"I have most implicit faith in tuberculin as a test for tuberculosis when it is used on animals standing in their own premises and undisturbed. It is not reliable when used on animals in a market or slaughter-house. A considerable number of errors at first were found when I examined animals in slaughter-houses after they had been conveyed there by rail, &c. Since that, using it on animals in their own premises, I have found that it is practically infallible. I have notes of one particular case where 25 animals in one dairy were tested, and afterwards all were killed. There was only one animal which did not react, and it was the only animal not found to be tuberculous when killed."

5. *Diphtheria.*—The *Bacillus diphtheriæ* (Klebs-Loeffler bacillus) was described by Klebs in 1875, and obtained in pure cultures by Loeffler in 1884. Behring and Kitasato, in 1890, succeeded in immunizing animals against the disease. The first cases treated with diphtheria-antitoxin were published in 1893, by Behring, Kossel, and Huebner. In England the antitoxin treatment was begun in the latter part of 1894. Beside its curative use, the antitoxin has also been used as a preventive, to stop an outbreak of diphtheria in a school or institute or hospital or village, and with admirable success. (See DIPHTHERIA.)

6. *Tetanus* (Lock-jaw).—Experiments on animals have taught us the true nature of this disease, and have led to the discovery of an antitoxin which has given fairly good results. We possess, moreover, a preventive treatment against the disease; though, unfortunately, the time of latency, when the antitoxin is most needed, cannot be recognized. The old, mischievous doctrine that tetanus was due to acute inflammation of a nerve, tracking up from a wound to the central nervous system, was abolished once and for ever by Sternberg (1880), Carle and Rattone (1884), and Nicolaier (1884), who proved that the disease is due to infection by a specific flagellate organism in superficial soil. "It is said to be present in almost all rich garden-soils, and that the presence of horse-dung favours its occurrence. There seems to be no doubt as to the ubiquity of the tetanus germ" (Poore, *Milroy Lectures*, 1899). The work of discovering and isolating the bacillus was full of difficulty. Nicolaier, starting from the familiar fact that the disease mostly comes from wounds or scratches contaminated with earth, studied the various microbes of the soil, and inoculated rabbits with garden-mould: he produced the

disease, and succeeded in finding and cultivating the bacillus, but failed to obtain a pure culture. Kitasato, in 1899, obtained a pure culture. Others have studied the chemical products of the bacillus, and have been able to produce the symptoms of the disease by injection of these chemical products obtained from cultures, or from the tissues in cases of tetanus. It has been proved that the infection tends to remain local; that the bacilli in and near the wound pour thence into the blood their chemical products, and that these have a selective action, like strychnine, on the cells of the central nervous system. Therefore the rule, that the wounded tissues should be at once excised, in all cases where this can possibly be done, has received confirmation. Before Nicolaier, while men were still free to believe that tetanus was the result of an acute ascending neuritis, this rule was neither enforced nor explained.

The antitoxin-treatment has given the following results. The *Journal of the American Medical Association*, November 13, 1897, gives 26 cases, with 12 recoveries. The *Münchener Med. Wochenschrift*, November 16, 1897, gives 98, with 57. The *Brit. Med. Journ.*, July 23, 1898, gives 36, with 25. Erdheim, in September 1898, published 22, with 11. Engelmann, in 1898, 51, with 36. But some of these cases may have been published more than once. Tavel of Berne lately published 10 cases, with 7 recoveries, against 13 cases treated without antitoxin, of whom 11 died. On the other hand, Baccelli (*Brit. Med. Journ.*, 1899) reported better results than these, without antitoxin. The figures are all of them too small, and the disease too variable in intensity, for a final judgment at present. At all events, the use of the antitetanic serum does not exclude the use of other drugs also. The mortality of tetanus in this country, before the serum-treatment, may be estimated at 75 or 80 per cent.

The preventive use of the serum, in veterinary practice, has yielded admirable results. In some parts of the world tetanus is terribly common among horses. Nocard of Paris has reported as follows:—"The use of antitetanus serum as a preventive has been in force for some years in veterinary practice in cases of wounds or surgical procedures. To this end the Pasteur Institute has supplied 7000 doses of antitetanus serum, a dose being 10 cubic centimetres; a quantity which has sufficed to treat preventively 3100 horses in those parts of the country where tetanus is endemic. Among these there has been no death from tetanus. In the case of one horse, injected five days after receiving a wound, tetanus developed, but the attack was slight. During the same time that these animals were injected, the same veterinary surgeon observed, among animals not treated by injection, 259 cases of tetanus" (*Lancet*, August 7, 1897).

7. *Rabies.*—The date of the first case treated by Pasteur's preventive method—Joseph Meister, an Alsatian shepherd-boy—is July 1885. The existence of a specific micro-organism of rabies was a matter of inference. The incubation period of the disease is so variable that no preventive treatment was possible unless this incubation period could be regulated. Inoculations of the saliva of a rabid animal, introduced under the skin of animals, sometimes failed; and if they succeeded, the incubation period of the disease thus induced was hopelessly variable. Next, Pasteur used not saliva, but an emulsion of the brain or the spinal cord; because the central nervous system is the chief seat of the poison. But this emulsion, introduced under the skin, was also uncertain in action, and gave no fixed incubation period.

Therefore, he argued, as the poison has a selective action on the nerve-cells of the central nervous system, and a sort of natural affinity with them, it must be introduced directly into them, where it will have its proper environment: the emulsion must be put not under the skin, but under the *dura mater* (the membrane enveloping the brain). These subdural inoculations were the turning-point of his work. By transmitting the poison through a series of rabbits, by subdural inoculation of each rabbit with a minute quantity of nerve-tissue from the rabbit that had died before it, he was able to intensify the poison, to shorten its period of incubation, and to fix this period at six days. Thus he obtained a poison of exact strength, a definite standard of virulence, *virus fixe*: the next rabbit inoculated would have the disease in six days, neither more nor less. By gradual drying, after death, of the cords of rabid animals, he was able to attenuate the poison contained in them. The spinal cord of a rabbit that has died of rabies slowly loses virulence by simple drying. A cord dried for four days is less virulent than a cord dried for three, and more virulent than a cord dried for five. A cord dried for a fortnight has lost all virulence; even a large dose of it will not produce the disease. By this method of drying, Pasteur was able to keep going one or more series of cords, of known and exactly graduated strengths, according to the length of time they had been dried, ranging from absolute non-virulence through every shade of virulence.

As with fowl-cholera and anthrax, so with rabies: the poison, attenuated till it is innocuous, can yet confer immunity against a stronger dose of the same poison. A man, bitten by a rabid animal, has at least some weeks of respite before the disease can break out; and during that time of respite he can be immunized against the disease, while it is still dormant: he begins with a dose of poison attenuated past all power of doing harm, and advances day by day to more active doses, guarded each day by the dose of the day before, till he has manufactured within himself enough antitoxin to make him proof against any outbreak of the disease. (See HYDROPHOBIA.)

7. *Cholera.*—The specific organism of Asiatic cholera, the "comma-bacillus," was discovered by Koch in 1883; but such a multitude of difficulties arose over it, that it was not universally recognized as the real cause of the disease before 1892, the year of the epidemic at Hamburg. The discovery of preventive inoculation was the work of many men, but especially of Haffkine, one of Pasteur's pupils. Ferran's earlier inoculations in Spain (1885) were a failure. Haffkine's first inoculations were made in 1893. At Agra, in April 1893, he vaccinated over 900 persons; and from Agra went to many other cities of India. Altogether, in twenty-eight months (April 1893–July 1895) no less than 42,179 persons were vaccinated (many of them twice) in towns, cantonments, jails, tea-estates, villages, schools, &c., "without having to record a single instance of mishap or accident of any kind produced by our vaccines." (See CHOLERA.)

9. *Bubonic Plague.*—The *Bacillus pestis* was discovered in 1894 by Kitasato and Yersin, working independently. The preventive treatment was worked out by Haffkine in 1896:—"Twenty healthy rabbits were put in cages. Ten of them were inoculated with Haffkine's plague vaccine. Then both the vaccinated rabbits and the other ten rabbits that had not been vaccinated were infected with plague. The unprotected rabbits all died of the disease, and in their bodies innumerable quantities of the microbes were found. But the vaccinated rabbits remained in good health. Professor Haffkine then vaccinated himself and his friends. This produced some fever, from which, after a day or two, they recovered. Plague broke out in Byculla Jail, in Bombay, in January 1897. About half the prisoners volunteered to be inoculated. Of these, 3 developed plague on the day of inoculation, and it is probable that they had already plague before the treatment was carried out. Of the remaining 148 who were inoculated, only 2 were afterwards attacked with plague, and both of them recovered. At the same time, of the 173 who had not been vaccinated, 12 of them were attacked; and out of these, 6 died." (See PLAGUE.)

10. *Typhoid Fever.*—The *Bacillus typhosus* was discovered by Klebs, Eberth, and Koch in 1880–81. The first protective inoculations in England were made at Netley Hospital in 1896 by Professor Wright and Surgeon-Major Semple: sixteen medical men and two others offered themselves as subjects. The first use of the vaccine during an actual outbreak of typhoid was in October 1897 at the Kent County Asylum:—"All the medical staff and a number of attendants accepted the offer. Not one of those vaccinated—84 in number—contracted typhoid fever; while of those unvaccinated, and living under similar conditions, 16 were attacked. This is a significant fact, though it should in fairness be stated that the water was boiled after a certain date, and other precautions were taken, so that the vaccination cannot be said to be altogether responsible for the immunity. Still, the figures are striking" (*Lancet*, March 1898).

In 1899 Professor Wright vaccinated against typhoid more than 3000 of the Indian army, at Bangalore, Rawal Pindi, and Lucknow. Typhoid, among the soldiers in India, is on the increase; and Government has now sanctioned voluntary inoculation against typhoid, at the public expense, among the British troops.

Beside the preventive treatment, bacteriology has given us "Widal's reaction" for the early diagnosis of the disease—a matter of the very highest practical importance. A drop of blood, from the finger of a patient suspected to be suffering from typhoid fever, is diluted fifty or more times, that the perfect delicacy of the test may be ensured; a drop of this dilution is mixed with a nutrient fluid containing living bacilli of typhoid, and a drop of this mixture is observed under the microscope. The motility of the bacilli is instantaneously or very quickly arrested, and in a few minutes the bacilli begin to aggregate together into clumps. This "clumping" is also made visible to the naked eye by the subsidence of the agglutinated bacilli to the bottom of the containing vessel. The amazing delicacy of "Widal's test" is but a part of the wonder. Long after recovery, a fiftieth part of a drop of the blood will still cause clumping: it has even been obtained from an infant whose mother had typhoid shortly before the child was born. A drop of blood from a case suspected to be typhoid can now be sent by post to be tested, a hundred miles away, and the answer telegraphed back.

11. *Malta Fever* (Mediterranean Fever).—The *Bacillus Melitensis* was discovered in 1887 by Surgeon-Major Bruce. The work of discovering and preparing an immunizing serum was done at Netley Hospital. In this fever, as in typhoid and some others, Widal's test is of great value: "the diagnosis of Malta fever from typhoid is, of course, a highly important practical matter. It is exceedingly difficult in the early stages" (Manson). Even in a

dilution of 1 in 1000, the blood of Malta fever can give the typical reaction with the *Bacillus Melitensis*; and this occurred in a case at Netley of accidental inoculation with Malta fever: one of three cases that have happened there. The case is reported in the *British Medical Journal*, October 16, 1897:—"It appears that he had scratched his hand with a hypodermic needle on September 17, when immunizing a horse for the preparation of serum-protective against Malta fever; and his blood, when examined, had a typical reaction with the micrococcus of Malta fever in 1000-fold dilution. The horse, which has been immunized for Malta fever for the last eight months, was immediately bled, and we are informed that the patient has now had two injections, each of 30 cub. cm. of the serum. He is doing well, and it is hoped that the attack has been cut short." About fifty cases of the fever, by April 1899, had been treated at Netley. The *Lancet*, April 15, 1899, says that the treatment was "with marked benefit: whereas they found that all drug-treatment failed, the antitoxin treatment had been generally successful."

12. *Yellow Fever.*—The *Bacillus icteroides* was discovered by Sanarelli in 1896 during his study of yellow fever in the lazaretto of Flores. By 1897 he had prepared an immunizing serum, which gave excellent results on animals:—"This serum was tried on guinea-pigs against a mortal dose of virulent cultures. Half a cubic centimetre of this serum, injected twenty-four hours before the dose of virulent cultures, gave immunity. Two centimetres of it succeeded in saving guinea-pigs already ill, even if it were injected forty-eight hours afterward. . . . The preventive and curative power of the serum of the guinea-pig, the dog, and the horse, vaccinated against the *Bacillus icteroides*, should be held as absolutely demonstrated in the case of animals." At Rio de Janeiro Sanarelli treated 8 cases of yellow fever, with 4 recoveries: at San Carlos do Pinhal, in January 1898, 22 cases, with 16 recoveries; and of the 6 who died, 4 appeared hopeless from the first. The case of two children at the isolation hospital at San Carlos is worth quoting:—"La plupart des gens préféraient rester chez eux pour mourir; les seuls malades à ce moment à l'hôpital étaient deux enfants, ramassés dans la maison où leur père était déjà mort de fièvre jaune. Ces deux petits malades présentaient les symptômes caractéristiques de la maladie, y compris le *vomito negro*. Ils furent soumis de suite au traitement, dont les résultats furent presque immédiats; la fièvre et l'albuminurie disparurent, les symptômes généraux s'atténuèrent, et les deux enfants entrèrent en franche convalescence." Sanarelli was careful to select severe cases; and his work was done in a part of the country where the fever was most fatal:—"Chaque cas était choisi de commun accord entre nous, dans le but de mettre bien en évidence l'action thérapeutique du sérum, mettant toujours de côté tous les cas qui se présentaient avec des symptômes vagues ou atténués ou en forme légère ou fruste." In February 1898 the fever broke out in the jail at San Carlos, with 4 cases and 3 deaths. Preventive treatment was given to all the prisoners, except one who had already had the fever; and at once the outbreak stopped; no more cases occurred, though only a weak serum was used, and though the fever, two months later, was still active in the town.

13. *Malaria.*—Laveran, in 1880, discovered the *Plasmodium malariæ*, an amœboid organism, in the blood of malarial patients. In 1894 Manson took, as a working theory of malaria, the old belief that the mosquito is the intermediate host of the parasite. In 1895 came MacCullum's observations on an allied organism, *Halteridium*. In 1897, after two years' work, Ross found bodies, pigmented like the *Plasmodium*, in the outer coat of the stomach of the grey or "dapple-winged" mosquito, after it had been fed on malarial blood. In February 1898 he started work in Calcutta:—"Arriving there at a non-fever season, he took up the study of what may be called 'bird malaria.' In birds, two parasites have become well known—(1) the *Halteridium*, (2) the *Proteosoma* of Labbé. Both have flagellate forms, and both are closely allied to the *Plasmodium malariæ*. Using grey mosquitoes and proteosoma-infected birds, Ross showed by a large number of observations that it was only from blood containing the proteosoma that pigmented cells in the grey mosquito could be got; therefore that this cell is derived from the proteosoma, and is an evolutionary stage of that parasite" (Manson, 1898). These pigmented cells give issue to innumerable swarms of spindle-shaped bodies, "germinal rods"; and in infected mosquitoes Ross found these rods in the glands of the proboscis. Finally, he completed the circle of development, by infecting healthy sparrows by causing mosquitoes to bite them. Other workers in this field of science have also infected themselves, from mosquito-bites, with the disease. It would be hard to surpass Ross's work, and that done in Italy by Grassi and others, for fineness and carefulness. He says, for instance, "out of 245 grey mosquitoes fed on birds with proteosoma, 178, or 72 per cent., contained pigmented cells; out of 249 fed on blood containing halteridium, immature proteosoma, &c., not one contained a single pigmented cell. . . . Ten mosquitoes fed on the sparrow with numerous proteosoma contained 1009 pigmented cells, or an aveage of 101 each. Ten mosquitoes fed on the sparrow with moderate proteosoma contained 292 pigmented cells, or an average of 29 each. Ten mosquitoes fed on the sparrow with no proteosoma contained no pigmented cells." The destruction of the breeding-puddles of the special mosquito of malaria is therefore the chief thing to be done: and the habits and habitations of *Anopheles claviger* have become a matter of world-wide importance. A mass of evidence has also been accumulated which shows that mosquitoes also convey the parasitic organisms that are the cause of *filariasis*.

The list of diseases studied by the help of bacteriology is not yet complete: nothing has been said of glanders, rinderpest, Texas fever, and other infective diseases. Nothing, again, has been said of the grosser parasites, tape-worms, hydatids, trichina, and the like: whose whole history and life-changes have been worked out by the help of feeding-experiments on animals. Only three more examples need be given of discoveries made by the help of experiments on animals; and these are the nature and treatment of myxœdema, the actions of certain important drugs, and the serum-treatment of cases of snake-bite.

14. *Myxœdema.*—Our knowledge of myxœdema, like our knowledge of cerebral localization, began not in experimental science but in clinical observation (Gull, 1873; Ord, 1877). In 1882–1883 Reverdin and Kocher published cases where removal of the thyroid gland for disease (goître) had been followed by symptoms such as Gull and Ord had described. In 1884 Horsley, by removal of the thyroid gland of monkeys, produced in them a chronic myxœdema, a cretinoid state, the exact image of the disease in man: the same symptoms, course, tissue-changes, mental and physical hebetude, the same alterations of the excretions, the temperature, and the voice. In 1888 the Clinical Society of London published an exhaustive report, of 215 pages, on 119 cases of the disease, giving all historical, clinical, pathological, chemical, and experimental facts; but out of 215 pages there is but half a page about treatment, of the useless old-fashioned sort. In 1890 Horsley published the suggestion that a graft of thyroid gland from a newly-killed animal should be transplanted beneath the skin in cases of myxœdema:—"The justification of this procedure rested on the remarkable experiments of Schiff and von Eisselsberg. I only became aware in April 1890 that this proposal had been in fact forestalled in 1889 by Dr Bircher in Aarau. Kocher had tried to do the same thing in 1883, but the graft was soon absorbed; but early in 1889 he tried it again in five cases, and one greatly improved." In 1891 George Murray published his *Note on the Treatment of Myxœdema by Hypodermic Injections of an Extract of the Thyroid Gland of a Sheep*. Later, the gland was administered in food. At the present time tabloids of thyroid extract are given. We could not have a better example how experiments on animals are necessary for the advancement of medicine. Now, with little bottles of tabloids, men and women are restored to health who had become degenerate in body and mind, disfigured and debased. The same treatment has given back mental and bodily growth to countless cases of sporadic cretinism. Moreover, the action of the thyroid gland has been made known, and the facts of "internal secretions" have been in part elucidated. (Claude Bernard, speaking of the thyroid, the thymus, and the suprarenal capsules, said: "We know absolutely nothing about the functions of these organs; we have not so much as an idea what use and importance they may possess, because experiments have told us nothing about them, and anatomy, left to itself, is absolutely silent on the subject.")

15. *The Action of Drugs.*—Even in the 18th century medicine was still tainted with magic and with gross superstition: the 1721 Pharmacopœia contains substances that were the regular stock-in-trade of witchcraft. Long after 1721 neither clinical observation, nor anatomy, nor pathology brought about a reasonable understanding of the action of drugs: it was the physiologists, more than the physicians, who worked the thing out—Bichat, Magendie, Claude Bernard. Magendie's study of upas and strychnine, Bernard's study of curare and digitalis, revealed the *selective* action of drugs: the direct influence of strychnine on the central nerve-cells, of curare on the terminal filaments of motor nerves.

Two instances may be given how experiments on animals have elucidated the action of drugs. A long list might be made—aconite, belladonna, chloride of calcium, cocain, chloral, ergot, morphia, salicylic acid, strophanthus, the chief diuretics, the chief diaphoretics—all these and many more have been studied to good purpose by this method; but it must suffice to quote here Professor Fraser's account of digitalis, and Sir Thomas Lauder Brunton's account of nitrite of amyl:—

"1. Digitalis was introduced as a remedy for dropsy; and on the applications which were made of it for the treatment of that disease, a slowing action upon the cardiac movements was observed, which led to its acquiring the reputation of a cardiac sedative. . . . It was not until the experimental method was applied in its investigation, in the first instance by Claude Bernard, and subsequently by Dybkowsky, Pelikan, Meyer, Boehm, and Schmiedeberg, that the true action of digitalis upon the circulation was discovered. It was shown that the effects upon the circulation were not in any exact sense sedative, but, on the contrary, stimulant and tonic, rendering the action of the heart more powerful, and increasing the tension of the blood-vessels. The indications for its use in disease were thereby revolutionized, and at the same time rendered more exact; and the striking benefits which are now afforded by the use of this substance in most (cardiac) diseases were made available to humanity."

"2. In the spring of 1867 I had opportunities of constantly observing a patient who suffered from angina pectoris, and of obtaining from him numerous sphygmographic tracings, both during the attack and during the interval. These showed that during the attack the pulse became quicker, the blood-pressure rose, and the arterioles contracted. . . . It occurred to me that if it was possible to diminish the tension by drugs instead of by bleeding, the pain would be removed. I knew from unpublished experiments on animals by Dr. A. Gamgee that nitrite of amyl had this power, and therefore tried it on the patient. My expectations were perfectly answered."

15. *Snake-Venom.*—Sewall (1887) showed that animals could be immunized, by repeated injection of small doses of rattlesnake's venom, against a sevenfold fatal dose. Kanthack (1891) immunized animals against cobra-venom: afterward Fraser, Calmette, and many others, worked at the subject. Fraser's work on the antidotal properties of the bile of serpents is of the very highest interest and value, both in physiology and in sero-therapy. Calmette's work is an admirable instance of the delicacy and accuracy of the experimental method. The different venoms were measured in decimal milligrammes, and their action was estimated by the body-weights of the animals inoculated; but of course this estimate of virulence was checked according to the susceptibility of the animals; guinea-pigs, rabbits, and especially rats, being more susceptible than dogs:—

"The following table gives the relative toxicity, for 1 kilogramme of rabbit, of the different venoms that I have tested":—

1. Venom of *Naja* . . . . 0·25 milligramme per kilogramme of rabbit. One gramme of this venom kills 4000 kilogrammes of rabbit: activity = 4,000,000.
2. Venom of *Hoplocephalus* . . . . 0·29 . . 3,450,000.
3. Venom of *Pseudechis* . . . . . 1·25 . . 800,000.
4. Venom of *Pelias berus* . . . . 4·00 . . 250,000.

By experiments *in vitro* Calmette studied the influence of heat and chemical agents on these venoms; and, working by various methods, was able to immunize animals:—

"I have got to immunizing rabbits against doses of venom that are truly colossal. I have several, vaccinated more than a year ago, that take without the least discomfort so much as forty milligrammes of venom of *Naja tripudians* at once. Five drops of serum from these rabbits wholly neutralize *in vitro* the toxicity of one milligramme of *Naja* venom. . . . It is not even necessary that the serum should come from an animal vaccinated against the same sort of venom as that in the mixture. The serum of a rabbit immunized against the venom of the cobra or the viper acts indifferently on all the venoms that I have tested."

In 1895 he had prepared a curative serum: "If you first inoculate a rabbit with such a dose of venom as kills the control-animals in three hours; and then, an hour after injecting the venom, inject under the skin of the abdomen four to five cubic centimetres of serum, recovery is the rule. When you interfere later than this, the results are uncertain; and out of all my experiments the delay of an hour and a half is the most that I have been able to reach."

In 1896 four successful cases were reported in the *British Medical Journal*. In 1898 Calmette reports:—

"It is now nearly two years since the use of my antivenomous serum was introduced in India, in Algeria, in Egypt, on the West Coast of Africa, in America, in the West Indies, Antilles, &c. It has been very often used for men and domestic animals (dogs, horses, oxen), and up to now none of those that have received an injection of serum have succumbed. A great number of observations have been communicated to me, and not one of them refers to a case of failure" (*Brit. Med. Journ.*, May 14, 1898; see also *Boston Medical and Surgical Journal*, April 7, 1898).

It is of course impossible that "antivenene" should be always at hand, or that it should bring about any great decrease in the number of deaths from snake-bite, which in India alone are 30,000 annually; but at least something has been accomplished with it.

The account given above of the chief discoveries that have been made by the help of experiments on animals, in physiology, pathology, bacteriology, and therapeutics, might easily have been lengthened if we added to it other methods of treatment that owe less, but yet owe something, to these experiments: for example, transfusion of saline fluid, hypodermic medication, torsion of arteries, grafting of skin, transplantation of bone, the absorbable ligature, the diagnostic and therapeutic uses of electricity. Nevertheless, the facts quoted in this article are sufficient to indicate the great debt that medicine owes to the experimental method. (S. P.)

Explosives.—Explosives are substances capable of producing, under certain circumstances, a more or less violent action. This action may be very local or may extend to some distance around the place where it happens. It is generally accompanied by an aërial disturbance or noise. Sometimes this action results in the propulsion of solids, or liquids, to some distance, or in a local disruption of matters in the immediate vicinity. Where the second action is very pronounced and projection is at a minimum, the term *detonation* is applied to the action, to distinguish it from *explosion*, and *detonator* or "disruptor" explosive to the substance. Explosives may be classified under these two headings. An explosive of the projecting, or propulsive, class generally acts by burning in a more or less rapid and regular manner, and producing from a comparatively small volume of solid (liquid or gas) a much larger volume of gases, and at the same time much heat may be evolved, which further expands the gases. Time is an important factor. Many ordinary combustion actions can be so accelerated as to become explosive, and this effect can be determined by increasing the area of contact between combustible and oxygen or oxygen-producers. Quantity of heat-energy alone does not necessarily give an explosive action. Some metals burn with extreme vigour, as indicated by the temperatures produced, but unless the products be gaseous, no real explosive action results.

Explosives may be mixtures of combustible matters with oxygen or suppliers of oxygen, or chemical compounds. All chemical compounds may be classified under one of two headings, being either "endothermic" or "exothermic." The former term means that in the construction or building up of the compound some amount of energy becomes latent or potential. This is the case where any two elementary substances unite only under the compulsion of a high temperature, an electric current, or while some other reactions are proceeding. For example, oxygen and nitrogen unite only under the influence of an electric spark; similarly with carbon and nitrogen and carbon and hydrogen. In some complex chemical reactions what are known as secondary products appear. In some of these the main reaction is one of running down of energy, and the secondary one a piling up of energy in the form of a complex and relatively unstable compound. The formation of chlorates is a good example of this, five-sixths of the reaction representing the running down of energy, and only one-sixth the formation of an "endothermic" compound. A further meaning of endothermic will be apparent from facts about acetylene, a compound of carbon and hydrogen. When 26 parts, by weight, of acetylene are burnt, the heat produced will warm up 310,450 parts of water one degree centigrade. Twenty-four of the 26 parts are carbon, and when this quantity in the form of pure charcoal is burnt, only 192,000 of these heat-units are produced, and from two parts of hydrogen 68,000 units, in all 256,000 units. Therefore 50,450 units of heat are given by the compound over the heat given by its constituents burning to the same end products. This excess of heat-energy is supposed to be due to a form of latent or potential, perhaps chemical, energy in the compound, which becomes actual energy in some form[1] or other when the compound is broken up or resolved.

The *manner* in which a substance is endothermic is of importance as regards the practical employment of explosives. Some particular endothermic state or form evidently

[1] Not necessarily heat. Silver acetylide, nitrogen chloride or iodide, and other compounds decompose with great violence, but very little heat is evolved.

results from the mode of formation, and the consequent internal structure as a chemical or physical molecule. Physical structure alone is certainly answerable for a decidedly endothermic condition in some materials, as, for instance, the chilled glass bulbs or drops known as Bologna phials and Ruperts drops. They are made by suddenly cooling glass from a melted state. They explode on scratching or cutting to a certain depth. The cause is probably that the glass is occupying at the ordinary temperature the same, or nearly the same, volume it occupied when in a melted state, so that all the particles are in a state of strain, tending to revert to an easier relative position. "Superfused" substances are probably in a similar physical state of potential. Acetate of soda melts when heated a little above 56° C., and if kept melted for some time and then cooled in a clean atmosphere, can be kept for any length of time in a fluid condition. On contact with a crystal of the same substance the whole will rapidly solidify, at the same time becoming heated to about 56° C. again. Among endothermic substances may be included almost all carbon compounds, with the exception of carbon dioxide; and many, if not all, compounds of nitrogen. As substances can be endothermic in more than one way, it is not at present possible to arrange the known examples in a strict order. Most explosives contain nitrogen in some form. It may be stated, generally, that all explosive compounds, whatever be the manner of their explosion, are endothermic, and all endothermic substances *should* be explosible under some circumstance.

The *detonating* explosives may be termed "disruptors" in distinction to propellants, because their effect is to break up immediately surrounding matter into very small particles—to pulverize them in fact—rather than to throw them any distance. Some few substances are so nearly purely "disruptors" that their action on explosion is always of this nature: for instance, silver acetylide, silver fulminate, chloride of nitrogen, some diazo compounds, &c. They cannot be used as propellants under any known conditions. Some substances can behave in both ways under certain circumstances and within limits. Gun-cotton, for instance, can be really detonated and also burnt quietly. Nitro-glycerine burns quietly as a constituent of cordite, but, as dynamite, detonates and "disrupts" in a typical manner.

Exothermic compounds are in a certain sense the reverse of endothermic. They are *relatively* dead or exhausted, and will do but little except when energy is expended upon them from the outside. Water and the ordinary minerals of the earth's crust belong to this class; they are the end products of the running down of energy.

Gunpowders are mechanical mixtures of a nitrate[1] with compounds of carbon (charcoal) and sulphur. The mechanical operations of manufacture are all to the end of producing an intimate mixture. The action on explosion is combustion only, and it is doubtful if gunpowders can be detonated by ordinary friction or percussion. Black powder contains 75 per cent. potassium nitrate, 10 per cent. sulphur, and 15 per cent. charcoal, which again may contain about 10 per cent. oxygen and nearly 3 per cent. hydrogen. As these proportions are not in any simple chemical relation, it is not easy to express the explosion by an equation. Debus thinks that at least two actions occur—first, $16KNO_3 + 13C + 5S = 3K_2CO_3 + 5K_2SO_4 + 9CO_2 + CO + 8N_2$. These products again interact; thus with carbon, $4K_2SO_4 + 7C = 2K_2CO_3 + 2K_2S_2 + 5CO_2$, and with sulphur $4K_2SO_4 + 7S = K_2SO_4 + 3K_2S_2 + 4CO_2$. The main products are carbon dioxide, nitrogen, a little carbon monoxide and steam as gases, and potassium carbonate, sulphate, and sulphide as solids.

[1] Potassium nitrate only can be employed; all others are either deliquescent, decompose too easily, or have other objectionable qualities.

The difference between black and brown powders lies in the nature of the carbonaceous material and in the amount of sulphur. In formulæ it may be represented

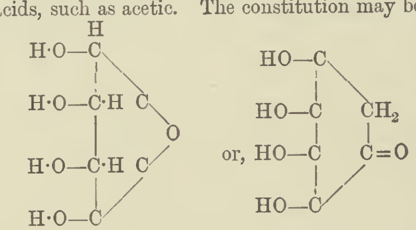
$$\text{as } 16KNO_3 \left\{ \begin{array}{l} 17{\cdot}39 \text{ carbon} \\ 12{\cdot}62 \text{ hydrogen} \\ 12{\cdot}0 \text{ oxygen} \end{array} \right\} \text{charcoal, } 1{\cdot}52 \text{ sulphur.}$$

The combustion products are carbon dioxide, nitrogen, much steam, and a very little carbon monoxide as gases; potassium carbonate, sulphate, and a little nitrite as solids. Brown powders burn slower than black, and, even under great pressures, the rate of burning is not appreciably quicker than when under moderate pressures. Black powder when burnt in large charges gives a sharp pressure curve somewhat approaching the character of a detonation. The reason for the slow burning of brown powder is that the cellulosic material (brown charcoal) requires to be further decomposed before it actually burns, as in the case of the wax of a candle, which only burns as vapour, not as wax.

Chlorates cannot be used in mixtures containing sulphur, being far too sensitive to friction. With organic materials, as sugar, it is possible to use them, but even such compounds are unsafe against percussion, and the way in which they develop pressure on explosion renders them dangerous for artillery purposes; in fact, they are only suitable for blasting-powders.

Gun-cotton was the earliest-discovered explosive compound, from a practical point of view. It is produced by the action of nitric acid on cotton, paper, or wood-fibre (Pelouze, 1838). Starch yields a similar substance. The product from cotton-wool was investigated in 1845 by Schönbein, who proposed its use as a substitute for gunpowder. Gun-cotton contains the elements of nitric acid combined in the whole cellulose molecule, no doubt in the form of an ester or nitrate. The precise constitution of this substance is still a matter of some controversy.

The smallest formula for cellulose is $C_6H_{10}O_5$, but the substance is probably more complex. Four of the oxygen atoms are supposed to be present in the hydroxylic form ($-OH$), as they are replaceable by some acids, such as acetic. The constitution may be therefore



On contact with strong nitric acid at the ordinary temperature a reaction—probably $C_6H_{10}O_5 + 2HNO_3 = 2H_2O + C_6H_8O_3(NO_3)_2$—takes place. Analyses of the product do not quite bear out this equation, but it is probably what would happen if the correct condition of temperature and strength of acid could be found and maintained. The product, after washing and drying, ignites at about 150° C. It is very soluble in a mixture of alcohol and ether, and is the main constituent of collodion. A mixture of nitric and sulphuric acids produces, under the same conditions, a more highly nitrated product, the sulphuric acid for the most part acting only as a dehydrating agent in taking up the water eliminated by the action of the nitric acid on the cellulose.

$$C_6H_{10}O_5 + 3HNO_3 = 3H_2O + C_6H_7O_2(NO_3)_3$$

$$\downarrow$$

$$+ \; {}^*3H_2SO_4$$

$$\|$$

$$3(H_2SO_4H_2O).$$

* The sulphuric acid does not appear in the final product, and may be omitted from the equation, but it is doubtful whether its action is confined to dehydration only.

As with nitric acid alone, this action takes some time at the ordinary temperature, depending on the fineness of the cotton employed. The product is unchanged in appearance, but shows a difference from cotton when examined by polarized light. It has gained in weight, but not up to the extent required by the equation. It is insoluble in alcohol and ether, singly or mixed, and its igniting point is about 180° C. It is very doubtful whether the formula $C_6H_7O_2(NO_3)_3$ is not much too simple, but serious difficulties occur in the investigation of this substance (and cellulose compounds generally) owing to its insoluble nature. Gun-cotton is certainly a nitrate. Alkalies and alkaline sulphides act somewhat readily upon it, tending to reproduce cellulose. The artificial silk process depends upon this circumstance. Ammonia is particularly active in decomposing it. Dilute acids have little or no action. Several substances, as acetone and acetic ether, dissolve or gelatinize gun-cotton, and on the solvent evaporating away, the gun-cotton is left in what is known as a colloidal state. The employment of gun-cotton as the basis or main ingredient of smokeless gunpowder depends entirely on this gelatinizing action, and all attempts to employ gun-cotton before this was discovered were failures. Fibrous gun-cotton may burn or explode at any rate, and under a little pressure detonation almost always takes place. In the colloid form burning can only take place at the outer surface, as gases are quite unable to penetrate a colloidal substance. Assuming gun-cotton to be a cellulose trinitrate, there is enough contained oxygen for a partial combustion without external air. The products of burning are steam, carbon monoxide, and dioxide (CO and CO_2), nitrogen, nitric oxide (NO), and sometimes methane (CH_4). The relative amounts of these vary considerably with the conditions of firing. There is some dispute and controversy about the matter, but probably nitric oxide is always one product. Dry gun-cotton can be detonated by a charge of fulminate or by a smart blow on an anvil, though the explosion seldom spreads from the piece struck. Wet gun-cotton can be detonated by the shock of the dry substance detonating. Starches, sugars, and many similar substances can be converted into nitrates of a similar type to gun-cotton, but some are soluble in water, and all have some objectionable properties which unfit them for practical use as explosives.

Nitro-glycerine, or glycerine nitrate, is the product of the action of a mixture of nitric and sulphuric acids on glycerine at temperatures below 20° C.

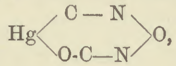
Its chemical constitution may be said to be accurately known. Glycerine has the composition and constitution shown by $\begin{matrix} CH_2OH \\ CHOH, \\ CH_2OH \end{matrix}$ as proved by synthetic methods. The action of the mixed acids is to replace the three hydroxyl groups (OH) by NO_3, so that nitro-glycerine is represented as $C_3H_5-(NO_3)_3$, or a trinitrate of the glycerine radical C_3H_5. Nitric acid alone does not form this compound. Sulphuric is, in addition, necessary, and probably exerts the same function here as in the case of gun-cotton formation. In making nitro-glycerine the glycerine is carefully added to the cooled acid mixture, a great excess of acids being employed. The reaction is completed within about one minute of contact, a slight rise in temperature taking place. The product is separated from the acids and washed repeatedly by water, and finally with an alkaline solution. Nitro-glycerine is an oily liquid heavier than water, and almost insoluble therein. It boils at about 120° C., and begins to decompose at the same time, generally detonating very violently at about this temperature, though when rapidly heated in very small quantity it may simply flash off quietly. Soaked into a porous substance, as blotting-paper, a little may be burnt quietly, as also when incorporated into a jelly of gun-cotton, as in cordite. Its combustion is more complete than is the case with gun-cotton, since it contains relatively more oxygen. Under atmospheric pressure the products are the same as with gun-cotton, but the quantity of carbon dioxide is greater in proportion. A probable equation is—

$$2(C_3H_5(NO_3)_3) = 5H_2O + 5CO_2 + CO + 2N_2 + 2NO.$$

Detonation may be brought about by a sharp blow on a hard surface, more completely when the nitro-glycerine is soaked into some porous material, as kieselguhr, or even sawdust, when almost any form of "detonator," as fulminate of mercury, will bring about a complete detonation. This is the essential condition in the various forms of *dynamite*. Nascent hydrogen, from almost any source, or alkaline sulphides will reduce nitro-glycerine to glycerine, and convert the NO_3 portion of the substance into ammonia; hence alkaline sulphides are well adapted for the quiet destruction of nitro-glycerine or dynamite. Glycerine belongs to a class of compounds known as alcohols. All these substances contain one or more groups of $-OH$, and in consequence of this react with nitric acid under certain circumstances, to produce nitrates with properties more or less resembling nitro-glycerine as to their explosiveness. Ordinary alcohol (C_2H_5OH), for instance, will form a nitrate $C_2H_5NO_3$, the vapour of which explodes with considerable violence. The volatile nature of this and several similar compounds preclude any practical employment as explosives.

Fulminates.—The first of the fulminates was discovered by Howard in 1800, as a product of the action of alcohol on a solution of mercury in nitric acid.

The only fulminate of practical importance is the mercury compound $HgC_2N_2O_2$. The essential condition for formation is that the nitrate of mercury solution shall contain some nitrous acid. The probable constitution of mercury fulminate may be



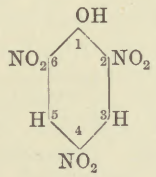
but several other formulæ have been proposed. Its explosiveness no doubt depends for the most part on its structure. It is a white crystalline solid, only slightly soluble in water. Small quantities, when heated in air, burn very rapidly. Slight friction or percussion will cause violent detonation. Its rate of burning is too high to allow it time to ignite common powder. In igniting and firing compositions, therefore, for which it is mostly employed, it is mixed with certain quantities of inert substances, as glass-powder, &c., which reduce the rate of burning or explosion. The products of its burning are: mercury, carbon, and carbon dioxide and nitrogen. Other metallic fulminates are known, but they are either too sensitive when in a dry state,—as silver fulminate, which when dry will explode if shaken on paper,—or decompose in solution. Alkaline sulphides act very rapidly on fulminate of mercury, decomposing it into quite non-explosive compounds. Fulminate of mercury is largely employed both as an igniting and detonating material for other explosives.

Nitro Explosives from Benzene.—Benzene, C_6H_6, is a hydrocarbon extracted from coal-tar. Nitric acid forms with it a number of derivatives called nitro compounds, most, if not all, of which are explosives under certain conditions.

The simplest is nitro-benzene, $C_6H_5NO_2$, a liquid; then comes dinitro-benzene, $C_6H_4(NO_2)_2$, known in three modifications, all of which are solids; then trinitro and tetra-nitro compounds, of which little is known. Dinitro-benzene can actually be employed as a constituent of blasting explosives, and to a small extent is also used in some sporting-powders. All these compounds are difficult to explode as compared with gun-cotton or nitro-glycerine.

Picric Acid.—Coal-tar contains some benzene compounds in addition to benzene itself. One of these is phenol or carbolic acid, C_6H_5OH, a hydrate of benzene. When this substance is brought in contact with nitric acid several products are formed, depending on strength of acid and temperature, the final stage being a trinitro derivative known as picric acid or trinitro-phenol, $C_6H_2(NO_2)_3OH$. The action is too violent to allow of this direct process of manufacture being employed on a large scale. As a matter of fact several physical modifications of trinitro-phenol are formed by the direct action of nitric acid on phenol, and some of these are very easily decomposed.

The usual method of manufacture is to act on phenol with hot sulphuric acid, which forms a phenol sulphonic acid of a particular kind, $C_6H_5OH + H_2SO_4 = C_6H_4{}^{OH}_{SO_3}H + H_2O$. This sulphonic acid, when heated with dilute nitric acid, gives a very perfect yield of the particular variety of trinitro-phenol known as picric acid. This is pictured in structural formula as



The other trinitro-phenols alluded to have a different structure, and in consequence differ in properties. Picric acid is a yellow crystalline solid, soluble in hot, but very slightly in cold, water. Metallic oxides combine with it to form picrates, as $C_6H_2(NO_2)_3OK$, the potassium salt. All its metallic compounds are very sensitive to heat or friction, and detonate very vigorously. When burnt in a vacuum vessel, the products from picric acid agree very closely with the equation: $2(C_6H_2(NO_2)_3OH) = 3H_2O + 3N_2 + 5CO_2 + CO + 6C$, but pressure exerts much influence on the relative amounts of these products. Many substances belonging to the class phenols will similarly form explosive nitro compounds.

Picric Acid melts at 122·5 C. to a pale yellow liquid, at which temperature a little vapour is formed, which can be ignited, and the substance then burns quietly, with a very smoky flame. When rapidly heated above its melting-point it may undergo internal decomposition and, depending on the quantity and pressure developed, either burn rapidly or detonate violently.

After melting and again solidifying, picric acid becomes somewhat denser, although still crystalline.

Lyddite is picric acid that has been melted. Owing to its more compact state, resulting from fusion, it is much easier to detonate by means of exploders of the fulminate class or, better, with some metallic compounds of picric acid itself (picrates) or even by rapidly heating in a confined space. Compared with gun-cotton or nitro-glycerine, and many other explosives, picric acid is difficult to detonate.

Melinite may consist of picric acid alone or mixtures of that substance with certain picrates or nitrates, as ammonium nitrate, which increase its sensibility to percussion or heat, and may add to the violence of explosion.

Diazo Compounds.—From the nitro-benzene compounds substances known as amino compounds, of which aniline, $C_6H_5 - NH_2$, is an example, may be obtained. Many of these react in a certain way with nitrous acid, producing diazo compounds, of which diazo-benzene, $C_6H_5 - NN{-}OH$, is an example. In a dry state these substances are generally not only very explosive but very sensitive to either heat or friction. They are scarcely practical explosives at present.

Amino explosives are becoming a large class. Amino acetic acid, CH_2NH_2COOH, combines with nitric acid and is known as glycocoll nitrate. It burns rapidly and quietly when ignited, or will detonate under pressure.

Hydrazoic acid, N_3H, is possibly the most powerful explosive known. It was discovered by Curtius. It is a gaseous substance which forms salts with metals,—as silver and sodium,—which explode with extreme violence on heating to a little above the boiling-point of water. The ammonia compound N_3NH_4 gives, according to Berthelot, 1148 cubic centimetres of gases for 1 gram weight of substance,—a greater change of volume than in any other known case.

See also PROPELLANTS, ORDNANCE (*Ammunition*), and MINING. (W. R. E. H.)

Exterritoriality is a term of international law, used to denominate certain immunities from the application of the rule that every person is subject for all acts done within the boundaries of a state to its local laws. It is also employed to describe the quasi-extraterritorial position, to borrow the phrase of Grotius, of the dwelling-place of an accredited diplomatic agent, and of the public ships of of one state while in the waters of another. Latterly its sense has been extended to all cases in which states refrain from enforcing their laws within their territorial jurisdiction. The cases recognized by the law of nations relate to: (1) the persons and belongings of foreign sovereigns, whether incognito or not; (2) the persons and belongings of Ambassadors, Ministers Plenipotentiary, and other accredited diplomatic agents and their suites (but not Consuls, except in some non-Christian countries, in which they sometimes have a diplomatic character); (3) public ships in foreign waters. Exterritoriality has also been granted by treaty to the subjects and citizens of contracting Christian states resident within the territory of certain non-Christian states. Lastly, it is held that when armies or regiments are allowed by a foreign state to cross its territory, they necessarily have exterritorial rights. "The ground upon which the immunity of sovereign rulers from process in our courts," said Mr Justice Wills in the case of Mighell *v.* Sultan of Johore, 1894, "is recognized by our law, is that it would be absolutely inconsistent with the status of an independent sovereign that he should be subject to the process of a foreign tribunal, unless he deliberately submits to its jurisdiction." It has, however, been held where the foreign sovereign was also a British subject (Duke of Brunswick *v.* King of Hanover, 1844), that he is amenable to the jurisdiction of the English Courts in respect of transactions done by him in his capacity as a subject. A "foreign sovereign" may be taken to include the President of a Republic, and even a potentate whose independence is not complete. Thus in the case, cited above, of Mighell *v.* the Sultan of Johore, the Sultan was ascertained to have abandoned all right to contract with foreign states, and to have placed his territory under British protection. The Court held that he was, nevertheless, a foreign sovereign in so far as immunity from British jurisdiction was concerned. The immunity of a foreign diplomatic agent, as the direct representative of a foreign sovereign (or state), is based on the same grounds as that of the sovereign authority itself. The international practice in the case of Great Britain was confirmed by an Act of Parliament of the reign of Queen Anne, which is still in force. The preamble to this Act states that "turbulent and disorderly persons in a most outrageous manner" had insulted the person of the then Ambassador of his Czarish Majesty, Emperor of Great Russia," by arresting and detaining him in custody for several hours, "in contempt to the protection granted by Her Majesty, contrary to the law of nations, and in prejudice of the rights and privileges which Ambassadors and other public Ministers, authorized and received as such, have at all times been thereby possessed of, and ought to be kept sacred and inviolable." This preamble has been repeatedly held by our Courts to be declaratory of the English common law. The Act provides that all suits, writs, processes, against any accredited Ambassador or public Minister or his domestic servant, and all proceedings and judgments had thereupon, are "utterly null and void," and that any person violating these provisions shall be punished for a breach of the public peace. Thus a foreign diplomatic agent cannot, like the sovereign he represents, waive his immunity by submitting to the British jurisdiction. The diplomatic immunity necessarily covers the residence of the diplomatic agent, which some writers describe as assimilated to territory of the state represented by the agent; but there is no consideration which can justify any extension of the immunity beyond the needs of the diplomatic mission resident within it. It is different with public ships in foreign waters. In their case the exterritoriality attaches to the vessel. Beyond its bulwarks captain and crew are subject to the ordinary jurisdiction of the state upon whose territory they happen to be. By a foreign public ship is now understood any ship in the service of a foreign state. It was even held in the case of the *Parlement Belge* (1880), a packet belonging to the Belgian Government, that the character of the vessel as a public ship was not affected by its carrying passengers and merchandise for hire.

Writers frequently describe the exterritoriality of both embassies and ships as absolute. There is, however, this difference, that the exterritoriality of the latter not being, like that of embassies, a derived one, there seems to be no ground for limitation of it. It was, nevertheless, laid down by the arbitrators in the *Alabama* case (Cockburn dissenting), that the privilege of exterritoriality accorded to vessels had not been admitted into the law of nations as an absolute right, but solely as a proceeding founded on the principle of courtesy and mutual deference between different nations, and that it could therefore "never be appealed to for the protection of acts done in violation of neutrality."

The exterritorial settlements in the Far East, the privileges of Christians under the arrangements made with the Ottoman Porte, and other exceptions from local jurisdictions, are subject to the conditions laid down in the treaties by which they have been created. There are also cases in which British communities have grown up in barbarous countries without the consent of any local authority. All these are regulated by Orders in Council, issued now in virtue of the Foreign Jurisdiction Act, 1890, an Act enabling the Crown to exercise any jurisdiction it may have "within a foreign country" in as ample a manner as if it had been acquired "by cession or conquest of territory." A very exceptional case of exterritoriality is that granted to the Pope under a special Italian enactment. (T. BA.)

Extradition.—(1) UNITED KINGDOM. The Extradition Acts, 1870–73 (33 and 34 Vict. cc. 62 and 36, and 37 Vict. c. 60), and the Fugitive Offenders Act, 1881 (44 and 45 Vict. c. 69), deal with different branches of the same subject, the recovery and surrender of fugitive criminals. The Extradition Acts apply in the case of countries with which Great Britain has extradition treaties. The Fugitive Offenders Act applies—(1) as between the United Kingdom and any British possession, (2) as between any two British possessions, and (3) as between the United Kingdom or a British possession and certain foreign countries, such as Turkey and China, in which the Crown exercises foreign jurisdiction. Most of the extradition treaties and the Fugitive Offenders Act are of later date than the article on EXTRADITION in the ninth edition of this work; and it appears desirable to present a general view of the law governing the recovery and surrender of fugitive criminals, including, for the sake of completeness, the case of fugitives from one part of the United Kingdom to another.

Conditions of Surrender.—In spite of some earlier authorities it has long been settled that in English law there is no power to surrender fugitive criminals to a foreign country without express statutory authority. Such authority is now given by the Extradition Acts, 1870–73, but only in the case of the offences therein specified, and with regard to countries with which an arrangement has been entered into, and to which the Acts have been applied by Order in Council. The Acts are further to be applied, subject to such "conditions, exceptions, and qualifications as may be deemed expedient" (s. 2); and these conditions, &c., are invariably to be found in the extradition treaty which is set out in the Order in Council applying the Extradition Acts to a particular country. To support a demand for extradition from Great Britain it is therefore necessary to show that the offence is one of those enumerated in the Extradition Acts, and also in the particular treaty, and that the acts charged amount to the offence according to the laws both of Great Britain and of the state demanding the surrender.

Surrender of Subjects.—A further question arises where a state is called on to surrender one of its own subjects. Some of the treaties, such as those with France and Germany, stipulate that neither contracting party shall surrender its own subjects, and in such cases a British subject cannot be surrendered by his own country. The treaties with Spain, Switzerland, and Luxembourg provide for the surrender by Great Britain of her own subjects, but there is no reciprocity. Other treaties, such as those with Austria, Belgium, Russia, and the Netherlands, give each party the option of surrendering or refusing to surrender its own subjects in each particular case. Under such treaties British subjects are surrendered unless the Secretary of State intervenes to forbid it. Lastly, some treaties, such as that with the United States, contain no restriction of this kind, and the subjects of each Power are freely surrendered to the other. Surrender by Great Britain is also subject to the following restrictions contained in s. 3 of the Extradition Act, 1870:—(1) that the offence is not of a political character, and the requisition has not been made with a view to try and punish for an offence of a political character; (2) that the prisoner shall not be liable to be tried for any but the specified extradition offences; (3) that he shall not be surrendered until he has been tried and served his sentence for offences committed in Great Britain; and (4) that he shall not be actually given up until fifteen days after his committal for extradition, so as to allow of an application to the courts.

Political offences.

The question as to what constitutes a political offence is one of some nicety. It was discussed in *In re* Castioni (1890, 1 Q.B. 149), where it was held, following the opinion of Mr Justice Stephen in his *History of the Criminal Law*, that to give an offence a political character it must be "incidental to and form part of political disturbances." Extradition was accordingly refused for homicide committed in the course of an armed rising against the constituted authorities. In the more recent case of *In re* Meunier (1894, 2 Q.B. 415), an Anarchist was charged with causing two explosions in Paris —one at the Café Véry resulting in the death of two persons, and the other at certain barracks. It was not contended that the outrage at the Café was a political crime, but it was argued that the explosion at the barracks came within the description. The Court, however, held that to constitute a political offence there must be two or more parties in the state, each seeking to impose a government of its own choice on the other, which was not the case with regard to Anarchist crimes. The party of anarchy was the enemy of all governments, and its effects were directed primarily against the general body of citizens. The test applied in the earlier case is perhaps the more satisfactory of the two.

With regard to the provision that surrender shall not be granted if the requisition has in fact been made with a view to try and punish for an offence of a political character, it was decided in the recent case of Arton (1896, 1 Q.B. 108) that a mere suggestion, that after his surrender for a non-political crime, the prisoner would be interrogated on political matters (his alleged complicity in the Panama scandal), and punished for his refusal to answer, was not enough to bring him within the provision. The Court also held that it had no jurisdiction to entertain a suggestion that the request of the French Government for his extradition was not made in good faith and in the interests of justice.

Extradition Offences.—The following is a list of crimes in respect of which extradition may be provided for under the Extradition Acts, 1870–73, and the Slave Trade Act, 1873. *Extradition Act*, 1870:—(1) Murder; (2) Attempt to murder; (3) Conspiracy to murder; (4) Manslaughter; (5) Counterfeiting and altering money, uttering counterfeit or altered money; (6) Forgery, counterfeiting, and altering and uttering what is forged or counterfeited or altered; (7) Embezzlement and larceny; (8) Obtaining money or goods by false pretences; (9) Crimes by bankrupts against bankruptcy law; (10) Fraud by a bailee, banker, agent, factor, trustee, or director, or member or public officer of any company made criminal by any law for the time being in force; (11) Rape; (12) Abduction; (13) Child-stealing; (14) Burglary and housebreaking; (15) Arson; (16) Robbery with violence; (17) Threats by letter or otherwise with intent to extort; (18) Crimes committed at sea, (*a*) Piracy by the law of nations, (*b*) Sinking or destroying a vessel at sea, or attempting or conspiring to do so, (*c*) Assault on board a ship on the high seas, with intent to destroy life or to do grievous bodily harm, (*d*) Revolt, or conspiring to revolt, by two or more persons on board a ship on the high seas against the authority of the master. *Extradition Act*, 1873:—(19) Kidnapping and false imprisonment; (20) Perjury and subornation of perjury. This Act also extends to indictable offences under 24 and 25 Vict. cc. 96, 97, 98, 99, 100, and amending and substituted Acts. Among such offences included in various extradition treaties are the following:—(21) Obtaining valuable securities by false pretences; (22) Receiving any money, valuable security, or other property, knowing the same to have been stolen or unlawfully obtained; (23) Falsification of accounts (see *In re* Arton, 1896, 1 Q.B. 509); (24) Malicious injury to property, if such offence be indictable; (25) Knowingly making, without lawful authority, any instrument, tool, or engine adapted and intended for the counterfeiting of coin of the realm; (26) Abandoning children; exposing or unlawfully detaining them; (27) Any malicious act done with intent to endanger the safety of any person in a railway train; (28) Wounding or inflicting grievous bodily harm; (29) Assault occasioning actual bodily harm; (30) Assaulting a magistrate or peace or public officer; (31) Indecent assault; (32) Unlawful carnal knowledge, or any attempt to have unlawful carnal knowledge, of a girl under age; (33) Bigamy; (34) Administering drugs or using instruments with intent to procure the miscarriage of women; (35) Any indictable offence under the laws for the time being in force in relation to bankruptcy. *Slave Trade Act*, 1873 (36 and 37 Vict. c. 88, s. 27):—(36) Dealing in slaves in such manner as to constitute a criminal offence against the laws of both states.

The Act of 1873 provides for the surrender of accessories before and after the fact to extradition crimes, and most of the treaties contain a clause by which extradition is to be granted for participation in any of the crimes specified in the treaty, provided that such participation is punishable by the laws of both countries. Several of the treaties also contain clauses providing for optional surrender in respect of any crime not expressly mentioned for which extradition can be granted by the laws of both countries.

Extradition Treaties.—The extradition treaties now in force, with their dates, and the dates of the Orders in Council applying them, are shown in the table below. The Orders in Council setting out the treaties will be found in the London *Gazette*. Extradition between Cape Colony and the Orange Free State and South African Republic was till the outbreak of war in 1899 regulated by the Cape Act, No. 22, of 1882.

It is not practicable to state which of the statutory extradition crimes are included in each of the treaties. It appears, however, from an examination kindly permitted of tables prepared for official use that the later treaties include nearly all the crimes in the above list. Rumania, however, reserves the right to refuse surrender for a crime punishable with death, and Portugal will not surrender in such a case. Of the earlier treaties, that with the United States, even as amended by the Convention of 1889, is much the most restricted, omitting crimes 8, 9, 17, 21, 24, 29, 30, 31, 32, 33, 34, 35 in the above list. It may be said generally that crimes 1 to 17 inclusive are covered by all the other treaties.

It is further to be noted that the restrictions on

Countries.	Dates.	
	Treaties.	Orders in Council.
Argentine Republic	22 May 1889	29 January 1894.
Austria	3 December 1873	17 March 1874.
Belgium	20 May 1876	21 July 1876.
Do. Declaration	23 July 1877	13 August 1877.
Do. do.	21 April 1887	13 May 1887.
Bolivia	22 February 1892	20 October 1898.
Brazil	13 November 1872	20 November 1873.
Chile	26 January 1897	9 August 1898.
Colombia	27 October 1888	28 November 1889.
Denmark	31 March 1873	26 June 1873.
Ecuador	20 September 1880	26 June 1886.
France	14 August 1876	16 May 1878.
Do. Declaration as to Tunis	31 December 1889	
Germany	14 May 1872	25 June 1872.
Guatemala	4 July 1885	26 November 1886.
Hayti	7 December 1874	5 February 1876.
Italy	5 February 1873	24 March 1873.
Do. Declaration	7 May 1873	
Liberia	16 December 1892	10 March 1894.
Luxembourg	24 November 1880	2 March 1881.
Mexico	7 September 1886	6 April 1889.
Monaco	17 December 1891	9 May 1892.
Netherlands	26 September 1898	2 February 1899.
Orange Free State	20 & 25 June 1890	20 March 1891.
Portugal	17 October 1892	3 March 1894.
Rumania	21 March 1893	30 April 1894.
Russia	24 November 1886	7 March 1887.
Salvador	23 June 1881	16 December 1882.
San Marino	16 October 1899	
Spain	4 June 1878	27 November 1878.
Do. Declaration	19 February 1889	28 May 1889.
Sweden and Norway	26 June 1873	30 September 1873.
Switzerland	26 November 1880	18 May 1881.
United States	9 August 1842	No Order in Council. See Extradition Act, 1870, sec. 27.
Do. Convention	12 July 1889	21 March 1890.
Uruguay	26 March 1884	5 March 1885.

surrender in the Extradition Acts apply only to surrenders by Great Britain. Foreign countries may surrender fugitives to Great Britain without any treaty, if they are willing to do so and their law allows of it, and such surrenders have not infrequently been made. But when surrendered for an extradition crime, the prisoner cannot be tried in England for any other crime committed before such surrender, until he has been restored, or has had an opportunity of returning, to the foreign state from which he was extradited.

Procedure.

To obtain from a foreign country the extradition of a fugitive from the United Kingdom, it is necessary to procure a warrant for his arrest, and to send it, or a certified copy, to the Home Secretary together with such further evidence as is required by the treaty with the country in question. In most cases an information or deposition containing evidence which would justify a committal for trial in Great Britain will be required. The Home Secretary will then communicate through the Foreign Secretary and the proper diplomatic channels with the foreign authorities, and in case of urgency will ask them by telegraph for a provisional arrest. For the arrest in the United Kingdom of fugitive criminals, whose extradition is requested by a foreign state, two procedures are provided in ss. 7 and 8 of the Act of 1870:—(1) On a diplomatic requisition supported by the warrant of arrest and documentary evidence, the Home Secretary, if he thinks the crime is not of a political character, will order the chief magistrate at Bow Street to proceed; and such magistrate will then issue a warrant of arrest on such evidence as would be required if the offence had been committed in the United Kingdom. (2) More summarily, any magistrate or justice of the peace may issue a provisional warrant of arrest on evidence which would support such a warrant if the crime had been committed within his jurisdiction. In practice a sworn information is required, but this may be based on a telegram from the foreign authorities. The magistrate or justice must then report the issue of the warrant to the Home Secretary, who may cancel it and discharge the prisoner. When arrested on the provisional warrant, the prisoner will be brought up before a magistrate and remanded to Bow Street, and will then be further remanded until the magistrate at Bow Street is notified that a formal requisition for surrender has been made; and unless such requisition is made in reasonable time the prisoner is entitled to be discharged. The examination of the prisoner prior to his committal for extradition ordinarily takes place at Bow Street. The magistrate is required to hear evidence that the alleged offence is of a political character, or is not an extradition crime. If satisfied in these respects, and if the foreign warrant of arrest is duly authenticated, and evidence is given which according to English law would justify a committal for trial, if the prisoner has not yet been tried, or would prove a conviction if he has already been convicted, the magistrate will commit him for extradition. Under the Extradition Act, 1895, the Home Secretary, if of opinion that removal to Bow Street would be dangerous to the prisoner's life, or prejudicial to his health, may order the case to be taken by a magistrate at the place where the prisoner was apprehended, or then is, and the magistrate may order the prisoner to be detained in such place. After committal for extradition, every prisoner has fifteen days in which to apply for *habeas corpus*, and after such period, or at the close of the *habeas corpus* proceedings if they are unsuccessful, the Home Secretary issues his warrant for surrender, and the prisoner is handed over to the officers of the foreign government.

The Extradition Acts apply to the British colonies, the Governor being substituted for the Secretary of State. Their operation may, however, be suspended by Order in Council, as in the case of Canada, where the colony has passed an Extradition Act of its own (see Statutory Rules and Orders).

Fugitive Offenders Act.—There are no extradition treaties with certain countries in which the Crown exercises foreign jurisdiction, such as Cyprus, Turkey, Egypt, China, Japan, Corea, Zanzibar, Morocco, Siam, Persia, Somali, &c. In these countries the Fugitive Offenders Act, 1881 (44 and 45 Vict. c. 69), has been applied, pursuant to s. 36 of that statute, and the measures for obtaining surrender of a fugitive criminal are the same as in a British colony. The Act, however, only applies to persons over whom the Crown has jurisdiction in these territories, and generally is expressly restricted to British subjects.

Under this Act a fugitive from one part of the King's dominions to another, or to a country where the Crown exercises foreign jurisdiction, may be brought back by a procedure analogous to extradition, but applicable only to treason, piracy, and offences punishable with twelve months' imprisonment with hard labour, or more. The original warrant of arrest must be endorsed by one of several authorities where the offenders happen to be,—in practice by the Home Secretary in the United Kingdom, and by the Governor in a colony. Pending the arrival of the original warrant a provisional arrest may be made, as under the Extradition Acts. The fugitive must then be brought up for examination before a local magistrate, who, if the endorsed warrant is duly authenticated, and evidence is produced "which, according to the law administered by the magistrate, raises a strong or probable presumption that the offender committed the offence, and that the Act applies to it," may commit him for return. An interval of fifteen days is allowed for *habeas corpus* proceedings, and (s. 10) the court has a large discretion to discharge the prisoner, or impose terms, if it thinks the case frivolous, or that the return would be unjust or oppressive, or too severe a punishment. The next step is for the Home Secretary in the United Kingdom, and the Governor in a colony, to issue a warrant for the return of the prisoner. He must be removed within a month, in the absence of reasonable cause to the contrary. If not prosecuted within six months after arrival, or if acquitted, he is entitled to be sent back free of cost.

In the case of fugitive offenders from one part of the United Kingdom to another, it is enough to get the warrant of arrest backed by a magistrate having jurisdiction in that part of the United Kingdom where the offender happens to be. A warrant issued by a metropolitan police magistrate may be executed, without backing, by a metropolitan police officer anywhere, and there are certain other exceptions, but as a rule a warrant cannot be executed without being backed by a local magistrate. (J. E. P. W.)

(2) United States. Foreign extradition is purely an affair of the United States, and not for the individual states themselves. Upon a demand upon the United States for extradition, there is a preliminary examination before a commissioner or judge before there can be a surrender to the foreign government (Revised Statutes, Title LXVI.; 22 Statutes at Large, 215). It is enough to show probable guilt (*Ornelas* v. *Ruiz*, 161 United States Reports, 502). An extradition treaty covers crimes previously committed. If a Power, with which the United States have such a treaty, surrenders a fugitive charged with a crime not included in the treaty, he may be tried in the United States for such crime. Inter-state extradition is regulated by Act of Congress under the Constitution of the United States (Article LV. s. 2; United States Revised Statutes, s. 5278). A surrender may be demanded of one properly charged with an act which constitutes a crime under the laws of the demanding state, although it be no crime in the other state. A party improperly surrendered may be released by writ of *habeas corpus*, either from a state or United States court (*Robb* v. *Conolly*, 111 United States Reports, 624). On his return to the state from which he fled, he is subject to prosecution for any crime, though on a foreign extradition the law is otherwise (*Lascelles* v. *Georgia*, 148 United States Reports, 537). (S. E. B.)

Eye. See Physiology (*Special Senses*), and Pathology (*Eye*).

Eyemouth, a police burgh and fishing town of Berwickshire, Scotland, situated at the mouth of the river Eye, 5½ miles north-north-west of Berwick-on-Tweed by rail. The bay is easily accessible and affords good anchorage. The harbour was increased in 1887. It is the centre of one of the Scottish fishery districts. The fish landed in 1898 was valued at £24,365. (See Berwickshire for statistics of district.) There are a town hall and a library, and Established, two United Free, Congregational, and Primitive Methodist churches. The public school had an average attendance of 457 in 1898–99. The population in 1881 was 2825, and in 1901, 2377.

Eyre, Edward John (1815–1901), colonial governor, the son of a Yorkshire clergyman, was born on 5th August 1815. He was intended for the army, but delays having arisen in procuring a commission, went out to New South Wales, where he engaged in the difficult but very necessary undertaking of transporting stock westward to the new colony of South Australia, then in great distress, and where he became magistrate and protector of the aborigines, whose interests he warmly advocated. Already experienced as an Australian traveller, he undertook the most extensive and difficult journeys in the desert country north and west of Adelaide, and after encountering the greatest hardships proved the possibility of land communication between South and West Australia. In 1845 he returned to England, and published the narrative of his travels. In 1846 he was appointed lieutenant-governor of New Zealand, where he served under Sir George Grey. After successively governing St Vincent and Antigua he was in 1862 appointed acting-governor of Jamaica, and in 1864 governor. In October 1865 a negro insurrection broke out, and was repressed with laudable vigour, but the unquestionable severity and alleged illegality of Eyre's subsequent proceedings raised a storm at home which induced the Government to suspend him and to despatch a special commission of investigation, the effect of whose inquiries, declared by his successor, Sir John Peter Grant, to have been "admirably conducted," was that he should not be reinstated in his office. The Government, nevertheless, saw nothing in Eyre's conduct to justify legal proceedings; indictments preferred by amateur prosecutors at home against him, and military officers who had acted under his direction, resulted in failure, and he retired upon the pension of a colonial governor. As an explorer Eyre must be classed in the highest rank, but opinions are always likely to differ as to his action in the Jamaica rebellion. He died 30th November 1901.

Fabre, Ferdinand (1830–1898), French novelist, was born at Bédarieux, in Hérault, a very picturesque division of the south of France, which he made completely his own in literature. He was the son of a local architect, who failed in business, and Ferdinand was brought up by his uncle, the Abbé Fulcran Fabre, at Camplong among the mulberry woods. Of his childhood and early youth he has given a charming account in *Ma Vocation*. He was destined to the priesthood, and was sent for that purpose to the seminary of St Pons de Thomières, where, in 1848, he had, as he believed, an ecstatic vision of Christ, who warned him "It is not the will of God that thou shouldst be a priest." He had now to look about for a profession, and, after attempting medicine at Montpellier, was articled as a lawyer's clerk in Paris. In 1853 he published a volume of verses, broke down in health, and crept back, humble and apparently without ambition, to his old home at Bédarieux. After some eight or nine years of country life he reappeared in Paris, with the MS. of his earliest novel, *Les Courbezon* (1862), in which he treated the subject which was to recur in almost all his books, the daily business of country priests in the Cevennes. This story enjoyed an immediate success with the literary class of readers; George Sand praised it, Sainte-Beuve hailed in its author "the strongest of the disciples of Balzac," and it was crowned by the French Academy. From this time forth Fabre settled down to the production of novels, of which at the time of his death he had published about twenty. Among these the most important were *Le Chevrier* (1867), unique among his works as written in an experimental mixture of Cevenol *patois* and French of the 16th century; *L'Abbé Tigrane* (1873), by common consent the best of all Fabre's novels, a very powerful picture of unscrupulous priestly ambition; *Mon Oncle Célestin* (1881), a study of the entirely single and tender-hearted country abbé; and *Lucifer* (1884), a marvellous gallery of serious clerical portraits. In 1883 Fabre was appointed curator of the Mazarine Library, with rooms in the Institute, where, on 11th February 1898, he died after a brief attack of pneumonia. Ferdinand Fabre occupies in French literature a position somewhat analogous to that of Mr Thomas Hardy amongst English writers of fiction. He deals almost exclusively with the population of the mountain villages of Hérault, and particularly with its priests. He loved most of all to treat of the celibate virtues, the strictly ecclesiastical passions, the enduring tension of the young soul drawn between the spiritual vocation and the physical demands of nature. Although never a priest, he preserved a comprehension of and a sympathy with the clerical character, and he always indignantly denied that he was hostile to the Church, although he stood just outside her borders. Fabre possessed a limited and a monotonous talent, but within his own field he was as original as he was wholesome and charming. (E. G.)

Fabrizi, Nicola (1804–1885), Italian patriot, was born at Modena, 4th April 1804. He took part in the Modena insurrection of 1831, and attempted to succour Ancona, but was arrested at sea and taken to Toulon, whence he proceeded to Marseilles. Afterwards he organized with Mazzini the ill-fated Savoy expedition. Taking refuge in Spain, he fought against the Carlists, and was decorated for valour on the battlefield (18th July 1837). At the end of the Carlist war he established a centre of conspiracy at Malta, endeavoured to dissuade Mazzini from the Bandiera enterprise, but aided Crispi in organizing the Sicilian revolution of 1848. With a company of volunteers he distinguished himself in the defence of Venice, afterwards proceeding to Rome, where he took part in the defence of San Pancrazio. Upon the fall of Rome he returned to Malta, accumulating arms and stores, which he conveyed to Sicily, after having, in 1859, worked with Crispi to prepare the Sicilian revolution of 1860. While Garibaldi was sailing from Genoa towards Marsala Fabrizi landed at Pizzolo, and, after severe fighting, joined Garibaldi at Palermo. Under the Garibaldian Dictatorship he was appointed Governor of Messina and Minister of War. Returning to Malta after the Neapolitan plebiscite, which he had vainly endeavoured to postpone, he was recalled to aid Cialdini in suppressing brigandage. While on his way to Sicily in 1862, to induce Garibaldi to give up the Aspromonte enterprise, he was arrested at Naples by Lamarmora. During the war of 1866 he became Garibaldi's chief of staff, and in 1867 fought at Mentana. In parliament he endeavoured to promote agreement between the chiefs of the Left, and from 1878 onwards worked to secure the return of Crispi to power, but died on 31st March 1885, two years before the realization of his object. His whole life was characterized by ardent patriotism and unimpeachable integrity. (H. W. S.)

Factors.—A *factor* is a mercantile agent (of the class known as "general" agents) employed to sell for a compensation, commonly called factorage or commission; but he differs from a broker (*q.v.*) in two respects—firstly, he has possession of the goods or the documents of title to them, and secondly, he may sell in his own name. A factor may also be employed to buy goods.

The main source of the law on the subject is now to be found in the Factors Act, 1889, where all previous enactments were repealed and their provisions consolidated and amended. But before discussing the Act it will be necessary to describe briefly what a factor is, and what are his duties and his authority.

I. Factor and Principal.

A factor is appointed or dismissed in the same way as any other agent. He may be employed for a single transaction or to transact all his principal's business of a certain class during a limited period or till such time as his authority may be determined. A factor's duty is to sell or buy as directed; to carry out any instructions he may receive with care, skill, and good faith; to receive or make payment; to keep accounts, and to hand over to his principal the balance standing to his principal's credit, without any deduction save for commission and expenses. All express instructions he must carry out to the full; and on any point not covered by his express instructions he must follow the usual practice of his particular business if not inconsistent with his instructions or his position as factor. Many usages of businesses in which factors are employed have been proved in court, and may now be regarded as legally established. For instance, he may, unless otherwise directed, sell in his own name, give warranties as to goods sold by him, sell by sample (in most businesses), give such credit as is usual in his business, receive payment in cash or as customary, and give receipts in full discharge, sell by indorsement of bills of lading, and insure the goods. It is his duty to clear the goods at the customs, take charge of them and keep them safely, give such notices to his principal and others as may be required, and if necessary take legal proceedings for the protection of the goods. On the other hand, he has not authority to delegate his employment, or to barter; and it was decided long ago that to pledge the goods is not within his authority. It is, moreover, inconsistent with his employment as agent that he should buy or sell on his own account from or to his principal. A factor has no right to follow any usage which is inconsistent with the ordinary duties and authority of a factor unless his principal has expressly or impliedly given his consent.

On the due performance of his duties the factor is entitled to his commission, which is usually a percentage on the value of the goods sold or bought by him on account of his principal, regulated in amount by the usages of each business. Sometimes the factor makes himself personally responsible for the solvency of the persons with whom he deals, in order that his principal may avoid the risk entailed by the usual trade credit. In such a case the factor is said to be employed on *del credere* terms, and is entitled to a higher rate of commission, usually 2½ per cent. extra. Such an arrangement is not a contract of guarantee within the Statute of Frauds, and therefore need not be in writing. Besides his remuneration, the factor is entitled to be reimbursed by his principal for any expenses, and to be indemnified against any liabilities which he may have properly incurred in the execution of his principal's instructions. For the purpose of enforcing his rights a factor has, without legal proceedings, two remedies. Firstly, by virtue of his general *lien* (*q.v.*) he may hold any of his principal's goods which come to his hands as security for the payment to him of any commission, out of pocket expenses, or even general balance of account in his favour. Although he cannot sell the goods, he may refuse to give them up until he is paid. Secondly, where he has consigned goods to his principal but not been paid, he may "*stop in transit*" subject to the same rules of law as an ordinary vendor; that is to say, he must exercise his right before the transit ends; and his right may be defeated by his principal transferring the document of title to the goods to some third person, who takes it in good faith and for valuable consideration (Factors Act 1889, section 10). If the factor does not carry out his principal's instructions, or carries them out so negligently or unskilfully that his principal gets no benefit thereby, the factor loses his commission and his right to reimbursement and indemnity. If by such failure or negligence the principal suffers any loss, the latter may recover it as damages. So too if the factor fails to render proper accounts his principal may by proper legal proceedings obtain an account and payment of what is found due; and threatened breaches of duty may be summarily stopped by an injunction. Criminal acts by the factor in relation to his principal's goods are dealt with by section 78 of the Larceny Act 1860.

II. Principal and Third Party.

(*a*) *At Common Law.*—The actual authority of a factor is defined by the same limits as his duty, the nature of which has been just described; *i.e.*, firstly, by his principal's express instructions; secondly, by the rules of law and usages of trade, in view of which those instructions were expressed. But his power to bind his principal as regards third parties is often wider than his actual authority; for it would not be reasonable that third parties should be prejudiced by secret instructions, given in derogation of the authority ordinarily conferred by the custom of trade; and, as regards them, the factor is said to have "*apparent*" or "*ostensible*" authority, or to be *held out* as having authority to do what is customary, even though he may in fact have been expressly forbidden so to do by his principal. But this rule is subject to the proviso that if the third party have actual notice of the factor's instructions, the "apparent" authority will not be greater than the actual. "The general principle of law," said Lord Blackburn in the case of Cole *v.* North-Western Bank (L. R. 10 C. P. at p. 363), "is that when the true owner has clothed any one with apparent authority to act as his agent, he is bound to those who deal with the agent on the assumption that he really is an agent with that authority, to the same extent as if the apparent authority were real." Under such circumstances the principal is for reasons of common fairness precluded, or, in legal phraseology, *estopped*, from denying his agent's authority. On the same principle of estoppel, but not by reason of any trade usages, a course of dealing which has been followed between a factor and a third party with the assent of the principal will give the factor apparent authority to continue dealing on the same terms even after the principal's assent has been withdrawn; provided that the third party has no notice of the withdrawal.

Such apparent authority binds the principal both as to acts done in excess of the actual authority and also when the actual authority has entirely ceased. For instance, A. B. receives goods from C. D. with instructions not to sell below 1s. per ℔; A. B. sells at 10½d., the market price; the buyer is entitled to the goods at 10½d., because A. B. had apparent authority, although he exceeded his actual authority. On the same principle the buyer would get a good title by buying from A. B. goods entrusted to him by C. D., even though at the time of the sale C. D. had revoked A. B.'s authority and instructed him not to sell at all. In either case the factor is held out as having authority to sell, and the principal cannot afterwards turn round and say that his factor had no such authority. As in the course of his business the factor must necessarily make representations preliminary to the contracts into which he enters, so the principal will be bound by any such representations as may be within the factor's actual or apparent authority to the same degree as by the factor's contracts.

(*b*) *Under the Factors Act* 1889.—The object of the Factors Acts (which deal with other persons as well as factors) has been to add to the number of cases in which third parties honestly buying or lending money on the security of goods may get a good title from persons in whose possession the goods are with the consent, actual or apparent, of the real owners, thus calling in aid the principle of French law that "*possession vaut titre*" as against the doctrine of the English common law that "*nemo dat quod non habet.*" The chief change in the law relating specially to factors has been to put pledges by factors on the same footing as sales, so as to bind a principal to third parties by his factor's pledge as by his factor's sale. The Factors Act 1889 in part re-enacts and in part extends the provisions of the earlier Acts of 1823, 1825, 1842, and 1877; and is, so far as it relates to sales by factors, in large measure merely declaratory of the law as it previously existed. Its most important provisions concerning factors are as follows:—

Section I., s.s. 1. The expression mercantile agent shall mean a mercantile agent having in the customary course of his business as such agent authority either to sell goods, or to consign goods for the purpose of sale, or to buy goods, or to raise money on the security of goods;

(2) A person shall be deemed to be in possession of goods or of the documents or title to goods when the goods or documents are in his actual custody or are held by any other person subject to his control or for him or on his behalf.

(4) The expression "document of title" shall include any bill of lading, dock warrant, warehouse keeper's certificate, and warrant or order for the delivery of goods, and any other document used in the ordinary course of business as proof of the possession or control of goods, or authorizing or purporting to authorize, either by endorsement or by delivery, the possessor of the document to transfer or receive goods thereby represented.

Section II., s.s. 1. Where a mercantile agent is, with the consent of the owner, in possession of goods or of the documents or title to goods, any sale, pledge, or other disposition of the goods made by him when acting in the ordinary course of business of a mercantile agent, shall, subject to the provisions of this Act, be as valid as if he were expressly authorized by the owner of the goods to make the same: provided that the person taking under the disposition acts in good faith, and has not at the time of the disposition notice that the person making the disposition has not authority to make the same.

(2) Where a mercantile agent has, with the consent of the owner, been in possession of goods or of the documents of title to goods, any sale, pledge, or other disposition, which would have been valid if the consent had continued, shall be valid notwithstanding the determination of the consent: provided that the person taking under the disposition has not at the time thereof notice that the consent has been determined.

(3) Where a mercantile agent has obtained possession of any documents of title to goods by reason of his being or having been, with the consent of the owner, in possession of the goods represented thereby, or of any other documents of title to the goods, his possession of the first-mentioned documents shall, for the purposes of the Act, be deemed to be with the consent of the owner.

III. Enforcement of Contracts.

(1) Where a factor makes a contract in the name of his principal and himself signs as agent only he drops out as soon as the contract is made, and the principal and third party alone can sue or be sued upon it. As factors usually contract in their own name this is not a common case.

(2) Where a factor makes a contract for the principal without disclosing his principal's name, the third party may, on discovering the principal, elect whether he will sue the factor or his principal; provided that if the factor contract expressly as factor, so as to exclude the idea that he is personally responsible, he will not be liable. The principal may sue upon the contract, so also may the factor, unless the principal first intervene.

(3) Where a factor makes a contract in his own name without disclosing the existence of his principal the third party may, on discovering the existence of the principal, elect whether he will sue the factor or the principal. Either principal or factor may sue the third party upon the contract. But if the factor has been permitted by the principal to hold himself out as the principal, and the person dealing with the factor has believed that the factor was the principal and has acted on that belief before ascertaining his mistake, then in an action by the principal the third party may set up any defences he would have had against the factor if the factor had brought the action on his own account as principal.

(4) Where a factor has a lien upon the goods and their proceeds for advances made to the principal it will be no defence to an action by him for the third party to plead that he has paid the principal, unless the factor by his conduct led the third party to believe that he agreed to a settlement being made with his principal.

(5) The factor who acts for a foreign principal will always be personally liable unless it is clear that the third party has agreed to look only to the principal.

(6) If a factor contract by deed under seal he alone can sue or be sued upon the contract; but mercantile practice makes contracts by deed uncommon.

Story. *Commentaries on the Law of Agency.* Boston, 1882. —Boyd and Pearson. *The Factors Acts (1823 to 1877).* London, 1884.—Blackwell. *The Law relating to Factors.* London, 1897. (L. F. S.)

Factory Acts. See Labour Legislation.

Faenza, a town and episcopal see of Italy (Emilia, prov. Ravenna), 31 miles S.E. from Bologna by rail. The picture gallery, the technical school, the school of design (1879), and the fountain (1621) deserve mention. The *fayence* industry is still carried on. Population about 18,500.

Faidherbe, Louis Léon César (1818–1889), French general, born on 3rd June 1818 at Lille, was educated at the Polytechnic schools at Paris and Metz, and entered the Engineer Corps in 1840. From 1844 to 1847 he served in Algeria, then two years in the West Indies, and again in Algeria, taking part in many expeditions against the Arabs. In 1852 he was transferred to Senegambia as sub-director of engineers, and in 1854 was promoted major and appointed governor of the colony. His eleven years' administration was notable for a number of successful expeditions and several large annexations (major-general, commander Legion of Honour). From 1867 to the early part of 1870 he commanded the subdivision of Bona in Algeria, when he became general of division, and was commanding the Constantine division at the commencement of the Franco-German war. Appointed by the Government of National Defence on 23rd November 1870 to be commander-in-chief of the Army of the North, he succeeded Bourbaki early in December, and proved himself an able general, although unable to relieve Paris. He fought several hotly contested but indecisive battles, such as Pont Noyelles and Bapaume against Manteuffel, but having been seriously defeated by Göben on the 19th January 1871 at St Quentin, he retired on Cambrai and Lille, where he remained until the armistice stopped operations. Elected to the National Assembly for the department of the North, he resigned his seat in consequence of its reactionary proceedings. For his services he was decorated with the Grand Cross, and made chancellor of the order, of the Legion of Honour. In 1872 he was sent on a scientific mission to Upper Egypt, where he studied the monuments and inscriptions. An enthusiastic geographer and archæologist, he wrote numerous works on his favourite subject, among which may be mentioned *Collection des Inscriptions Numidiques* (1870) and *Epigraphie Phénicienne* (1873). He also wrote on the Senegal and the Sahara, and *La Campagne de l'Armée du Nord* (1871). He was elected a senator in 1879. He died on 29th September 1889, and his remains received a public funeral. (R. H. V.)

Failsworth, a suburban township of Manchester, 4 miles to the N.E. by rail, in the Prestwich parliamentary division of Lancashire, England, on the Manchester and Leeds canal. The industries are mainly cotton-spinning, silk-weaving, and the manufacture of hats. Area of township (an urban district), 1073 acres. Population (1881), 7912; (1891), 10,425; (1901), 14,152.

Fairhaven, a city of Whatcom County, Washington, U.S.A., on Bellingham Bay, on the east coast of Puget Sound, 3 miles south of New Whatcom, and on a line of the Great Northern railroad. Like most of the smaller places on Puget Sound, its chief industry is the manufacture of lumber, and it contains several saw and shingle mills. Population (1890), 4076; (1900), 4228.

Fairmont, capital of Marion County, West Virginia, U.S.A., on the Monongahela river, at the intersection of two railways. Population (1890), 1023; (1900), 5655.

Fair Oaks, a station on a branch of the Southern railroad, 6 miles east of Richmond, Virginia, U.S.A. It is noted as the site of one of the great battles of the Civil War, fought 31st May and 1st June 1862, between McClellan and Johnston, in command of the Union and Confederate forces respectively. The result was indecisive, the Union troops having, however, rather the best of it. The Union losses were 5031 in killed, wounded, and missing; those of the Confederates were 6134. The battle is sometimes known as the Battle of Seven Pines.

Fajardo, a small city and port of entry at the north-east end of Porto Rico, in the province of Humacao. Population (1899), 3414.

Falk, Paul Ludwig Adalbert (1827–1900), German politician, was born at Matschkau, Silesia, 10th August 1827. In 1847 he entered the Prussian State service, and in 1853 became public prosecutor at Lyck. In 1858 he was elected a deputy, joining the Old Liberal party. In 1868 he became a privy-councillor in the ministry of justice. In 1872 he was made minister of education, and in connexion with Bismarck's policy of the Kultur-kampf he was responsible for the famous May Laws against the Catholics (see GERMANY, *May Laws*, and VATICANISM). In 1879 his position became untenable, owing to the death of Pius IX. and the change of German policy with regard to the Vatican, and he resigned his office, but retained his seat in the Reichstag till 1882. He was then made president of the supreme court of justice at Hamm, where he died in 1900.

Falkirk, a parliamentary burgh (Falkirk group) of Stirlingshire, Scotland, is 25½ miles W. by N. of Edinburgh by rail. In recent years the iron trade has greatly increased, and the town is the chief seat of the light-casting trade in Scotland. There now are in the burgh and immediate neighbourhood 23 foundries; and brewing, distilling, and the manufacture of dynamite and chemicals are all carried on. The cattle "trysts," or open markets, though still among the largest in the kingdom, have greatly diminished in importance, owing to the common preference for auction marts. There are county buildings, burgh buildings, a town hall, a free library and institute, parish council chambers, and a new post office. Waterworks have been opened, and the parish church has been renovated and a hall added to it. There are two United Free churches. A high school and a science and art school are under the School Board. Population of parliamentary burgh (1881), 13,170; (1901), 20,503; of burgh and suburbs (1881), 15,599; (1891), 19,769; (1901), 29,271.

Falkland Islands, a group of islands in the South Atlantic, belonging to Great Britain, lie about 250 miles east of the nearest point in the mainland of South America. The area of the islands is about 6500 square miles, of which the two main islands, East and West Falkland, take up 5300. The soil is well adapted for sheep-farming, which is the main industry. "Practically the entire acreage of the colony is sold or leased to some thirty-six farmers for pastoral purposes, the leased lands giving a total rental to the crown of about £5000." The revenue and expenditure were (1880), £5519 and £5607; (1890), £9492 and £9456; (1899), £13,219 and £13,314. There is no public debt. The imports and exports were (1880), £33,503 and £88,564; (1890), £67,182 and £115,845; (1899), £73,978 and £139,203. The main export is naturally wool. The population was (1881), 1414; (1897), 2050. The large majority are found in the East island, and the predominating element is Scotch—Scotch shepherds having superseded the South American Guachos. Education has been made compulsory, "with the best results." The climate is healthy. The temperature is normally low, always cold, without either the extreme frosts or summer heats of England. The prevailing winds, from west, south-west, and south, which blow continuously, make the cold more penetrating. "At the same time they contribute largely to the healthy condition which prevails in the absence of organized sanitation." The rainfall is not great, about 20 inches in the year, but slight rain is very frequent, and November is the only dry month. The mails are delivered by a German line of steamers once in every three weeks. The average length of the journey to England is about five weeks.

The Falkland Islands are a crown colony, with a governor and executive and legislative councils. The legislative council consists of the governor and two official and two unofficial nominated members.

Historical Geography of the British Colonies, vol. ii., "The West Indies," Lucas, 1890, and *Colonial Reports Annual*. (H. E. EG.)

Fall River, a city of Bristol County, Massachusetts, U.S.A., situated in 41° 30′ N. and 71° 09′ W. on Hope Bay, at the mouth of the Taunton river, and at the terminus of a branch of the New York, New Haven, and Hartford railway. Its plan is irregular; it has an excellent water supply, pumped from Watuppa Lake, east of the city; it is well sewered; the streets are macadamized or gravelled, and there are nine wards. Its public library contains 55,000 volumes. Fall River is a port of entry, with a good harbour and considerable commerce, and is the eastern terminus of the Fall River Line of Sound steamers to New York. But it is as a manufacturing city that Fall River is pre-eminent. In 1895 there were 571 establishments, with an aggregate capital of $43,850,952, employing 28,703 hands. The value of the product was $38,934,678. Of this, $26,403,043, or more than two-thirds, consisted of cotton goods; several of the other industries, such as dyeing and finishing establishments, are accessory to this. Formerly the water power of Taunton river was largely used, but at present steam power is in general use. The assessed valuation of property, real and personal, was, in 1899, $71,601,670, the net debt of the city was $3,688,434, and the rate of taxation was $17·80 per $1000. Population (1880), 48,961;

(1890), 74,398; (1900), 104,863. Of the total population in 1890, 50,042 were foreign-born, and 324 negroes. There were 35,532 persons of school age (5 to 20 years inclusive). Of 26,842 males of voting age, 4158 were illiterate (unable to write). The death-rate was 22·4.

Falmouth, a municipal and contributory parliamentary borough (returning with Penryn one member), seaport, and market-town of Cornwall, England, on Falmouth Bay, 306 miles S.W. of London by rail. Recent erections are an Established church, new buildings of the Meteorological and Magnetic Observatory, a submarine mining establishment, a Seamen's Bethel and Institute, a hospital, a cottage hospital, and a free library. The defences of Pendennis and St Mawes Castle have been reconstructed. Engineering and shipbuilding are carried on. There are also oyster and trawl fisheries. The registered shipping at the end of 1898 consisted of 134 vessels of 18,531 tons. In 1888, 1707 vessels of 209,938 tons entered, and 1760 of 212,468 tons cleared. In 1898, 1825 vessels of 347,434 tons entered, and 1749 of 353,750 tons cleared. Population (on the unextended area of 617 acres), (1881), 5973; (1891), 4737; (on the area extended in 1892 to include the whole of Falmouth parish, 643 acres, and part of an adjoining parish), (1891), 12,791; (1901), 11,773.

False Bay. See SIMONS TOWN.

Falticeni, chief town of the district of Suceava, Rumania, 265 miles from Bucarest. It is a place of some commercial standing. An important fair is annually held there, commencing on the 20th of July and lasting for five weeks, the chief trade being in cattle, horses, and carriages. The population, about one-half Jews, is 9643.

Falun, a town of Sweden, capital of the province of Kopparberg (or Dalecarlia), 57 miles by rail W. from Gefle, famous for its copper mines. In 1896 the yield was 15,985 tons of ore, from which were extracted 1506 tons of sulphate of copper and 112 tons of iron pyrites; other products, 2400 oz. gold, 9684 oz. silver, 66 tons of sulphur, 2267 tons of sulphuric acid, and 796 tons of red ochre. The mines belong to the Kopparberg Mining Company, the largest joint stock concern in Sweden, many of the shares, since the reorganization of the company in 1888, being held by the crown, by philanthropic institutions, and by other public bodies. The company also owns iron mines, limestone quarries, and quartz quarries, some 3600 acres of forests, two large ironworks, steam and water-driven sawmills; and, besides the output of the copper mine, they produce manufactured iron and steel, bricks, timber, wood-pulp, and charcoal. Besides the mining establishments there are railway engine and waggon works. Population (1880), 7305; (1898), 9115.

Famagusta (Greek, AMMOCHOSTOS), a town and harbour on the east coast of Cyprus, about 2½ miles south of the ruins of Salamis. About 800 Moslems live within the walls of the fortress; the Christian population has migrated to a suburb called Varosia. The foundation of Salamis was ascribed to Teucer: it was probably the most important town in early Cyprus. St Barnabas, it is said, was born and buried there. The revolt of the Jews under Trajan, and earthquakes under Constantius and Constantine the Great, helped in turn to destroy it. It was restored by Fl. Constantius II. (A.D. 337–361) as Constantia. The ruins were partially explored in 1890. The sites of two temples, the *agora*, and a remarkable reservoir (*loutron*, *castellum*, or *piscina*) were disclosed, and a fine bull's head capital of Ptolemaic date secured for the British Museum (*Journal of Hell. Studies*, vol. xii., 1891). More valuable antiquities were unearthed by Dr A. S. Murray in 1896 from a Mycenean necropolis at Encomi. Another town a little to the south, built by Ptolemy Philadelphus in 274 B.C., and called Arsinoe in honour of his sister, received the refugees driven from Constantia by the Arabs under Muʿawiyah, became the seat of the orthodox archbishopric, and was eventually known as Famagusta. This received a large accession of population at the fall of Acre in 1291; was coveted and annexed by the Genoese in 1373; reunited to the throne of Cyprus in 1464; and surrendered, after an investment of more than a year, to the Turks in 1571. The fortifications, remodelled by the Venetians after 1489, the castle, the grand cathedral church of St Nicolas, and the remains of the palace and many other churches make Famagusta a place of unique interest. Acts ii. and v. of *Othello* pass there. It is melancholy to add that its charm is threatened under a scheme to spend part of a sum of £314,000, advanced by the Colonial Loans Act 1899, on railway and harbour works, which would destroy a great part of the sea front.

Fano, a town and episcopal see of Italy (the Marches, prov. Pesaro and Urbino), on the Adriatic coast, 8 miles S.E. from Pesaro by rail. It has important silk industries, and makes bricks. There is also a technical school. In 1899 several Roman statues and other remains of a large building were discovered in the former convent of St Philip. Population about 11,250.

Fanö, an island of Denmark, off the west coast of Jutland, 2 miles south from Esbjerg, the northernmost of the North Frisian Islands, is in great part (75 per cent.) covered with drift-sand, dunes, and barren heath. Area, 20 square miles. Population, 3202. Chief town, Nordby (population 2600), on the east coast, which has recently acquired repute as a summer seaside resort, and possesses a school of navigation. There is another village, Sönderho, near the south extremity, which also attracts visitors for the sea-bathing. The inhabitants, who are Frisians, support themselves by seafaring and fishing. In 1897 they owned a fleet of 109 vessels of 40,450 tons.

Fargo, capital of Cass County, North Dakota, U.S.A., on the west bank of the Red river, which is here not navigable, at an altitude of 902 feet. It lies in the rich wheat region of the Red river valley, and is a very important market for wheat, farm implements, and machinery. It is entered by the Northern Pacific, the Great Northern, and the Chicago, Milwaukee, and St Paul railways. Fargo College is a Congregational institution, founded in 1887. In 1893 a large part of the town was destroyed by fire, at an estimated loss of $3,000,000. Population (1880), 2693; (1890), 5664; (1900), 9589, of whom 2564 were foreign-born.

Faribault, capital of Rice County, Minnesota, U.S.A., on the Cannon river, and the Chicago, Milwaukee, and St Paul, and the Chicago Great Western railways, at an altitude of 1000 feet. It contains the State schools for the blind, deaf, and feeble-minded. Its manufactures consist largely of flour and furniture. Population (1880), 5415; (1890), 6520; (1900), 7868, of whom 1586 were foreign-born.

Faridkot, a native state of India within the Punjab. It ranks as one of the Cis-Sutlej states which came under British influence in 1809. Its area is 643 square miles. In 1881 the population was 97,034, and in 1891 it was 115,040, giving an average density of 178 persons per square mile. In 1901 the population was 124,912, showing an increase of 9 per cent. The estimated gross revenue is Rs. 3,56,000; the military force numbers 571 men; there is no tribute. The territory is traversed by the Rewari-Ferozepore railway, and also crossed by the Fazilka line, which starts from Kotkapura, the old capital. It is irrigated by a branch of the Sirhind canal. In 1896–97 there were seven schools attended by 262 pupils; the proportion of boys at school was as low as one in 243 of the total male population. The town of FARIDKOT has a railway station, 84 miles from Lahore.

Faridpur, or **Furreedpore,** a town and district of British India, in the Dacca division of Bengal. The town, which has a railway station, stands on an old channel of the Ganges. Population about 10,500. There are a Baptist mission, a Government high school, attended in 1896–97 by 277 pupils, and three printing presses, with two vernacular newspapers. The DISTRICT comprises an area of 3267 square miles. Population (1881), 1,636,785; (1891), 1,797,320, showing an average density of 792 persons per square mile. Classified according to religion, Hindus numbered 699,307; Mahommedans, 1,120,612; Christians, 3539, of whom 99 were Europeans; "others," 85. In 1901 the population was 1,937,922, showing an increase of 6 per cent. The land revenue and rates were Rs.6,47,392; the number of police was 433; there were 37,980 boys at school in 1896–97, being 27·9 per cent. of the male population of school-going age; the registered death-rate in 1897 was 39·45 per thousand, a high mortality attributed to the contamination of drinking-water by the steeping of jute. The north of the district is crossed by the line of the Eastern Bengal railway to Goalundo, the port of the Brahmaputra steamers, and a branch runs to Faridpur town. But most of the trade is conducted by river.

Faringdon, Great, a market-town and railway station in the Abingdon parliamentary division of Berkshire, England, 17 miles S.W. by W. of Oxford. Edward the Elder died in a royal palace there in 925. All Saints' church has an Early English tower, and contains memorials; there are an ancient town-hall, a corn exchange, with a library and reading-room, a cottage hospital, and Faringdon House, built by Henry James Pye, poet laureate from 1790 to 1813. About 6½ miles to the S.E. is the White Horse, a figure dug in the slope of a chalk hill. Area of civil parish, 5897 acres; population (1881), 3141; (1901), 2900.

Farnborough, a parish in the Basingstoke parliamentary division of Hampshire, England, 2½ miles N. of Aldershot by rail. The parish church is ancient; St Michael's Catholic memorial church, erected in 1887 by the ex-Empress Eugénie, contains the remains of Napoleon III. and the Prince Imperial. An adjoining priory is occupied by Benedictine fathers; the convent is a ladies' boarding school. Aldershot north camp is within the parish. Area of civil parish (an urban district), 2331 acres; population (1881), 6266 (including 2840 military); (1901), 11,499 (including 5070 military).

Farnborough, Thomas Erskine May, 1ST BARON (1815–1886), was born in 1815, and educated at Bedford Grammar School under Dr Brereton. In 1831 he was nominated by Mr Manners Sutton, speaker of the House of Commons, to the post of assistant librarian, so that his long connexion with parliament began in his youth. He studied for the bar, and was called at the Middle Temple in 1838. In 1844 he published the first edition of his *Treatise on the Law, Privilege, Proceedings, and Usage of Parliament.* This work, which has passed through many editions, is not only an invaluable mine of information for the historical student, but it is known as the text-book of the law by which parliament governs its proceedings. It has been observed that "since its first publication the framers of constitutions have found in it the groundwork of their various systems; and while colonial legislatures have been modelled on the lines laid down in it, its translation into more than one foreign language has extended its influence beyond the English-speaking race." In 1846 Mr Erskine May was appointed examiner of petitions for private bills, and the following year taxing-master of the House of Commons. He published his *Remarks to Facilitate Public Business in Parliament* in 1849; a work *On the Consolidation of Election Laws* in 1850; and his *Rules, Orders, and Forms of the House of Commons* was printed by command of the House in 1854. In 1856 he was appointed clerk assistant at the table of the House of Commons. He received the Companionship of the Bath in 1860 for his parliamentary services, and became a Knight Commander in 1866. His important work, *The Constitutional History of England since the Accession of George III.* (1760–1860), was published in 1861–63, and it received frequent additions in subsequent editions. In 1871 Sir Erskine May was appointed clerk of the House of Commons. His *Democracy in Europe: a History,* appeared in 1877, but it failed to take the same rank in critical esteem as his *Constitutional History.* He retired from the post of clerk to the House of Commons in April 1886, having for fifteen years discharged the onerous duties of the office with as much knowledge and energy as unfailing tact and courtesy. Shortly after his retirement from office he was raised to the peerage under the title of Baron Farnborough of Farnborough, in the county of Southampton, but he only survived to enjoy the dignity for a few days. He died 10th May 1886, and as he left no issue the title became extinct. (G. B. S.)

Farnworth, a town in the Radcliff-cum-Farnworth parliamentary division of Lancashire, England, on the Irwell, 3 miles S.E. of Bolton by rail. The churches and chapels are four parish, a chapel of ease, Roman Catholic, Baptist, four Congregational, three Wesleyan, Catholic-Apostolic, &c. There are a grammar-school, market-place, public baths, recreation ground, a fever hospital, and a theatre. A public park of 16 acres was opened in 1864. Cotton mills, iron foundries, brick and tile works, and collieries supply industries. Area of urban district, 1502 acres; population (1881), 20,708; (1901), 25,927.

Faroe Islands, in Danish FÆRÖERNE—that is, "the Sheep Islands,"—belonging to Denmark, between Iceland (250 miles to the N.W.) and the Shetland Islands (180 miles to the S.E.), on the submarine ridge which separates the Atlantic from the Norwegian Sea. Strömö has an area of 144 sq. miles. Total population (1880), 11,220; (1900), 15,230. Chief town, Thorshavn; population, 1656. The loftiest elevations are Slattaretinde (2894 ft.) in Österö, and Kopende (2592 ft.) and Skellingfjeld (2520 ft.) in Strömö. The cultivation of the soil (which belongs for the most part to the Danish state) is extremely primitive, and the cultivated area only about 6 per cent. Hay is the principal crop. Coal is mined. In 1897 the islanders owned a fleet of 87 vessels of a total of 6150 tons.

V. U. Hammershaimb has published a collection of folk-songs and popular legends (*Færöisk Anthologi,* 2 vols., Copenhagen, 1886–91). Engl. version of the *Fœreyinga Saga,* by F. York Powell (Lond. 1896). The islands are being surveyed by the Danish General Staff. See *Geog. Tidskrift,* Copenhagen, 1895 (vol. xiii.) and 1897 (vol. xiv.).

Farr, William (1807–1883), English statistician, was born at Kenley, in Shropshire, on 30th November 1807. When nineteen he became the pupil of a doctor in Shrewsbury, also acting as dresser in the infirmary there. He then went to Paris to study medicine, but after two years returned to London, where, in 1832, he qualified as L.S.A. Next year he began to practise, but without very brilliant results, for five years later he definitely abandoned the exercise of his profession on accepting the post of compiler of abstracts in the registrar-general's office. The commissioners for the 1841 census consulted him on several points, but did not in every case follow his advice. For the next two decennial censuses he acted as assistant-commissioner; for that of 1871 he was a commissioner, and he wrote the greater part of the reports of all. He had an ambition to become registrar-general; and when that post became vacant in 1879, he was so disappointed at the selection of Sir Brydges Henniker instead of himself, that he refused to stay any longer in the registrar's office. He died of paralysis of the brain a year or two later, on 14th April 1883. A great part of Farr's literary production is to be found in the papers which, from 1839 to 1880, he wrote for each annual report of the registrar-general on the cause of the year's deaths in England. He was also the author of many papers on general statistics and on life-tables for insurance, some read before the Royal Statistical Society, of which he was president in 1871 and 1872, some contributed to the *Lancet* and other periodicals. A selection from his statistical writings was published in 1885 under the editorship of Mr Noël Humphreys.

Farrar, Frederic William (1831——), English divine, was born 7th August 1831, in the Fort of Bombay, his father, afterwards rector of Sidcup, Kent, being then a missionary of the Church Missionary Society. While very young he was sent to England, and placed in King William's College, Castletown, Isle of Man, a school whose external surroundings are reproduced in his popular schoolboy tale, *Eric; or, Little by Little.* In 1847 he entered King's College, London. Through the influence of Maurice he was led to the study of Coleridge, whose writings had a profound influence upon his faith and opinions. He proceeded to Trinity College, Cambridge, in October 1851, but while studying here returned to take his degree of B.A. at the university of London. He became a foundation scholar at Cambridge in 1852, and two years later he took his degree as fourth junior optime, and fourth in the first class of the classical tripos. In addition to other college prizes he gained the chancellor's medal for the English prize poem on the search for Sir John Franklin in 1852, the Le Bas prize, and the Norrisian prize. He was elected fellow of Trinity College in 1856. On leaving the university, Mr Farrar became an assistant master under Dr Cotton at Marlborough College. In November 1855 he was appointed an assistant-master at Harrow; here he remained for fifteen years. He was elected a fellow of the Royal Society in 1864, university preacher in 1868, honorary chaplain to the queen in 1869, and Hulsean lecturer in 1870. Mr Farrar was appointed headmaster of Marlborough College in 1871, and in the following year became chaplain-in-ordinary to the queen. In 1876 he was appointed canon of Westminster and rector of St Margaret's, Westminster. He took his D.D. degree in 1874, being the first to take theological degrees in accordance with the new regulations at Cambridge. Dr Farrar began his literary labours with the publication of *Eric* in 1858, succeeded in the following year by *Julian Home* and *Lyrics of Life*, and in 1862 by *St Winifred's; or the World of School.* He had already published a work on *The Origin of Language;* and now for a number of years philology took the place of fiction. His series of works on grammar and scholastic philology included *Chapters on Language*, 1865; *Greek Grammar Rules*, 1865; *Greek Syntax*, 1866; and *Families of Speech*, 1869. He edited *Essays on a Liberal Education* in 1868; and published *Seekers after God* in the Sunday Library, 1869. It was by his theological works, however, that Dr Farrar attained his greatest popularity. His Hulsean lectures were published in 1870 under the title of *The Witness of History to Christ.* *The Life of Christ*, which was published in 1874, speedily passed through a great number of editions, and ultimately became one of the most widely-read theological works of the 19th century. It reveals considerable powers of imagination and eloquence, and was partly inspired by a personal knowledge of the sacred localities depicted. In 1877 appeared *In the Days of My Youth*, sermons preached in the chapel of Marlborough College; and during the same year his volume of sermons on *Eternal Hope*—in which he called in question the doctrine of eternal punishment—caused much controversy in religious circles. In 1879 appeared *The Life and Works of St Paul*, and this was succeeded in 1882 by *The Early Days of Christianity.* Then came in order of publication the following works: *Every-day Christian Life; or, Sermons by the Way*, 1887; *Lives of the Fathers*, 1888; *Sketches of Church History*, 1889; *Darkness and Dawn*, 1891; *The Voice from Sinai*, 1892; *The Life of Christ as Represented in Art*, 1894; a work on Daniel, 1895; *Gathering Clouds*, a tale of the days of Chrysostom, 1896; and *The Bible, its Meaning and Supremacy*, 1896. In addition to his separate works, Dr Farrar has been a copious contributor of articles to various magazines, encyclopædias, and theological commentaries. In 1883 he was made archdeacon of Westminster and rural dean; and in 1885 he was appointed Bampton lecturer at Oxford, taking for his subject "The History of Interpretation." Dr Farrar was appointed dean of Canterbury in 1895. From 1890 to 1895 he was chaplain to the speaker of the House of Commons, and in 1894 he was appointed deputy-clerk of the closet to Queen Victoria. As a theologian Dean Farrar occupies a position midway between the Evangelical party and the Broad Church; while as a rather rhetorical preacher and writer he exerts a commanding influence over wide circles of readers. He is an ardent temperance and social reformer, and was one of the founders of the institution known as the Anglican Brotherhood, a religious band with modern aims and objects.

Farrer, Thomas Henry Farrer (1819–1899), 1st Baron, English civil servant and statistician, was the son of Thomas Farrer, a solicitor in Lincoln's Inn Fields. Born 24th June 1819, he was educated at Eton and Balliol College, Oxford, where he graduated in the second class in classics in 1840. He was called to the bar at Lincoln's Inn in 1844, but retired from practice in the course of a few years. In 1857 he was appointed assistant-secretary in the marine department of the Board of Trade, and permanent secretary to the Board of Trade in 1862. His tenure of this office, which he held for upwards of twenty years, was marked by many reforms and an energetic administration. Not only was he an advanced Liberal in politics, but he was a thorough Free-trader of the strictest school. He was created a baronet for his services at the Board of Trade in 1883, and in 1886 he retired from office. During the same year he published a work entitled *Free Trade versus Fair Trade*, in which he dealt with an economic controversy then greatly agitating the public mind. He had already written for the Citizen Series a volume on *The State in its Relation to Trade.* In 1889 he was co-opted by the Progressives an alderman of the London County Council, of which he became vice-chairman in 1890. His efficiency and ability in this capacity were warmly recognized; but in the course of time divergencies arose between his personal views and many of those of his colleagues. The tendency towards socialistic legislation which became apparent was quite at variance with his principles of individual enterprize and responsibility. He consequently resigned his position. In 1893 he was raised to the peerage. From this time forward he devoted much of his energy and leisure to advocating his views at the Cobden Club, the Political Economy Club, on the platform, and in the public press. Especially were his efforts directed against the opinions of the Fair Trade League, and upon this and other controversies on economic questions he wrote able, clear, and uncompromising letters, which left no doubt that he still adhered to the doctrines of free trade as advocated by its earliest exponents. In 1898 he published his *Studies in Currency*. He died at Abinger Hall, Dorking, 11th October 1899.

Fars (the name FARSISTAN is seldom used), one of the five great provinces of Persia. It has a population of about 750,000, and pays a yearly revenue of about £140,000. The subdivision of the province in districts, the chief places of the districts and their population, and the number of inhabited villages in each, as they appear in the latest available lists (dated 1884), are shown in the following table:—

	Name of District.	Chief Place or Seat of Government.		Number of Inhabited Villages in District.
		Name.	Population.	
1	Abádeh Iklid	Abádeh	4,000	33
2	Abádeh Tashk	Tashk		8
3	Abarj	Dashtek	2,000	6
4	*Abbássi*—			
	1. Bender Abbássi and Villages	Bender Abbássi	10,000	14
	2. Issín and Tázián	Issín		6
	3. Shamíl	Shamíl	1,000	18
	4. Móghistán	Ziárat		10
	5. Mínáb	Mínáb	4,000	23
5	Abrkúh	Abrkúh	10,000	22
6	Afzar	Nímdeh		12
7	'Alamrúd	Sabzpushán	1,000	16
8	*Arb'ah* (the four)—			
	1. Deh Rúd 2. Deh Ram 3. Hengám 4. Rúdbál	Deh Ram	1,500	19
9	Ardakán	Ardakán	5,000	10
10	Arsinján	Arsinján	5,000	25
11	Asír	Asír	500	10
12	Baizá	Baizá	2,000	55
13	Bashákerd	Angúrán		5
14	Bídshehr and Juvim	Bídshehr	3,000	23
15	Bovanát	Súrián	500	23
16	Daráb	Daráb	5,000	62
17	*Dashti*—			
	1. Bardistán	Bender Dair	1,000	28
	2. Bulúk	Bushgán		18
	3. Mándistán	Kákí	1,500	40
	4. Tassúj	Tang Bágh	500	11
	5. Shumbeh	Shumbeh		15
18	*Dashtistán*—			
	1. Angáli	Haftjúsh		10
	2. Ahrom	Ahrom	1,500	5
	3. Borazján	Borazján	4,000	19
	4. Bushire	Bushire	25,000	20
	5. Dálikí	Dálikí	1,500	7
	6. Gonávah	Gonávah	1,000	12
	7. Hayát Daúd	Bender Ríg	1,000	6
	8. Khurmúj	Khurmúj	1,000	5
	9. Rúd Hillah	Kelát Sukhteh		10
	10. Shabánkáreh	Deh Kohneh		27
	11. Tangistán	Tangistán	1,000	31
	12. Zengeneh	Samal	750	4
	13. Zíráh	Zíráh		6
19	Dizgird	Cherkes	500	6
20	Famúr	Págáh	300	3
21	Farráshband	Farráshband	1,000	14
22	Fasá	Fasá	5,000	40
23	Fírúzábád	Fírúzábád	4,000	29
24	Gillehdár	Gillehdár	1,000	43
25	Húmeh (immed. environs) Shiráz	Zerkán	1,000	89
26	Istahbonát	Istahbonát	10,000	12
27	Jahrom	Jahrom	10,000	33
28	Jireh	Ishfáyikán		23
29	Kámfírúz	Palangerí		34
30	Kamin	Kalílek		11
31	Kázerún	Kázerún	8,000	46
32	Kavár	Kavár		26
33	Kír and Karzín	Kír	1,000	23
34	Khafr	Khafr	1,000	41
35	Khájeh	Zanjírán	500	15
36	Khisht	Khisht	2,500	25
37	Khunj	Khunj	1,500	27
38	Kongán	Bender Kongán		12
39	Kúh Gílúyeh	Behbahan	10,000	182
40	Kurbál	Gávkán	600	67
41	*Láristán*—			
	1. Lár	Lár	8,000	34
	2. Panjeh Ihshám	Bairam		11
	3. Panjeh Fál	Ishkenán		10
	4. Jehángíriyeh	Bastak	4,000	30
	5. Shíb Kúh	Bender Chárek		36
	6. Fúmistán, or Gávbandi	Gávbandi		13
	7. Kauristán	Kauristán		4
	8. Lingah	Bender Lingah	10,000	11
	9. Mazáyiján	Mazáyiján		6
42	Maimand	Maimand	5,000	14
43	Maliki	Bender Assalú	1,000	25
44	*Mamasenni* (old Shúlistán)—			
	1. Bekesh	Kalát Safíd		8
	2. Javídí, or Jáví			6
	3. Dushmanziári			16
	4. Rustami			26
	5. Fahlián			7
	6. Kákán			5
45	Marvast and Herát	Marvast		14
46	*Marvdasht*—			
	1. Upper Khafrek	Fathábád	1,250	14
	2. Lower Khafrek			16
	3. Marvdasht			22
47	Mashhad Mádar Sulimán	Murgháb	800	6
48	Máyin	Máyin		8
49	Nairíz	Nairíz	9,000	24
50	Ramjird	Jashíán		36
51	Rúdán and Ahmedí	Dehbáriz		21
52	*Sab'ah* (the seven)—			
	1. Bívunj	Durz		14
	2. Hassanábád	Hassanábád		7
	3. Tarom	Tarom	2,000	15
	4. Fáraghán	Fáraghán	1,500	13
	5. Forg	Forg	3,000	18
	6. Fín and Gulreh	Fín		13
	7. Gilch Gáh (abandoned)			—
53	Sarchahán	Ziáret	1,000	11
54	*Sarhad Chahár Dungeh*—			
	1. Dasht Uján 2. Dasht Khosro va Shirín 3. Dasht Khúngasht 4. Dasht Kúshk Zard	Kúshk Zard		31
55	*Sarhad Shesh Nahíyeh*—			
	1. Pádiná	Khúr		24
	2. Henná	Henná		
	3. Samíram	Samíram		
	4. Felárd	Felárd		
	5. Vardasht	Garmabad		
	6. Vank	Vank		
56	Sarvistán	Sarvistán	4,500	23
57	Shíráz (town)		53,607[1]	—
58	Síyákh	Darinján		13
59	Simkán	Dúzeh		38

[1] Persian census (1884): 6327 houses; 25,284 males, 28,323 females; total population, 53,607.

The above fifty-nine districts are grouped into eighteen sub-provinces, under governors appointed by the Governor-general of Fars, but the towns of Bushire, Lingah, and Bender Abbássi, together with the villages in their immediate neighbourhood, form a separate government known as that of the "Persian Gulf ports" (Benáder i Khalíj i Fárs), under a governor appointed from Teherán. Many districts are fertile, but some, particularly those in the south-eastern part of the province, do not produce sufficient grain for the requirements of the population. In consequence of droughts, ravages of locusts, and misgovernment by local governors, the province has been much impoverished, and hundreds of villages are in ruins and deserted. Turbulent and lawless nomad tribes, when on the march from summer to winter, or from winter to summer camping grounds, frequently render the roads insecure, and occasionally plunder whole districts, leaving the inhabitants without means of subsistence.

The province produces much wheat, barley, rice, and cotton, but the authorities every now and then prohibiting the exportation of cereals, the people only sow just as much as they think will suffice for their own wants. Much tobacco, principally for home consumption, is also grown (specially in Fasa and Daráb), and a considerable quantity of opium, much of it for export to China, is produced. Salt, lime, and gypsum are abundant. There are some oil wells at Dálikí, near Bushire, but attempts to tap the oil have been unsuccessful. There are no valuable oyster banks in Persian waters, and all the Persian Gulf pearls are obtained from banks on the coast of Arabia and near Bahrain. (A. H.-S.)

Farukhabad, a city and district of British India, in the Agra division of the North-West Provinces. The city is near the right bank of the Ganges, 87 miles by rail from Cawnpore. It forms a joint municipality with Fatehgarh, the civil headquarters of the district, with a military cantonment. Population (1881), 62,437; (1891), 78,032; (1901), 62,878. The municipal income in 1897–98 was Rs. 53,427; the registered death-rate in 1897 was 42 per thousand. At Fatehgarh is the government gun-carriage factory; also an American Presbyterian mission, with high school, and a tent factory. The district of FARUKHABAD has an area of 1720 square miles, and had a population in 1881 of 907,608, and in 1891 of 856,687, giving an average density of 499 persons per square mile. In 1901 the population was 924,660, showing an increase of 8 per cent. The land revenue and rates were Rs. 13,24,696, the incidence of assessment being R. 1-1-8 per acre; the cultivated area in 1896–97 was 504,976 acres, of which 278,480 were irrigated; the number of police was 2912; the number of vernacular schools in 1896–97 was 104, with 3880 pupils; the registered death-rate in 1897 was 43·42 per thousand. There are eight printing-presses, issuing four vernacular periodicals, and 87 indigo factories, employing 3927 persons, with an out-turn valued at Rs. 2,07,000. Part of the district is watered by distributaries of the Ganges canal, and it is now traversed throughout its length by the Agra-Cawnpore line of the Rajputana railway.

Fashoda. See EGYPT (*History*), and NILE.

Fatehpur (*Fathepur*), a town and district of British India, in the Allahabad division of the North-West Provinces. The town is 73 miles by rail north-west of Allahabad. In 1881 the population was 21,328, in 1891 it was 20,179; the municipal income in 1897–98 was Rs. 12,191. The district of FATEHPUR has an area of 1633 square miles. It had a population in 1881 of 683,745, and in 1891 of 699,157, giving an average density of 428 persons per square mile. In 1901 the population was 686,411, showing a decrease of 2 per cent. The land revenue and rates were Rs. 11,79,482, the incidence of assessment being R. 1-14-1 per acre; the cultivated area was 307,439 acres, of which 127,703 were irrigated from wells, &c.; the number of police was 2370; the number of vernacular schools in 1896–97 was 95, with 2952 pupils; the registered death-rate in 1897 was 54·35 per thousand. There are three printing-presses, issuing three vernacular periodicals. The district is traversed by the main line of the East Indian railway from Allahabad to Cawnpore, 55 miles in length.

Faure, François Félix (1841–1899), President of the French Republic, was born in Paris, 30th January 1841, being the son of a small furniture maker. Having started as a tanner and merchant at Havre, he acquired considerable wealth, was elected to the National Assembly in August 1881, and took his seat as a member of the Left, interesting himself chiefly in matters concerning economics, railways, and the Navy. In November 1882 he became under-secretary for the colonies in M. Ferry's Ministry, and retained the post till 1885. He held the same post in M. Tirard's Ministry in 1888, and in 1893 was made vice-president of the Chamber. In 1894 he obtained cabinet rank as minister of marine in the administration of M. Dupuy. In the January following he was unexpectedly elected President of the Republic upon the resignation of M. Casimir-Périer. The principal cause of his elevation was the determination of the various sections of the moderate republican party to exclude M. Brisson, who had had a majority of votes on the first ballot, but had failed to obtain an absolute majority. To accomplish this end it was necessary to unite among themselves, and union could only be secured by the nomination of some one who offended nobody. M. Faure answered perfectly to this description. His fine presence and his tact on ceremonial occasions rendered the state some service when in 1896 he received the Tsar of Russia at Paris, and in 1897 returned his visit, after which meeting the momentous Franco-Russian alliance was publicly announced. The latter days of M. Faure's presidency were embittered by the Dreyfus affair, which he was determined to regard as *chose jugée*. But at a critical moment in the proceedings his death occurred suddenly, from apoplexy, on 16th February 1899. With all his faults, and in spite of no slight amount of personal vanity, President Faure was a shrewd political observer and a good man of business. After his death, some alleged extracts from his private journals, dealing with French policy, were published in the Paris press.

Fauré, Gabriel (1845 ——), French musical composer, was born at Pamiers on 13th May 1845. He studied at the school of sacred music directed by Niedermeyer, first under Dietsch, and subsequently under Saint-Saëns. He became "maître de chapelle" at the church of the Madeleine in 1877, and organist in 1896. His works include a symphony in D minor (Op. 40), two quartets for piano and strings (Opp. 15 and 45), a suite for orchestra (Op. 12), sonata for violin and piano (Op. 13), concerto for violin (Op. 14), berceuse for violin, elegie for violoncello, pavane for orchestra, incidental music for Alexandre Dumas' *Caligula* and De Haraucourt's *Shylock*, a requiem, a cantata, *The Birth of Venus*, produced at the Leeds Festival in 1898. He has also written a quantity of piano music and a large number of songs. Fauré occupies a place to himself among modern French composers. He delights in the *imprévu*, and loves to wander through labyrinthine harmonies. There can be no denying the intense fascination and remarkable originality of his music. He is a composer whose works are more likely to appeal to those of delicate and refined tastes than to the masses. His muse is essentially aristocratic, and suggests the surroundings of the boudoir and the perfume of the hothouse.

Faversham, a municipal borough, port, and market-town, in the Faversham parliamentary division of Kent, England, on a creek of the Swale, 9 miles W.N.W. of Canterbury by rail. Recent erections are an Established church, a cottage hospital, and an isolation hospital. Area, 693 acres; population (1881), 9374; (1901), 11,234.

Favre, Jules (1809–1880), French advocate and statesman, was born at Lyons on 31st March 1809. After a brilliant career as a barrister, especially as counsel for defendants in political prosecutions, he achieved political importance by his defence of Felice Orsini in 1858, and in 1860 was returned to the Legislative Assembly as one of the miniature but formidable party of five opposed to the Empire. Unlike most of his colleagues, he consistently maintained this hostile attitude, and it was upon his proposition that the deposition of Napoleon III. was proclaimed after the disaster of Sedan. He naturally obtained a leading position in the new Government, but the post of Minister of Foreign Affairs was unsuited to him; his famous declaration, "Not an inch of our territory, not a stone of our fortresses," had to be taken back, and his neglect of Prince Bismarck's advice to disarm the National Guard brought about the horrors of the Commune. After this, though still practising with distinction as a pleader, he took little part in political affairs. He died at Versailles on 20th January 1880.

Fawcett, Henry (1833–1884), English politician and economist, was born at Salisbury on 26th August 1833. His father, William Fawcett, a native of Kirkby Lonsdale, in Westmorland, started life as a draper's assistant at Salisbury, opened a draper's shop on his own account in the market-place there in 1825, married a solicitor's daughter of the city, became a prominent local man, took a farm, developed his north-country sporting instincts, and displayed his shrewdness by successful speculations in Cornish mining. His second son, Henry, inherited a full measure of his shrewdness, along with his masculine energy, his straightforwardness, his perseverance, and his fondness for fishing. The father was active in electioneering matters, and his wife was an ardent reformer. Henry Fawcett was educated locally and at King's College school (1848–51), and proceeded to Peterhouse, Cambridge, in October 1852, migrating in 1853 to Trinity Hall. He was seventh wrangler in 1856, and was elected to a fellowship at his college. He had already attained some prominence as an orator at the Cambridge Union. Before he left school he had formed the ambition of entering parliament, and, being a poor man, he resolved to approach the House of Commons through a career at the bar. He had already entered Lincoln's Inn. His prospects, however, were shattered by a calamity which befell him in September 1858, when two stray pellets from his father's fowling-piece passed through the glasses he was wearing and blinded him for life. Within ten minutes after his accident he had made up his mind "to stick to his old pursuits as much as possible." He kept up all recreations contributing to the enjoyment of life; he fished, rowed, skated, took abundant walking and horse exercise, and learnt to play cards with marked packs. Soon after his accident he established his headquarters at Trinity Hall, Cambridge, entered cordially into the social life of the college, and came to be regarded by many as a typical Cambridge man. He gave up mathematics (for which he had little aptitude), and specialized in political economy. He paid comparatively little attention to economic history, but he was in the main a devout believer in economic theory, as represented by Ricardo and his school. The later philosophy of the subject he believed to be summed up in one book, Mill's *Principles of Political Economy*, which he regarded as the indispensable "vade mecum" of every politician. He was not a great reader, and Mill probably never had a serious rival in his regard, though he was much impressed by Buckle's *History of Civilization* and Darwin's *Origin of Species* when they severally appeared. He made a great impression in 1859 with a paper at the British Association, and he soon became a familiar figure there and at various lecture halls in the north as an exponent of orthodox economic theory. Of the sincerity of his faith he gave the strongest evidence by his desire at all times to give a practical application to his views and submit them to the test of experiment. Among Mill's disciples he was, no doubt, far inferior as an economic thinker to Cairnes, but as a popularizer of the system and a demonstrator of its principles by concrete examples he had no rival. His power of exposition was illustrated in his *Manual of Political Economy* (1863), of which in twenty years as many as 20,000 copies were sold. Alexander Macmillan had suggested the book, and it appeared just in time to serve as a credential, when, in the autumn of 1863, Fawcett stood and was elected for the Chair of Political Economy at Cambridge. The appointment attached him permanently to Cambridge, gave him an income, and showed that he was competent to discharge duties from which a blind man is often considered to be debarred. He was already a member of the Political Economy Club, and was becoming well known in political circles as an advanced Radical. In January 1863, after a spirited though abortive attempt in Southwark, he was only narrowly beaten for the borough of Cambridge. Early in 1864 he was adopted as one of the Liberal candidates at Brighton, and at the general election of 1865 he was elected by a large majority. Shortly after his election he became engaged to Millicent, daughter of Mr Newson Garrett of Aldeburgh, Suffolk, and in 1867 he was married.

Fawcett entered parliament just in time to see the close of Palmerston's career and to hail the adoption by Gladstone of a programme of reform to which most of the *laissez-faire* economists gave assent. He was soon known as a forcible speaker, and quickly overcame the imputation that he was academic and doctrinaire, though it is true that a certain monotony in delivery often gave a slightly too didactic tone to his discourses. But it was as the uncompromising critic of the political shifts and expedients of his leaders that he attracted most attention. He constantly insisted upon the right of exercising private judgment, and he especially devoted himself to the defence of causes which, as he thought, were neglected both by his official leaders and by his Radical comrades. Reelected for Brighton to the parliament of 1868–74, he greatly hampered the Government by his persistence in urging the abolition of clerical fellowships and the payment of election expenses out of the rates, and by opposing the "permissive compulsion" clauses of the Elementary Education Bill, and the exclusion of agricultural children from the scope of the Act. His hatred of weak concessions made him the terror of parliamentary wirepullers, and in 1871 he was not undeservedly spoken of in the

Times as the most "thorough Radical now in the House." His liberal ideals were further shocked by the methods by which Gladstone achieved the abolition of Army Purchase. His disgust at the supineness of the Cabinet in dealing with the problems of Indian finance and the growing evil of Commons' Enclosures were added to the catalogue of grievances which Fawcett drew up in a powerful article, "On the Present Position of the Government," in the *Fortnightly Review* for November 1871. In 1867 he had opposed the expenses of a ball given to the Sultan at the India Office being charged upon the Indian budget. In 1870 he similarly opposed the taxation of the Indian revenue with the cost of presents distributed by the duke of Edinburgh in India. In 1871 he went alone into the lobby to vote against the dowry granted to the Princess Louise. The soundness of his principles was not impeached, but his leaders looked askance at him, and from 1871 he was severely shunned by the Government whips. Their suspicion was justified when in 1873 Fawcett took a leading share in opposing Gladstone's scheme for university education in Ireland as too denominational, and so contributed largely to a conclusive defeat of the Gladstone Ministry.

From 1869 to 1880 Fawcett concentrated his energies upon two important subjects which had not hitherto been deemed worthy of serious parliamentary attention. The first of these was the preservation of commons, especially those near large towns; and the second was the responsibility of the British Government for the amendment of Indian finance. In both cases the success which he obtained exhibited the sterling sense and shrewdness which made up such a great part of Fawcett's character. In the first case Fawcett's great triumph was the enforcement of the general principle that each annual Enclosure Act must be scrutinized by parliament and judged in the light of its conformity to the interests of the community at large. Probably no one did more than he did to prevent the disafforestation of Epping Forest and of the New Forest. From 1869 he regularly attended the meetings of the Commons Preservation Society, and he remained to the end one of its staunchest supporters. His intervention in the matter of Indian finance, which gained him the sobriquet of the "member for India," led to no definite legislative achievements, but it called forth the best energies of his mind and helped to rouse an apathetic and ignorant public to its duties and responsibilities. Fawcett was defeated at Brighton in February 1874. Two months later, however, he was elected for Hackney, and retained the seat during his life. He was promptly replaced on the Indian Finance Committee, and continued his searching inquiries with a view to promote a stricter economy in the Indian budget, and a more effective responsibility in the management of Indian accounts.

As an opponent of the Disraeli Government (1874–80) Fawcett came more into line with the Liberal leaders. In foreign politics he gave a general adhesion to Gladstone's views, but he continued to devote much attention to Indian matters, and it was during this period that he produced two of his best publications. His *Free Trade and Protection* (1878) illustrated his continued loyalty to Cobdenite ideas. At the same time, his admiration for Palmerston and his repugnance to schemes of Home Rule show that he was not by any means a peace-at-any-price man. He thought that the Cobdenites had deserved well of their country, but he always maintained that their foreign politics were biassed to excess by purely commercial considerations. As befitted a writer whose linguistic gifts were of the slenderest, Fawcett's English was a sound homespun, clear and unpretentious. In a vigorous employment of the vernacular he approached Cobbett, whose writing he justly admired. The second publication was his *Indian Finance* (1880), three essays reprinted from the *Nineteenth Century*, with an introduction and appendix. When the Liberal party returned to power in 1880 Gladstone offered Fawcett a place in the new Government as Postmaster-General (without a seat in the Cabinet). On Egyptian and other questions of foreign policy Fawcett was often far from being in full harmony with his leaders, but his position in the Government naturally enforced reserve. He was, moreover, fully absorbed by his new administrative functions. He gained the sympathy of a class which he had hitherto done little to conciliate, that of public officials, and he showed himself a most capable head of a public department. To his readiness in adopting suggestions, and his determination to push business through instead of allowing it to remain permanently in the stage of preparation and circumlocution, the public is mainly indebted for five substantial postal reforms:—(1) The parcels post, (2) postal orders, (3) sixpenny telegrams, (4) the banking of small savings by means of stamps, (5) increased facilities for life-insurance and annuities. In connexion with these last two improvements Fawcett, in 1880, with the assistance of Mr James Cardin, took great pains in drawing up a small pamphlet called *Aids to Thrift*, of which over a million copies were circulated gratis. A very useful minor innovation of his provided for the announcement on every pillar-box of the time of the "next collection." In the post office, as elsewhere, he was a strong advocate of the employment of women. Proportional representation and the extension of franchise to women were both political doctrines which he adopted very early in his career, and never abandoned. Honours were showered upon him during his later years. He was made an honorary D.C.L. of Oxford, a Fellow of the Royal Society, and was in 1883 elected Lord Rector of Glasgow University. But the stress of departmental work soon began to tell upon his health. In the autumn of 1882 he had a sharp attack of diphtheria complicated by typhoid, from which he never properly recovered. He resumed his activities, but on the 6th November 1884 he succumbed at Cambridge to an attack of congestion of the lungs. He was buried in Trumpington churchyard, near Cambridge, and to his memory were erected a monument in Westminster Abbey, a statue in Salisbury market-place, and a drinking fountain on the Thames embankment.

In economic matters Fawcett's position can best be described as transitional. He believed in co-operation almost as a panacea. In other matters he clung to the old *laissez-faire* theorists, and was a strong anti-socialist, with serious doubts about free education, though he supported the Factory Acts and wished their extension to agriculture. Apparent inconsistencies were harmonized to a great extent by his dominating anxiety to increase the well-being of the poor. One of his noblest traits was his kindliness and genuine affection for the humble and oppressed, country labourers and the like, for whom his sympathies seemed always on the increase. Another was his disposition to interest himself in and to befriend younger men. In the great affliction of his youth Fawcett bore himself with a fortitude which it would be difficult to parallel. The effect of his blindness was, as the event proved, the reverse of calamitous. It brought the great aim and purpose of his life to maturity at an earlier date than would otherwise have been possible, and it had a mellowing influence upon his character of an exceptional and beneficent kind. As a youth he was rough and canny, with a suspicion of harshness. The kindness evoked by his misfortune, a strongly reciprocated family affection, a growing capacity for making and keeping friends—these and other causes tended to ripen all that was best, and apparently that only, in a strong but somewhat stern character. His acerbity passed away, and in later life was reserved exclusively for official witnesses before parliamentary committees. Frank, helpful, conscientious to a fault, a shrewd gossip, and a staunch friend, he was a man whom no one could help liking. Several of his letters to his father and mother at different periods of his career are preserved in Mr Stephen's admirable *Life* (1885), and show a goodness of heart, together with a homely simplicity of nature, which is most touching. In appearance Fawcett was gaunt and tall, over 6 feet 3 inches in height, large of bone, and massive in limb. (T. SE.)

Fayrer, Sir Joseph, BART. (1824– ——), English physician, was born at Plymouth, 6th December 1824. Beginning his medical career in the navy, he was present as a surgeon at the sieges of Palermo and Rome, and then, after a short time in the army, entered the Bengal medical service in 1850. During the next few years he was again actively engaged in the field, for he went through the Burmese campaign of 1852 and was political assistant and Residency surgeon at Lucknow during the Mutiny. From 1859 to 1874 he was professor of surgery at the Medical College of Bombay, and when the Prince of Wales made his tour in India he was appointed to accompany him as physician. Returning from India he acted as president of the Medical Board of the India Office from 1874 to 1895, and in 1896 he was created a baronet. Sir Joseph Fayrer, who became a fellow of the Royal Society in 1877, has written much on subjects connected with the practice of medicine in India; but he is especially known for his studies on the poisonous snakes of that country and on the physiological effects produced by their virus.

Fazokl, or **Fazogl,** a town of the Anglo-Egyptian Sudan, on the left bank of the Blue Nile, close to the Tumat confluence, and opposite FAMAKA, near the Abyssinian frontier, formerly the residence of a powerful native king. During the Egyptian rule it was capital of the upper province of the Blue Nile of the same name, but was soon replaced by Famaka, where Mahomet Ali built a palace in 1839. Then Fazokl dwindled to a mere hamlet, and both places were abandoned at the outbreak of the Mahdi's revolt. It was reoccupied in 1899, and is now a chief station in the reconstituted Equatorial province under Anglo-Egyptian rule. It is important both as a frontier post towards Abyssinia, and as the nearest station to the auriferous district of the Tumat basin. The chief gold-washings lie on the west slope of the hills draining to the White Nile. Here is the steep Jebel-Dul, which appears to contain rich gold-bearing reefs, as the precious metal occurs in all the ravines on its flanks.

Fécamp, a town in the arrondissement of Havre, department of Seine Inférieure, 27 miles N.N.E. of Havre by rail. It has a library and museum of painting and objects of art, a hydrographical school, and an establishment for pisciculture. In 1900 1,681,237 bottles of liqueurs were produced. The total value of the imports, in 1900, was £185,600, and of the exports £39,934; 120 vessels of 49,516 tons entered and cleared, and 59 ships were engaged in the Newfoundland cod-fisheries. Amongst minor improvements, it may be said that a length of 165 yards of new quay wall was completed in 1900; that the north pier has been lengthened, and that a new lighthouse with powerful light has been erected on the extremity to replace that on the cliff. Population (1881), 11,831; (1896), 13,679; (comm.) 14,448.

Fechner, Gustav Theodor (1801–1887), the founder of German experimental psychology, was born on 19th April 1801 at Gross-Särchen, near Muskau, in Lower Lusatia, where his father was pastor. He was educated at Sorau and Dresden and the university of Leipzig. In this city he spent the rest of his life. In 1834 he was appointed professor of Physics, but in 1839 contracted a disease of the eyes while studying the phenomena of colour and subjective light, and, after much suffering, resigned. He now turned to the study of mind and the relations between body and mind, giving public lectures on the subjects of which his books treat. He died on 16th November 1887. Among his works may be mentioned: *Das Büchlein vom Leben nach dem Tode* (1836), which has been translated into English; *Nanna, oder über das Seelenleben der Pflanzen* (1848); *Zendavesta, oder über die Dinge des Himmels und des Jenseits* (1851); *Ueber die physikalische und philosophische Atomenlehre* (1855); *Elemente der Psychophysik* (1860); *Vorschule der Aesthetik* (1876); *Die Tagesansicht gegenüber der Nachtansicht* (1876). He also published chemical and physical papers, and translated chemical works by Biot and Thénard from the French. A different but essential side of his character is seen in his poems and humorous pieces, such as the *Vergleichende Anatomie der Engel* (1825), written under the pseudonym of Dr Mises. Fechner's epoch-making work was his *Elemente der Psychophysik*. He starts from the Spinozistic thought that bodily facts and conscious facts, though not reducible one to the other, are different sides of one reality. His originality lies in trying to discover an exact mathematical relation between them. The most famous outcome of his inquiries is the law known as Weber's or Fechner's law which may be expressed as follows:—In order that the intensity of a sensation may increase in arithmetical progression, the stimulus must increase in geometrical progression. Though holding good within certain limits only, the law has been found immensely useful. Unfortunately, from the tenable theory that the intensity of a sensation increases by definite additions of stimulus, Fechner was led on to postulate a unit of sensation, so that any sensation S might be regarded as composed of n units. Sensations, he argued, thus being representable by numbers, psychology may become an "exact" science, susceptible of mathematical treatment. His general formula for getting at the number of units in any sensation is $S = C \log R$; where S stands for the sensation, R for the stimulus numerically estimated, and C for a constant that must be separately determined by experiment in each particular order of sensibility. This reasoning of Fechner's has given rise to a great mass of controversy, but the fundamental mistake in it is simple. Though stimuli are composite, sensations are not. "Every sensation," says Professor James, "presents itself as an indivisible unit; and it is quite impossible to read any clear meaning into the notion that they are masses of units combined." Still, the idea of the exact measurement of sensation has been a fruitful one, and mainly through his influence on Wundt, Fechner is the father of that "new" psychology of laboratories which investigates human faculties with the aid of exact scientific apparatus. Though Fechner has had a vast influence in this special department, the disciples of his general philosophy are few. His world-conception is highly animistic. He feels the thrill of life everywhere, in plants, earth, stars, the total universe. Man stands midway between the souls of plants and the souls of stars, who are angels. God, the soul of the universe, must be conceived as having an existence analogous to men. Natural laws are just the modes of the unfolding of God's perfection. In his last work Fechner, aged but full of hope, contrasts this joyous "daylight view" of the world with the dead, dreary "night view" of materialism. Fechner's work in æsthetics is also important. He conducted experiments to show that certain abstract forms and proportions are naturally pleasing to our senses, and gave some new illustrations of the working of æsthetic association. Fechner's position in reference to predecessors and contemporaries is not very sharply defined. He was remotely a disciple of Schelling, learnt much from Herbart and Weisse, and decidedly rejected Hegel and the monadism of Lotze. (H. St.)

Fechter, Charles Albert (1824–1879), actor, was born in London, of French parents, 23rd October 1824. While he was still a child his parents returned to France. He inherited considerable artistic ability from his father (who was a sculptor), and would probably have at once devoted himself to a sculptor's life but for the accident of a striking success made in some private theatricals. The result of this was an engagement early in 1841 to play in a travelling company that was going to Italy. The tour was a failure, and the company broken up; whereupon Fechter returned home and worked assiduously at sculpture. At the same time he attended classes at the Conservatoire with the view of gaining admission to the Comédie Française. Late in 1844 he enjoyed the double success of winning the grand medal of the Académie des Beaux Arts with a piece of sculpture and of being admitted to make his *début* at the Comédie Française. He acquitted himself at the latter with considerable credit; but, tired of the small parts he found himself condemned to play, returned again to his sculptor's studio in 1846. In that year he accepted an engagement to play with a French company in Berlin, where he made his first decisive success as an actor. He there became acquainted with Eléonore Rabut, an actress, whom he married on his return to Paris in the following year. Previously to this he appeared for some months in London, in a season of French classical plays given at the St James's Theatre. In Paris for the next ten years he fulfilled a series of engagements at the Ambigu-Comique, Théâtre Historique, Porte St Martin, and Vaudeville theatres, his chief successes being his performance of Armand Duval in *La Dame aux Camélias*. From March 1857 to December 1858 he was manager of the Odéon, where he produced *Tartufe* and other pieces from the classical repertory. Having received tempting offers to play in English at the Princess's Theatre, London, he made a diligent study of the language, and appeared there in October 1860 in a version of *Ruy Blas*. This was followed by *The Corsican Brothers* and *Don Cæsar de Bazan;* and in March 1861 he first attempted *Hamlet*. The result was an extraordinary triumph, the play running for 115 nights. This was followed by *Othello*, in which he played at first the character of the Moor, and afterwards that of Iago. In January 1863 he became lessee of the Lyceum Theatre, which he opened with *The Duke's Motto;* this was followed by *The King's Butterfly*, *The Mountebank* (in which his son Paul, a boy of seven, appeared), *The Roadside Inn*, *The Master of Ravenswood*, and *The Lady of Lyons*. After this he appeared at the Adelphi (in 1868) in *No Thoroughfare*, *Monte Cristo*, and *Black and White;* and after a tour through the English provinces in 1869, he set sail in 1870 for the United States, where (with the exception of a visit to London in 1872) he remained till his death. He played in the United States between 1870 and 1876 in most of the parts in which he had won his chief triumphs in England, making at various times attempts at management. As manager, however, he was rarely successful, owing to his ungovernable temper. The downfall of his career began after an accident upon the ice in 1876, which rendered him physically infirm. Ill-health speedily overtook him, and the last three years of his life were spent in practical seclusion on a farm which he had bought at Rockland Centre, near Quakertown, in Pennsylvania. He died there, of a painful internal malady, on 5th August 1879, and was buried in Mount Vernon cemetery, Philadelphia. (R. F. S.)

Felanitx, or Felaniche, a town of Spain, in the south-east of the island of Majorca, stands 11 miles from the sea, surrounded by hills. Population, 11,442. It has well-built streets, a good town hall, and a fine parish church. Near at hand are the ruins of a Moorish castle. There is trade in wine, fruit, wheat, cattle, brandy, chalk, and soap.

Felixstowe, a seaside resort of England, straggling about 3 miles along the coast of Suffolk, just outside the estuary of the Orwell, 12 miles south-east from Ipswich. It has good golf-links, and is much frequented by visitors in the summer for its excellent sea-bathing. Population of Felixstowe and Walton (1901), 5805.

Fens, a district in the east of England, possessing a distinctive history and peculiar characteristics. It lies west and south of the Wash, and extends over more than 70 miles in length (Lincoln to Cambridge) and some 35 miles in maximum breadth (Stamford to Brandon in Suffolk), its area being considerably over half a million acres. Although low and flat, and seamed by innumerable watercourses, the entire region is not, as the Roman name of *Metaris Æstuarium* would imply, a river estuary, but is a silted up bay of the North Sea, of which the Wash is the last surviving portion. Hydrographically, the Fens embrace the lower parts of the drainage-basins of the rivers Witham, Welland, Nene, and Great Ouse; and against these streams, as also against the ocean, they are protected by earthen embankments, 10 to 15 feet high. As a rule the drainage water is lifted off the Fens into the rivers by means of steam-pumps, formerly by windmills.

General History.—According to fairly credible tradition, the first systematic attempt to drain the Fens was made by the Romans. They dug a catchwater drain (as the artificial fenland watercourses are called), the Caer or Car Dyke, from Lincoln to Ramsey (or, according to Stukeley, as far as Cambridge), along the western edge of the Fens, to carry off the precipitation of the higher districts which border the fenland, and constructed alongside the Welland and on the seashore earthen embankments,[1] of which some 150 miles still survive. After the departure of the Romans from Britain in the first half of the 5th century the Fens fell into neglect; and despite the preservation of the woodlands for the purposes of the chase by the Norman and early Plantagenet kings, and the unsuccessful attempt which Richard de Rulos, chamberlain of William the Conqueror, made to drain Deeping Fen, the fenland region became almost everywhere waterlogged, and relapsed to a great extent into a state of nature. In addition to this it was ravaged by serious inundations of the sea, for example, in the years 1178, 1248 (or 1250), 1288,[2] 1322, 1335, 1467, 1571. Yet the fenland was not altogether a howling wilderness of reed-grown marsh and watery swamp. At various spots, more particularly in the north and in the south, there existed islands of firmer and higher ground, resting generally on the boulder clays of the Glacial epochs and on the inter-Glacial gravels of the Palæolithic Age.[3]

---

[1] See, for a full discussion, S. H. Miller and S. B. J. Skertchly, *The Fenland*, p. 144 *et seq.* (Wisbech and London, 1878). Mr Miller is disposed to credit the native British inhabitants of the Fens with having executed certain of these works.

[2] W. Chapman, *Facts and Remarks relative to the Witham and the Welland* (Boston, 1800), pp. 21–23.

[3] Miller and Skertchly, *op. cit.*, pp. 513–551. In Chap. xv. (pp. 492–583) of the same work will be found an exhaustive discussion of the geology of the entire region.

On these isolated localities members of the monastic orders (especially at a later date the Cistercians) began to settle after about the middle of the 7th century. At Medeshampstead (*i.e.*, Peterborough), Ely, Crowland, Ramsey, Thorney, Spalding, Peakirk, Swineshead, Tattershall, Kirkstead, Bardney, Sempringham, Bourne, and numerous other places, they made settlements, built churches and monasteries, founded abbeys, and even reared magnificent cathedrals.[1] And, in spite of the appalling incursions of the predatory Northmen and Danes in the 9th and 10th centuries, and of the disturbances consequent upon the establishment of the Camp of Refuge by Hereward the Wake in the fens of the Isle of Ely in the 11th century, these scattered outposts continued to shed rays of civilization across the lonely Fenland down to the dissolution of the monasteries in the reign of Henry VIII. Then they, too, were partly overtaken by the fate which befell the rest of the Fens; and it was only in the end of the 18th century and the beginning of the 19th century that the complete drainage and reclamation of the Fen region was finally effected. Attempts, and on a considerable scale, were indeed made to reclaim them in the 17th century—notably the Witham Fens by Sir Anthony Thomas, the Earl of Lindsey, Sir William Killigrew, King Charles I., and others in 1631 and succeeding years; the Deeping or Welland Fens in 1638 by Sir W. Ayloff, Sir Anthony Thomas, and other "adventurers," after one Thomas Lovell had ruined himself in a similar attempt in the reign of Queen Elizabeth; and the Fens of the Nene and Great Ouse, known generally as the Bedford Level, by the Dutch engineer Cornelius Vermuyden and the Earls of Bedford, in the first half of the century; although Lord Chief-Justice Popham and a Company of Londoners had begun the work in 1605.[2] But all these attempts equally failed, owing to the determined opposition[3] of the native fenmen, whom the drainage and appropriation of the unenclosed fenlands would deprive of valuable and long-enjoyed rights of commonage, turbary (turf-cutting), fishing, fowling, &c. Holland and other Fens on the west side of the Witham were finally drained in 1767, although not without much rioting and lawlessness;[4] and a striking account of the wonderful improvements effected by a generation later is recorded in Arthur Young's *General View of the Agriculture of the County of Lincoln* (London, 1799). The East, West, and Wildmore Fens on the east side of the Witham were drained in 1801–7 by John Rennie, who carried off the precipitation which fell on the higher grounds by catchwater drains, on the principle of the Roman Car Dyke, and improved the outfall of the river, so that it might the more easily discharge the Fen water which flowed or was pumped into it.[5] The Welland or Deeping Fens were drained in 1794, 1801, 1824, 1837, and other years.[6] The drainage of the Great Bedford Level between the year 1630 and the end of the 17th century has been treated of in the ninth edition (see BEDFORD LEVEL, iii. 482).[7] Almost the only portion of the original wild Fens now remaining is Wicken Fen, which lies east of the river Cam, and south-east of the Isle of Ely.

Map of the Fens.

The Fen Rivers.—The preservation of the Fens depends in an intimate and essential manner upon the preservation of the rivers, and especially upon the preservation of their banks. The Witham, known originally as the Grant Avon, also called the Lindis,[8] some 70 miles long, and draining an area of 1070 square miles, owes its present condition to engineering works carried out in the years 1762–64, 1865, 1881, and especially in 1880–84. In 1500 the river was dammed immediately above Boston by a large sluice, the effect of which was, not only to hinder free navigation up to Lincoln (to which city sea-going vessels used to penetrate in the 14th and 15th centuries), but also to choke the channel below Boston with sedimentary matter. The sluice, or rather a new structure made in 1764–66, still remains; but the river below Boston has been very materially improved (1880–84), first by the construction of a new outfall, 3 miles in length, whereby the channel was not only straightened, but its current carried directly into deep water, without having to battle against the sandbanks, often shifting, of the Wash; and secondly, by the deepening and regulation of the river-bed up to Boston, so

---

1 For complete lists, compiled from Dugdale and Speed, see Thompson, *History of Boston*, pp. 737–747 (Boston, 1856), and Miller and Skertchly, *op. cit.*, p. 137; consult also G. Oliver, *An Account of the Religious Houses formerly situated on the Eastern Side of the River Witham*, pp. 30–80 (London, 1846).

2 Baldwin Latham, *Papers on the Drainage of the Fens.* Read before the Society of Engineers, 3rd November 1862.

3 For the Witham Fens, see Sir William Dugdale, *The History of Imbanking and Draining*, pp. 419 *et seq.* (2nd ed., London, 1772); Marratt, *History of Lincolnshire*, vol. i. pp. 138–146, and vol. ii. pp. 187–189 (Boston, 1814–16); and P. Thompson, *History of Boston*, pp. 625–636. For the Welland Fens, Dugdale, *op. cit.*, pp. 391 *et seq.* And for the Bedford Level, see *Fenland Notes and Queries*, 1894, pp. 355–359; 1895, pp. 8–10, 52–56, 119–122 (Peterborough); and M. Noble, *Memoirs of the Protectoral House of Cromwell*, pp. 107–108 (Birmingham, 1787).

4 See Marratt, *loc. cit.*

5 See W. H. Wheeler, *A History of the Fens of South Lincolnshire*, pp. 223 *et seq.* (Boston, 2nd ed., [1897]).

6 W. H. Wheeler, *op. cit.*, pp. 298 *et seq.*; and for a list of the Acts of Parliament authorizing the various drainage schemes, see *Fenland Notes and Queries*, 1894, pp. 366–370.

7 See also S. Wells, *History and Drainage of the Great Level of the Fens*, 2 vols. (London, 1828 and 1830); W. Elstobb, *A Historical Account of the Great Level* (Lynn, 1793); Moore, *Associated Architectural Societies' Reports and Papers* (1893); Miller and Skertchly, *op. cit.*, pp. 158 *et seq.*; and *Fenland Notes and Queries* (1893 and following years).

8 By Leland (*Itinerary*, vol. vii. p. 41), and in Jean Ingelow's *High Tide on the Lincolnshire Coast.*

that vessels drawing nearly 3000 feet can now steam up to the docks of the town.[1] The Welland, which is about 40 miles long, and drains an area of 760 square miles, was made to assume its present shape and direction in 1620, 1638, 1650, 1794, and 1835 and following years.[2] The most radical alteration took place in 1794, when a new outfall was made from the confluence of the Glen (30 miles long) to the Wash, a distance of nearly 3 miles. The Nene, 100 miles long, and draining an area of some 1005 square miles, was first regulated by Bishop Morton (of Peterborough) between the years 1478 and 1490, and it was further improved in 1631, 1721, and especially, under plans by Rennie and Telford, in 1827–30 and 1832.[3] The work done in the years last quoted (1721 onwards) consisted in straightening the lower reaches of the stream and in directing and deepening the outfall. The Great Ouse, which has a length of over 140 miles, and drains an area of 2605 square miles, seems to have been deflected, at some unknown period, from a former channel connecting *viâ* the Old Croft river with the Nene, into the Little Ouse[4] below Littleport; and the courses of the two streams are now linked together by an elaborate network of artificial drains, the results of the great engineering works carried out in the Bedford Level in the 17th century. The salient features of the plan executed by Vermuyden[5] for the Earl of Bedford in the years 1632–53 were as follows:—Taking the division of the area made in 1697–98 into (i) the North Level, between the river Welland and the river Nene; (ii) the Middle Level, between the Nene and the Old Bedford river (which was made at this time, *i.e.*, 1630); and (iii) the South Level, from the Old Bedford river to the south-eastern border of the fenland. In the North Level the Welland was embanked, the New South Eau, Peakirk Drain, and Shire Drain made, and the existing main drains deepened and regulated. In the Middle Level the Nene was embanked from Peterborough to Guyhirn, also the Ouse from Earith to Over, both places at the south-west edge of the fenland; the New Bedford river was made from Earith to Denver, and the north side of the Old Bedford river and the south side of the New Bedford river were embanked, a long narrow "wash," or overflow basin, being left between them; several large feeding-drains were dug, including the Forty Foot or Vermuyden's Drain, the Sixteen Foot river, Bevill's river, and the Twenty Foot river; and a new outfall was made for the Nene, and Denver sluice (to dam the old circuitous Ouse) constructed. In the South Level Sam's Cut was dug and the rivers were embanked.[6] Since that period the mouth of the Ouse has been straightened above and below King's Lynn (1795 to 1821), a new straight cut made between Ely and Littleport, the North Level Main Drain and the Middle Level Drain constructed, and the meres of Ramsey, Whittlesea (1851–52), &c., drained and brought under cultivation.[7] The effect of all these drainage schemes has been to lower the level of the fenlands generally by some 18 inches, owing to the shrinkage of the peat consequent upon the extraction of so much of its contained water; and this again has tended, on the one hand, to diminish the speed and erosive power of the fenland rivers, and, on the other, to choke up their respective outfalls with the sedimentary matters which they themselves sluggishly roll seawards.

The Wash.—From this it will be plain that the Wash, although 24 miles long by 12 miles wide, is being slowly but gradually overtaken by the fate which has already come upon the rest of the once considerably greater bay; namely, it is being silted up by riverine detritus. Its floor is already thickly beset with sandbanks, many of them fixed and permanent, and showing 8 to 15 feet above low water, but several of them constantly shifting, and so diverting the interlacing and often antagonistic currents of the rivers. Through these sandbanks there are two main channels into deep water; one, Boston Deeps, is kept open by the conjoint waters of the Witham and the Welland; the other, Lynn Deeps, gives passage to the waters of the Nene and the Great Ouse. The formation of new dry land, known at first as "marsh," goes on however but slowly. During the sixteen or seventeen hundred years which have elapsed since the Romans are believed to have constructed the sea-banks which shut out the ocean, it is computed that an area of not more than 60,000 to 70,000 acres has been won from the Wash, embanked, drained, and brought more or less under cultivation. The greatest gain has been at the direct head of the bay, between the Welland and the Great Ouse, where the average annual accretion is estimated at 10 to 11 lineal feet. On the Lincolnshire coast, farther north, the average annual gain has been not quite 2 feet; whilst on the opposite, Norfolk coast, it has been little more than 6 inches annually. On the whole some 35,000 acres were inclosed in the 17th century, about 19,000 acres during the 18th, and about 10,000 acres during the 19th century.[8]

The first comprehensive scheme for regulating the outfall channels and controlling the currents of the Fen rivers seems to be that proposed by Nathaniel Kinderley in 1751. His idea[9] was to link the Nene with the Ouse by means of a new cut to be made through the marshland, and guide the united stream through a further new cut "under Wotten and Wolverton through the Marshes till over against Inglesthorp or Snetsham, and there discharge itself immediately into the Deeps of Lyn Channel." In a similar way the Witham, "when it has received the Welland from Spalding," was to be carried "to some convenient place over against Wrangle or Friskney, where it may be discharged into Boston Deeps." This scheme was still further improved upon by Sir John Rennie, who, in a report which he drew up in 1839, recommended that the outfalls of all four rivers should be directed by means of fascined channels into one common outfall, and that the land lying between them should be inclosed as rapidly as it consolidated. By this means he estimated that 150,000 acres would be won to cultivation. But beyond one or two abortive or half-hearted attempts, *e.g.*, by the Lincolnshire Estuary Company in 1851, and in 1876 and subsequent years by the Norfolk Estuary Company, no serious effort has ever been made to execute either of these schemes.

Climate.—The annual mean temperature, as observed at Boston, in the period 1864–85, is 48·7° F.; January, 36·5°; July, 62·8°; and as observed at Wisbech, for the period 1861–75, 49·1°. The average mean rainfall for the seventy-one years 1830–1900, at Boston, was 22·9 inches;[10] at Wisbech for the fifteen years 1860–75, 24·2 inches,[11] and for the fifteen years 1866–80, 26·7 inches; and at Maxey near Peterborough, 21·7 for the nineteen years 1882–1900.[12] Previous to the drainage of the Fens, ague, rheumatism, and other ailments incidental to a damp climate were widely prevalent, but at the present day the Fen country is as healthy as the rest of England; indeed, there is reason to believe that it is conducive to longevity.[13]

Historical Notes.—The earliest inhabitants of this region of whom we have record were the British tribes of the Iceni confederation; the Romans, who subdued them, called them Coriceni or Coritani. In Saxon times the inhabitants of the Fens were known (*e.g.*, to Bede) as Gyrvii, and are described as traversing the country on stilts. Macaulay, writing of the year 1689, gives to them the name of Breedlings, and describes them as "a half-savage population . . . who led an amphibious life, sometimes wading, sometimes rowing, from one islet of firm ground to another." In the end of the 18th century those who dwelt in the remoter parts were scarcely more civilized, being known to their neighbours by the expressive term of "Slodgers." And yet these rude fen-dwellers have in all ages been animated by a tenacious love of liberty. Boadicea, queen of the Iceni, the worthy foe of the Romans; Hereward the Saxon, who defied William the Conqueror; Cromwell and his Ironsides, are representative of the fenman's spirit at its best. And the Fen peasantry showed a stubborn defence of their rights, not only when they resisted the encroachments and selfish appropriations of the "adventurers" in the 17th century, in the Bedford Level, in Deeping Fen, and in the Witham Fens, and again in the 18th century, when Holland Fen was finally inclosed, but also in the Peasants' Rising of 1381, and in the Pilgrimage of Grace in the reign of Henry VIII. So long as the Fens were uninclosed and thickly studded with immense "forests" of reeds, and innumerable marshy pools and "rows" (channels connecting the pools), they were a very paradise of wild fowl, being regularly frequented by various species of wild duck and geese, garganies, polchards, shovelers, teals, widgeons, peewits, terns, grebes, coots, water-hens, water-rails, red-shanks, lapwings, godwits, whimbrels, cranes, bitterns, herons, swans, ruffs and reeves.[14]

---

[1] Thompson's *Boston*, pp. 353–368; Wheeler's *Fens of South Lincolnshire*, pp. 365–370; and Chapman, *Facts and Remarks*, pp. 8 *et seq.*

[2] Wheeler, pp. 295 *et seq.*

[3] Miller and Skertchly, *Fenland*, pp. 187–203; Wells, *History of Great Level*, pp. 20 *et seq.*, 682 *et seq.*, and 705 *et seq.*

[4] Dugdale, *History of Imbanking*, pp. 394–396.

[5] The principles upon which he proceeded are set forth in his *Discourse touching the Draining of the Great Fennes* (1642), reprinted in *Fenland Notes and Queries* (1898), pp. 26–38, and 81–87.

[6] See Dugdale, *History of Imbanking*, p. 410, &c.; Wells, *Great Level*, pp. 103 *et seq.*

[7] See Wells, pp. 755 *et seq.*

[8] It is interesting to compare with these data the vastly greater reclamations made in the Netherlands (see article HOLLAND), and the losses and gains, as betwixt land and sea, which have been made in the Frisian Islands.

[9] Set forth in *The Present State of the Navigation of the Towns of Lyn, Wisbeach, Spalding, and Boston* (2nd ed., London, 1851), p. 82 *et seq.*

[10] By Mr W. H. Wheeler, in *Fenland Notes and Queries*, April 1901, p. 47.

[11] For fuller particulars see Miller and Skertchly, *op. cit.*, pp. 226–290.

[12] *Fenland Notes and Queries*, 1901, p. 47.

[13] See Wheeler, *op. cit.*, p. 487 *et seq.*

[14] See Thompson's *Boston*, pp. 675–678, where are further references to Pennant, Drayton, Fuller, and other older writers; Wheeler, pp. 471–475; and Miller and Skertchly, pp. 362–388.

Vast numbers of these were taken in decoys,[1] and sent to the London markets. At the same time equally vast quantities of tame geese were reared in the Fens, and driven by road[2] to London to be killed at Michaelmas. Their down, feathers, and quills (for pens) were also a considerable source of profit. The Fen waters, too, abounded in fresh-water fish, especially pike, perch, bream, tench, rud, dace, roach, eels, and sticklebacks. The Witham, on whose banks so many monasteries stood, was particularly famous for its pike; as were certain of the monastic waters in the southern part of the Fens for their eels.[3] The soil of the reclaimed Fens is of exceptional fertility, being almost everywhere rich in humus, which is capable not only of producing very heavy crops of wheat and other corn, but also of fattening live-stock with peculiar ease. Lincolnshire oxen were famous in Elizabeth's time,[4] and are specially singled out by Arthur Young,[5] the breed being the shorthorn. Of the crops peculiar to the region it must suffice to mention the old British dye-plant woad, which is still grown on a small scale in two or three parishes immediately south of Boston; hemp, which was extensively grown in the 18th century,[6] but is not now planted; and peppermint, which is occasionally grown, *e.g.*, at Deeping and Wisbech. In the second half of the 19th century the Fen country acquired a certain celebrity in the world of sport from the encouragement it gave to speed skating. Whenever practicable, championship and other racing meetings are held, chiefly at Littleport and Spalding. The little village of Welney, between Ely and Wisbech, has produced some of the most notable of the typical Fen skaters, *e.g.*, "Turkey" Smart and "Fish" Smart.[7]

Apart from fragmentary ruins of the former monastic buildings of Crowland, Kirkstead, and other places, the Fen country of Lincolnshire (division of Holland) is especially remarkable for the size and beauty of its parish churches, which, in many cases, are crowned by lofty and graceful spires. Amongst the finest of these churches, mostly built of Barnack rag from Northamptonshire, may be mentioned Boston, Kirton, Donington, Swineshead, Gosberton, Pinchbeck, Spalding, Moulton, Holbeach, Gedney, Whaplode, and Long Sutton.[8] Using these fine opportunities, the Fen folk have long cultivated the science of campanology.

Dialect.—Owing to the comparative remoteness of their geographical situation, and the relatively late period at which the Fens were definitely inclosed, the Fenmen have preserved several dialectal features of a distinctive character, not the least interesting being their close kinship with the classical English of the present day.[9] It was the late Professor E. Freeman[10] who reminded modern Englishmen that it was a native of the Fens, "a Bourne man, who gave the English language its present shape." This was Robert Manning, or Robert of Brunne, who in or about 1303 wrote *The Handlynge Synne.* Tennyson's dialect poems, *The Northern Farmer*, &c., do not reproduce the pure Fen dialect, but rather the dialect of the Wold district of Mid Lincolnshire.

Authorities.—In addition to the works already quoted, see the bibliographies printed as an appendix to *Lincs. N. and Q.*, vol. ii. pp. 27–31 (1890–91); W. H. Wheeler, *Fens of South Lincolnshire*, Appendix ii.; and in *Fenland N. and Q.*, vol. iii. pp. 28–29 (1895). For a discussion of the general principles of draining low-lying lands like the Fens, see River Engineering. Various phases of Fen life, mostly of the past, are described in Charles Kingsley's *Hereward the Wake* (Cambridge, 1866), Baring Gould's *Cheap-Jack Zita* (London, 1893), Manville Fenn's *Dick o' the Fens* (London, 1887), and J. T. Bealby's *A Daughter of the Fen* (London, 1896).

(J. T. Be.)

Fenton, a township adjoining the east side of Stoke-upon-Trent (in which parliamentary division it is included), Staffordshire, England, on the North Staffordshire railway. There is a town hall (1889). The principal industry is the manufacture of earthenware. Area of urban district, 1748 acres. Population (1881), 13,830; (1901), 22,742. The area of the civil parish is 1726 acres; population (1881), 14,136; (1891), 17,323.

Ferdinand, Maximilian Karl Leopold Maria, Prince of Bulgaria (1861——), fifth and youngest son of Prince Augustus of Saxe-Coburg and Gotha, was born 26th February 1861. Great care was exercised in his education, and every encouragement given to the taste for natural history which he exhibited at an early age. In 1879 he travelled with his brother Augustus to Brazil, and the results of their botanical observations were published at Vienna, 1883–88, under the title of *Itinera Principum S. Coburgi.* Having been appointed to a lieutenancy in the 2nd regiment of Austrian hussars, he was holding this rank when, by unanimous vote of the National Assembly, he was elected prince of Bulgaria, 7th July 1887, in succession to Prince Alexander, who had abdicated on the 7th of September preceding. He assumed the government 14th August 1887, but Russia for a long time refused to acknowledge the election, and he was accordingly exposed to frequent military conspiracies, due to the influence or attitude of that Power. The firmness and vigour with which he met all attempts at revolution were at length rewarded, and his election was confirmed in March 1896 by the Porte and the great Powers. On 20th April 1893 he married Marie Louise de Bourbon, eldest daughter of Duke Robert of Parma, and in May following the Grand Sobranjé confirmed the title of Royal Highness to the prince and his heir. The prince adheres to the Roman Catholic faith, but his son and heir, the young Prince Boris, was received into the Orthodox Greek Church, 14th February 1896. The latter, who is the godson of Tsar Nicholas III., accompanied his father to Russia in 1898, when Prince Ferdinand visited St Petersburg and Moscow, and still further strengthened the bond already existing between Russia and Bulgaria. The prince is a widower, having lost his consort 31st January 1899. (See also Bulgaria.)

Fergana, a province of Russian Turkestan, formed in 1876 out of the former khanate of Kokand. It is bounded by the Russian provinces of Syr-daria on the N. and N.W., and Semiryechensk on the N.E., China (Kashgaria) on the E., and the Bokhara and Afghanistan bekdoms of Vakhan, Shugnan, Darvaz, and Karateghin, and the Russian province of Samarkand on the S. Its southern limits, on the Pamirs, were established by an international commission, from Lake Zor-kul (Victoria) to the Chinese frontier, while the Shugnan, the Roshan, and the Vakhan were given, in consequence of an agreement between Great Britain and Russia, to Bokhara, in exchange for part of Darvaz (on the left bank of the Panj), which was assigned to Afghanistan. The area is about 57,000 square miles, of which about 17,600 square miles are on the Pamirs. It occupies the rich and fertile valley of the upper Syr and Naryn, which opens towards the south-west, and it extends northwards over the mountains of the Tian Shan system, while in the south it spreads over

[1] For descriptions of these see Oldfield, Appendix, pp. 2–4, of *A Topographical and Historical Account of Wainfleet* (London, 1829); and Miller and Skertchly, pp. 369–375.

[2] See De Foe's account in *A Tour through the Eastern Counties, 1722* (1724–25).

[3] See, for the fauna generally, Miller and Skertchly, pp. 321–412 and 591–634, and, for the fish, the same work, pp. 391–400; and consult Thompson's *Boston*, pp. 674–683, and Wheeler's *Fens of South Lincolnshire*, pp. 477–484.

[4] See John Fletcher's *Fair Maid of the Inn* (1616) and *Love's Pilgrimage* (1618).

[5] *General View*, pp. 174–194 and 288–304.

[6] *Ib.*, pp. 149–161. For lists of the botanical species found in the Fens, see Miller and Skertchly, pp. 298–306; Thompson's *Boston*, pp. 684–689; and White's *Lincolnshire* (Sheffield, 1892–93), pp. 42–63; and compare *Lincolnshire Notes and Queries*, Supplements to the years 1893–97 inclusive.

[7] See N. and A. Goodman, *Handbook of Fen Skating* (London, 1882).

[8] See Murray's *Handbook to Lincolnshire* (London, 1890), pp. [17] to [25], by the Rev. G. E. Jeans.

[9] Lists of dialect words and provincialisms are printed in Thompson's *Boston*, pp. 698–733; Miller and Skertchly, pp. 126–131; *Fenland N. and Q.*, vol. i. pp. 48, 88, 151 (1889–91); vol. ii. pp. 97, 135, 180, 272, 326, 359, 392 (1892–94); vol. iii. pp. 21, 78, 167, 201, 248, 258, 347 (1895–97); and vol. iv. pp. 87, 122, 139, 179, 213 (1898–1900); Wheeler, Appendix iv.; and compare Streatfeild, *Lincolnshire and the Danes*, pp. 314–377 (London, 1884); E. Peacock, *Glossary of Words used in . . . Lincolnshire*, 2 vols. (London, 1889); R. E. G. Cole, *Glossary of Words in Use in South-West Lincolnshire* (London, 1886); J. E. Brogden, *Provincial Words current in Lincolnshire* (Lincoln, 1866).

[10] In *Longman's Magazine*, 1875.

the Alai and Transalai Mountains, including also a portion of the Pamirs. The valley is thus surrounded by a ring of high mountains, reaching their highest altitude in Peak Kaufmann (23,000 feet).

Two rivers, rising in the mountains, water the valley—the Naryn and the Kara-daria, which, by their confluence near Namangan, form the Syr. This latter, by the numerous irrigation canals drawn from it, gives life to the valley; but it receives also many small affluents, which bring down great masses of sand, which is deposited along its banks, especially where it pierces the Khojent-Ajar ridge (Karakchi-kums). Here nearly 750 square miles are covered with moving sands, which invade under the influence of the prevailing south-west winds the agricultural districts.

The climate of the valley is dry and warm. In March the temperature reaches 68° F., rapidly rising to 95° in June, July, and August. For five months, from May, there is no rain, which begins to fall in October. Snow and frosts occur in December and January and occasionally in February. All the fertility of the valley is thus dependent on irrigation.

The population in 1897 was 1,560,411, of whom 707,132 were women, and 286,369 lived in towns. Two-thirds of the people are Sarts (of Turkish origin), who mostly live in the valley, while Kirghiz, partly nomad and partly agricultural, occupy the slopes of the mountains. Tajiks are not numerous, and are scattered everywhere. There are, besides, some Dungans, Kipchaks, Jews, and Tsiganes. On the Pamirs the population was only 2348. The Russians belong to the ruling, merchant, and artizan class, and have only one agricultural settlement. The mass of the population (1,039,115) are Musulmans, and only 3985 belong to the Russian Church.

Of the 2,563,100 acres of cultivated land, 1,936,700 acres are under constant and the remainder under partial irrigation. The land is admirably cultivated, and the crops in 1896 were: wheat, 3,223,000 cwts.; rice, 1,277,000; *jugara*, 2,395,000; millet, 388,000; various, 1,606,000. Lucerne, tobacco, root plants, and all sorts of vegetables are grown in large quantities. Tobacco is exported. Gardening reaches a high degree of perfection. The number of cattle kept by the agricultural population is very great (198,530 horses, 266,700 cattle, 402,200 sheep, 7145 camels). Moreover, the nomads, who graze their cattle on the alpine meadows, keep 113,600 horses, 122,200 cattle, 626,500 sheep, and 16,000 camels. No less than 17,300 acres are under vineyards (yielding 460,000 cwts. of grapes) and 347,500 acres under cotton, the crop of which in 1896 attained to 2,203,000 cwts. Nearly the whole of this (2,006,200 cwts.) was American cotton, which was mostly cleaned within the province, representing an income of £1,300,000. The remainder was transformed into about 660,000 cwts. of cotton wool, worth about £200,000. Nearly 150,000 acres are under forests belonging to the Crown. The state keeps at Marghilan a forestry farm, from which from 120,000 to 200,000 young trees are given free every year to the population. The silkworm culture, formerly prosperous, has decayed, notwithstanding the efforts of a state farm at Novo-Marghilan. The total income from this source was estimated at about £48,000 in 1896. Naphtha, coal, sulphur, gypsum, rock-salt and lake-salt are known to exist, but only the latter is extracted. The aggregate production of all factories, chiefly sixty-nine cotton-cleaning works, reached £112,500 in 1896, and the small factories and workshops (9000 in number) showed a return of £150,000. A considerable trade is carried on with Russia for the export of raw cotton, raw silk, hides, sheepskins, and some cotton and leather goods, and the import of various manufactured goods, which are exported to Kashgaria and Bokhara.

The Transcaspian railway has given a fresh impetus to trade. As to the routes leading to the Pamirs and Kashgaria they are mere bridle paths crossing the mountains. Two passes, Karakazyk (14,400 feet) and Tenghiz-bai (11,200 feet), which are open all the year, lead from Marghilan to Karateghin and the Pamirs, while Kashgar is reached from Osh to Gulcha, and then across the passes Terek-davan (13,000 feet; open all the year), Taldyk (11,600), Archat (11,600), and Shart-davan (about 14,000 feet).

Only 347 boys and girls received education in Russian schools in 1896, and 14,072 in the native and Russian-native schools.

A railway now enters the province from Kokand, reaching Andijan, while a branch runs south to New Marghilan and Kuva.

The province is divided into five districts, of which the chief towns are: New Marghilan, capital of the province (8977 inhabitants), Andijan (46,680), Kokand (82,054), Namangan (61,906), and Osh (36,474). To these Old Marghilan (36,592) and Chust (13,686) must be added. (P. A. K.)

Fergus Falls, capital of Ottertail County, Minnesota, U.S.A., on the Red river and on two railways. It has fine water power, which is utilised for flour mills. Population (1890), 3772; (1900), 6072, of whom 2131 were foreign-born.

Ferguson, Sir Samuel (1810–1886), Irish antiquarian and poet, was born at Belfast, 10th March 1810. He went to the bar, and was made Q.C. in 1859, but in 1867 retired from practice upon his appointment as deputy-keeper of the Irish records, then in a much neglected condition. All causes of complaint were removed during his administration. His spare time was given to general literature, and in particular to poetry. He had long been a leading contributor to the *Dublin University Magazine* and to *Blackwood*, where he had published his two literary masterpieces, "The Forging of the Anchor," one of the finest of modern ballads, and the humorous extravaganza of "Father Tom and the Pope." He published volumes of miscellaneous poems in 1865 and 1880, and in 1872 "Congal," a metrical narrative of the heroic age of Ireland, and, though far from ideal perfection, perhaps the most successful attempt yet made by a modern Irish poet to revivify the spirit of the past in a poem of epical proportions. Lyrics have succeeded better in other hands; many of Ferguson's pieces on modern themes are, nevertheless, excellent. He was an extensive contributor on antiquarian subjects to the *Transactions of the Royal Irish Academy*, and was elected its president in 1882. His manners were delightful, and his hospitality was boundless. He died at Howth on 9th August 1886. (R. G.)

Fergusson, James (1808–1886), an eminent Scottish writer on architecture, was born at Ayr on the 22nd of January 1808. His father was an army surgeon with advanced views (for his day) on the hygiene and construction of hospitals, and thus the son may have inherited a capacity for the study of plan and construction. But the bent of his life was probably decided when he went to Calcutta as partner in a mercantile house. Here he was attracted by the remains of the ancient architecture of India, little known or understood at that time. This he studied, illustrating and classifying it in his book on *The Rock-cut Temples of India*, published in 1845. The task of analysing the historic and æsthetic relations of this type of ancient buildings led him to undertake a historical and critical comparative survey of the whole subject of architecture, a work which first appeared in 1855 under the title of *The Handbook of Architecture*. Although this was in itself a remarkable survey of so wide and complex a subject, it did not satisfy him, and the work was reissued ten years later in a much more extended form under the title of *The History of Architecture*. The chapters on Indian architecture, which had been considered at rather disproportionate length in the *Handbook*, were removed from the general *History*, and the whole of this subject treated more fully in a separate volume, *The History of Indian and Eastern Architecture*, which appeared in 1876, and formed a kind of appendix to the *History of Architecture*, although complete in itself. Previously to this, in 1862, he issued his *History of Modern Architecture*, in which the subject was continued from the Renaissance to the present day, "modern architecture" being distinguished as the period of revivals and imitations of ancient styles, which began with the Renaissance. The essential difference between this and the spontaneously evolved architecture of preceding ages Fergusson was the first clearly to point out and characterize. His treatise on *The True Principles of Beauty in Art*, an early publication which attracted little notice at the time, is nevertheless one of the best and most thoughtful of the class of metaphysical studies to which it belongs. Some of his essays on special points in archæology, such as the treatise on *The Mode in which Light was introduced into Greek Temples*, and his *Notes on the Site of the Holy Sepulchre*, included theories which have not received general acceptance. His real monument is his *History of Architecture*, which, for grasp of the whole subject, comprehensiveness of plan, and thoughtful critical analysis, stands quite alone in architectural literature; nor has any other country produced a book comparable with it. His breadth and impartiality of view are especially remarkable. A French or German treatise on architecture, historical or æsthetic, always represents the subject from a French or German point of view; but Fergusson is absolutely cosmopolitan in his standpoint. He received the gold medal of the Royal Institute of British Architects in 1871. Among his works, besides those already mentioned, are: *A Proposed New System of Fortification* (1849), *Palaces of Nineveh and Persepolis restored* (1851), *Mausoleum at Halicarnassus restored* (1862), *Tree and Serpent Worship* (1868), *Rude Stone Monuments in all Countries* (1872), and *Temples of the Jews and other Buildings in the Haram Area at Jerusalem* (1878). The sessional papers of the Institute of British Architects include papers by him on *The History of the Pointed Arch*, *Architecture of Southern India*, *Architectural Splendour of the City of Beejapore*, *On the Erechtheum* (an exceedingly interesting paper), and on the *Temple of Diana at Ephesus*.

Although Fergusson never practised, he took a keen interest in all the professional work of his time. He was adviser with Mr (afterwards Sir) Austen Layard in the scheme of decoration for the Assyrian Court at the Crystal Palace, and indeed assumed in 1856 the duties of General Manager to the Palace Company, a post which he held for two years. Moreover, he was largely instrumental in establishing the Palestine Exploration Fund. His manifold activities continued till his death, which took place in London on 8th January 1886. (H. H. S.)

Fermanagh, an inland county of Ireland, province of Ulster, bounded on the N. by Donegal and Tyrone; on the E. by Tyrone and Monaghan; on the W. by Cavan and Leitrim; and on the S. by Cavan. The area of the administrative county in 1900 was 417,665 acres, of which 98,287 were tillage; 249,574, pasture; 83, fallow; 5777, plantation; 18,680, turf bog; 1774, marsh; 21,196, barren mountain; and 22,294, water, roads, fences, &c. The new administrative county under the Local Government (Ireland) Act, 1898, is identical with the old judicial county. The population in 1881 was 84,879; and in 1891, 74,170, of whom 37,344 were males, and 36,826 females, divided as follows among the different religions: Roman Catholics, 41,102; Protestant Episcopalians, 26,869; Presbyterians, 1312; Methodists, 4779; and other denominations, 108. The decrease of population between 1881 and 1891 was 12·62. The average number of persons to an acre was ·16. Of the total, 68,600 inhabited the rural districts, being an average of 127 persons to each square mile under crops and pasture. In 1901 the population was 65,243 (Roman Catholics, 36,066; Protestant Episcopalians, 23,109; Presbyterians, 1269; Methodists, 4702; others, 97), being a decrease of 12·0 per cent.

The following table gives the number of births, deaths, and marriages in various years:—

Year.	Births.	Deaths.	Marriages.
1881	1569	1203	287
1891	1392	1245	294
1899	1306	1095	270

In 1899 the birth-rate per 1000 was 17·6, and the death-rate 14·8; the rate of illegitimacy was 2·9 per cent. of the total births. The total number of emigrants who left the county between 1st May 1851 and 31st December 1899 was 53,895, of whom 27,642 were males and 26,253 females. Enniskillen (5570 in 1891) is the only town with a population of over 1000.

Education.—The following table gives the degree of education in 1891:—

	Males.	Females.	Total.	Percentage.			
				R. C.	Pr.Ep.	Presb.	Meth.
Read and write	24,723	22,980	47,703	62·9	72·2	88·1	89·2
Read only .	4,035	5,394	9,429	16·6	11·5	6·9	7·3
Illiterate .	5,164	5,214	10,378	20·5	10·3	5·0	3·5

The percentage of illiterates among Roman Catholics in 1881 was 28·2. In 1891 there was one superior school with 102 pupils (all Protestants except one), and there were 190 primary schools, with 9486 pupils (Roman Catholics 5077, and Protestants 4409). The number of pupils on the rolls of the national schools on 30th September 1899 was 11,352, of whom 6329 were Roman Catholics and 5023 Protestants.

Administration.—The county is divided into two parliamentary divisions, north and south, the number of registered electors in 1900 being respectively 5242 and 5622. The rateable value in 1900 was £241,360. By the Local Government (Ireland) Act, 1898, the fiscal and administrative duties of the grand jury and (to a less extent) of other bodies were transferred to a county council; urban and rural district councils were established; and under that Act the county now comprises one urban and five rural sanitary districts.

Agriculture.—The following tables give the acreage under crops, including meadow and clover, and the amount of live stock, in 1881, 1891, 1895 and 1900.

Year.	Wheat.	Oats.	Barley, Beans, &c.	Potatoes.	Turnips.	Other Green Crops.	Flax.	Meadow and Clover.	Total.
1881	579	23,252	295	16,353	3097	1788	3323	57,752	106,439
1891	872	19,676	400	15,401	3081	1985	1455	65,083	107,953
1895	491	19,149	226	14,434	3127	1647	1610	64,251	104,935
1900	789	16,120	216	13,056	2713	1594	268	63,531	98,287

In 1899 the total value of the cereal and other crops was estimated by the Registrar-General at £652,280. The number of acres under pasture in 1881 was 235,423; in 1891, 239,003; and in 1900, 249,574.

Year.	Horses and Mules.	Asses.	Cattle.	Sheep.	Pigs.	Goats.	Poultry.
1881	7075	4088	91,780	6,691	16,851	4411	390,969
1891	8283	4547	102,731	18,742	24,843	5450	439,611
1895	8611	4837	98,398	11,116	23,981	4746	480,555
1900	7609	4854	98,639	11,942	20,150	4702	517,813

The number of milch cows in 1891 was 41,125, and in 1900, 39,572. It is estimated that the total value of cattle, sheep, and pigs in 1899 was £1,290,668. In 1900 the number of holdings not exceeding 1 acre was 767; between 1 and 5, 1047; between 5 and 15, 3414; between 15 and 30, 4204; between 30 and 50, 2328; between 50 and 100, 1273; between 100 and 200, 355; between 200 and 500, 82; and above 500, 12;—total, 13,482. The number of loans issued (the number of loans being the same as the number of tenants) under the Land Purchase Acts, 1885, 1891, and 1896, up to 31st March 1900, was 1785, amounting to £531,351. The number of loans for agricultural improvements, sanctioned under section 31 of the Land Act, 1881, between 1882 and 1900 was 181, and the amount issued was £9815. The total amount issued on loan for all classes of works, under the Land Improvement Acts, from the commencement of operations in 1847 to 31st March 1900, was £87,158. (W. H. Po.)

Fernando Po, a Spanish island off the west coast of Africa, about 20 miles from the mainland, facing the Kamerun coast. About 44 miles from N. to S., and 20 miles broad, it has an area of 760 square miles; the population in 1887 was 30,000. The capital, Santa Isabel, was said to have 1284 inhabitants in 1885: 170 whites, 31 half-breeds, and 1082 negroes. The island is now administered by a governor, generally an officer of rank in the Spanish navy, who is at the same time commandant of the naval station in the Gulf of Guinea, as which part of his duty is to superintend the sub-governor of the island of Elobey Chico, and the Spanish agents in Annobon, Elobey Grande, and the mainland between the Campo and Muni rivers. The Spanish claim to rule on the mainland from the Campo to the Gabun has often caused considerable friction between the Spanish and French Governments. After very protracted negotiations on the matter, a mixed delimitation commission was appointed, and the respective territorial rights were partly defined by a treaty in 1885. The French again began encroaching, despite Spanish protests; but at last the limits of the Spanish sphere of influence were definitely fixed in June 1900, when, in return for concessions in the Adrar country, France acknowledged Spain's right to the country from the Campo river and the Cameroon frontier as far south as the Muni river—some 75 miles. Inland, Spanish authority is to extend about 110 miles, the eastern boundary being fixed along, roughly, 11° 30′ E. long.

Spain keeps an old and badly-equipped war vessel and a few companies of marines to assert her rights in Fernando Po and its mainland dependencies and other isles. The cost of maintaining her rule is £20,500 a year, of which three-quarters are assigned to army, navy, and civil services, barely a quarter going to public works and other useful expenditure. The governor rules the island with a council of officials. Public education is in the hands of the Father of the Immaculate Heart of Mary order. Long neglected by its Spanish rulers, Fernando Po has excited more interest in the peninsula since the Spaniards awoke to the fact that other European nations were casting longing eyes at a colony of strategical, naval, and commercial importance, the latter through an increasing trade in the hands of foreigners. The exports of Fernando Po exceeded £200,000 in 1899, and the area of cultivation in the island increased from 4190 acres in the seventies to 15,000 acres in 1899. Negro labourers drawn from Lagos and other British West African colonies chiefly contributed to the development of the resources of the island.

Ferozepore, or **Firozpur,** a city and district of British India, in the Jullundur division of the Punjab. The city is a railway junction connecting the North-Western and Rajputana railways, and is situated about 4 miles from the present south bank of the Sutlej. The population in 1881 was 39,570, in 1891 it was 50,437; the municipal income in 1897–98 was Rs. 44,681. The arsenal is the largest in India. The District comprises an area of 4302 square miles. It had a population in 1881 of 747,329, and in 1891 of 886,676, giving an average density of 206 persons per square mile. In 1901 the population was 958,218, showing an increase of 8 per cent. The land revenue and rates were Rs. 11,34,911, the incidence of assessment being a little over 8 annas per acre; the cultivated area in 1896–97 was 1,009,006 acres, of which 756,401 were irrigated, including 536,808 from government canals; the number of police was 670; the number of schools in 1896–97 was 210, with 6337 pupils, the proportion of boys at school to the male population of school-going age being 7·6 per cent.; the registered death-rate in 1897 was 31·73 per thousand. There are four printing-presses, issuing one vernacular periodical. The district has 117 miles of railway, and the length of metalled roads is 97 miles. Distributaries of the Sirhind canal water the whole.

Ferrara, a fortified city and archiepiscopal see of Italy (Emilia), capital of the province of Ferrara, on a low, marshy site, $7\frac{3}{4}$ feet above sea-level, but 3 feet *below* the level of the Po, 3 miles distant, the town itself being on the Po di Volano, a southern arm of the Po delta. Under modern conditions of warfare the fortifications would count for little. There are fine law-courts (Palazzo della Ragione), a brick building in the Gothic style, dating from the 14th cent., but renewed in the 16th, and again in 1838. There are further statues to Savonarola (1875), who was born here, to Ariosto (1833), also a native, and to Victor Emmanuel (1890). The free university, with courses in law, medicine, and natural science, was attended in 1898 by 77 students, the number of professors being 22. Amongst the other educational institutions may be mentioned an engineering college, a musical academy, and a school of design (1882). The principal industry is the manufacture of clothing. Population of commune (1881), 75,553; (1901), 87,697; of province, (1881), 230,807; (1901), 271,467.

Ferrol, a seaport of Spain, 12 miles north-east of Corunna. Population in 1897, 24,957. Both the arsenal and dockyards have been much improved, and the defences seawards increased and mounted with heavy modern guns. A new dock was constructed in 1879, since when good quays have been constructed for the merchant vessels, and, in the new part of the town called Esteiro, for the coasting and smaller vessels. Private building yards have been recently established near the town, which has, indeed, been generally improved, notably in its public buildings—the town hall, palace of the naval captain-general for Ferrol, Cartagena, and Cadiz; prison, foundling hospital, theatres, casinos, bull-ring, and excellent schools of primary and secondary instruction. In 1898, 299 vessels of 140,638 tons entered, and the same number cleared. The principal exports were pit-wood, old iron and copper, cotton textiles, salt fish, and pyrites. The principal imports were coal (chiefly from England), cereals, cotton, flour, iron, olive oil, textiles, timber, and wines. The total exports in 1898 were valued at £48,946, imports at £273,553, as compared with £19,240 and £317,950 respectively in 1897.

An excellent relief plan of the fortifications of Ferrol, ancient and modern, exists in the Madrid Royal Engineers' Museum.

Ferry, Jules François Camille (1832–1893), French statesman, was born at Saint Dié, Vosges, 5th April 1832. In 1851 he went to the bar, and both as advocate and in the press he took an active part in opposition to the Second Empire. In 1869 he was elected for the Seine to the *Corps législatif*, and fought energetically against Ollivier. He was a member of the Government of National Defence after the revolution of 1870, and was entrusted by it with the administration of the Seine department; but, for all his energy, he was powerless against the Communards; he was even taken prisoner by them, but rescued. In 1872 he was sent by Thiers as minister to Athens, but returned in 1873. He joined the Republican Left, opposed the *Seize Mai*, and was a prominent and bitter fighter against clericalism. In 1879, after MacMahon's retirement, he became minister of education in M. Waddington's cabinet; and besides successfully reorganizing the Paris University, he brought forward the measure of March 1880, aimed at dissolving the "Jesuits' unauthorized religious associations." In September 1880 he became prime minister, and undertook an active colonial programme, including the extension of French influence over Tunis; but his ministry broke up in November 1881. In 1883, however, he again formed a cabinet, and, pursuing his colonial programme, authorized campaigns in Madagascar and Tongking, the latter of which, owing to the disaster at Langson in 1885, not only brought about his downfall, but ruined his popularity. In future he was to Frenchmen *le*

Tonkinois, and his influence was permanently damaged. In 1887 he was proposed for the Presidency on Grevy's retirement, but though assisted by the Monarchists, was beaten through M. Clemenceau's tactics in supporting an "outsider" rather than that he should succeed. It was not till 1891 that he recovered his position to some extent, being then elected senator for the Vosges, and two years later became president of the Senate. He died in Paris on 17th March 1893. Jules Ferry was a man of great administrative ability, but his name will inevitably be associated chiefly with his anti-clerical campaign and with the Tongking failure.

Fertö, an extensive lake in the western part of Hungary, between the counties of Moson and Sopron. The Romans knew it under the name of *Teiso*, and the Germans call it *Neusiedler-See*. Its surface (335 square kilomètres) frequently varies, and the lake is so shallow that it sometimes dries up in parts. Eastwards it is united with a marsh, called the *Hanság*. It has only a few tributaries. Its water has a taste of salt and alkali, and is much recommended for bathing. Among the reeds on its banks waterfowl congregate in vast numbers, and the fishing is also considerable. In several places of the dry bed traces of prehistoric lake-dwellings (pile-dwellings) have been discovered. Plans for drying up the lake have been proposed.

Festiniog, a town and parish of Merionethshire, Wales, at the head of Festiniog valley, standing at a height of over 600 feet above the sea, near the river Dwyryd, 19 miles W.N.W. of Bala by rail. There are many and large slate quarries in this extensive parish. The extension of the railway from Bettws-y-coed to Blaenau Festiniog in 1879 has given a great accession of life to the latter place, which, the centre of the slate quarries and the nucleus of three railways, is a modern town compared with Festiniog "the original village." The "toy" railway, as it is called, has a length of 13 miles from Portmadoc to Blaenau, with a rise of about 700 feet. Area of urban district, 16,323 acres; population (1881), 11,274; (1891), 11,073; (1901), 11,435.

Feuillet, Octave (1821–1890), French novelist and dramatist, was born at Saint-Lô, Manche, on the 11th of August 1821. He was the son of a Norman gentleman of learning and distinction, who would have played a great part in politics "sans ses diables de nerfs," as Guizot said. This nervous excitability was inherited, though not to the same excess, by Octave, whose mother died in his infancy and left him to the care of the hypersensitive invalid. The boy was sent to the Collège de Louis-le-Grand, in Paris, where he achieved high distinction, and was destined for the diplomatic service. In 1840 he appeared before his father at Saint-Lô, and announced that he had determined to adopt the profession of literature. There was a stormy scene, and the elder Feuillet cut off his son, who returned to Paris and lived as best he could by a scanty journalism. In company with Paul Bocage he began to write for the stage, and not without success; at all events, he continued to exist until, three years after the quarrel, his father consented to forgive him. Enjoying a liberal allowance, he now lived in Paris in comfort and independence, and he published his early novels, none of which are quite of sufficient value to retain the modern reader. The health and spirits of the elder M. Feuillet, however, having still further declined, he summoned his son to leave Paris and bury himself as his constant attendant in the melancholy château at Saint-Lô. This was to demand a great sacrifice, but Octave Feuillet cheerfully obeyed the summons in 1850, after printing his novel called *Bellah*. In 1851 he married his cousin, Mlle. Valérie Feuillet, who helped him to endure the mournful captivity to which his filial duty bound him. Strangely enough, in this exile—rendered still more irksome by his father's mania for solitude and by his tyrannical temper—the genius of Octave Feuillet developed. He wrote books which have held their place for half a century, *La Petite Comtesse*, *Dalila*, and in particular that universal favourite, *Le Roman d'un jeune Homme pauvre*. He himself fell into a nervous state in his "prison," but he was sustained by the devotion and intelligence of his wife and her mother. In 1857, having been persuaded to make a play of the novel of *Dalila*, he brought out this piece at the Vaudeville, and enjoyed a brilliant success; on this occasion he positively broke through the *consigne* and went up to Paris to see his play rehearsed. His father bore the shock of his temporary absence, and the following year Octave ventured to make the same experiment on occasion of the performance of *Un jeune Homme pauvre*. To his infinite chagrin, during this brief absence his father died. Octave was now, however, free, and the family immediately moved to Paris, where they took part in the splendid social existence of the Second Empire. The elegant and distinguished young novelist became a favourite at court; his pieces were performed at Compiègne before they were given to the public, and on one occasion the Empress Eugénie deigned to play the part of Mme. de Pons in *Les Portraits de la Marquise*. Feuillet did not abandon the novel, and in 1862 he achieved a great success with *Sibylle*. His health, however, had by this time begun to decline, affected by the sad death of his eldest son. He determined to quit Paris, where the life was far too exciting for his nerves, and to regain the quietude of Normandy. The old château of the family had been sold, but he bought a house called "Les Paillers" in the suburbs of Saint-Lô, and there he lived, buried in his roses, for fifteen years. He was elected to the French Academy in 1862, and in 1868 he was made librarian of Fontainebleau Palace, where he had to reside for a month or two in each year. In 1867 he produced his masterpiece of *Monsieur de Camors*, and in 1872 he wrote *Julia de Trécœur*, which is hardly less admirable. His last years, after the sale of "Les Paillers," were passed in a ceaseless wandering, the result of the agitation of his nerves. He was broken by sorrow and by ill-health, and when he passed away in Paris on December 29, 1890, his death was a release. His last book was *Honneur d'Artiste* (1890). Among the too-numerous writings of Feuillet, the novels have lasted longer than the dramas; of the former three or four seem destined to retain their charm as classics. He holds a place midway between the romanticists and the realists, with a distinguished and lucid portraiture of life which is entirely his own. He drew the women of the world whom he saw around him with dignity, with indulgence, with extraordinary penetration and clairvoyance. There is little description in his novels, which sometimes seem to move on an almost bare and colourless stage, but, on the other hand, the analysis of motives, of emotions, and of "the fine shades" has rarely been carried further. Few have written French with greater purity than Feuillet, and his style, reserved in form and never excessive in ornament, but full of wit and delicate animation, is in admirable uniformity with his subjects and his treatment. It is probably in *Sibylle* and in *Julia de Trécœur* that he can now be studied to most advantage, though *Monsieur de Camors* gives a greater sense of power, and though *Le Roman d'un jeune Homme pauvre* still preserves its popularity.

(E. G.)

Fever. See Pathology.

Fez (*Fás*), the most important city of Morocco, is situated about 150 miles, or six days by caravan, south of Tangier, and contains probably 150,000 inhabitants, including several thousand Jews. Progress has shown itself there by the establishment in 1888 of English lady missionaries, previous to which no foreigners resided in this capital, and subsequently of British and French vice-consulates. European visitors are now more frequent.

Fichte, Immanuel Hermann von (1797–1879), German philosopher, son of the famous J. G. Fichte, was born at Jena on the 18th of July 1796 or 1797 (authorities differ), and began life as a schoolmaster at Saarbrücken and at Düsseldorf. In 1836, having published some philosophical writings, he became extra-professor of Philosophy at Bonn, and in 1839 full professor. In 1842 he received a call to Tübingen; retired in 1863, when he was ennobled, and died at Stuttgart on the 8th of August 1879. Fichte's writings cover the whole field of philosophy. The titles of the most noteworthy are: *System der Ethik*, 2 vols. (1850–53), *Anthropologie* (1856), *Psychologie* (1864), *Die theistische Weltansicht* (1873). In 1837 he had founded the still-existing *Zeitschrift für Philosophie* as an organ of his views, more especially on the subject of philosophy of religion, where he was in alliance with Weisse. The difference between Weisse and Fichte is, that whereas Weisse thought that the Hegelian structure was sound in the main, and that its imperfections might be mended, Fichte held it to be incurably defective, and spoke of it as a "masterpiece of erroneous consistency or consistent error." Fichte's general views on philosophy seem to have changed considerably as he advanced in years, and his influence has been impaired by these inconsistencies and an appearance of eclecticism; an appearance strengthened by his predominantly historical treatment of problems, his desire to include divergent systems within his own, and the conciliatory tone of his writing. He is best remembered as an opponent of Hegel in the interests of religion and ethics. He attacks Hegelism for its pantheism, its lowering of human personality, and imperfect recognition of the demands of the moral consciousness. God, he says, is to be regarded not as an Absolute but as an Infinite Person, whose nature it is that He should realize himself in finite persons. These persons are objects of God's love, and He arranges the world for their good. Fichte, in short, advocates an ethical theism, and his arguments might easily be turned to account by the apologist of Christianity. In his conception of finite personality Fichte recurs to something like the monadism of Leibnitz. His insistence on moral experience is connected with his insistence on personality. One of the tests by which Fichte discriminates the value of previous systems is the adequateness with which they interpret moral experience. The same reason that made him depreciate Hegel made him praise Krause and Schleiermacher, and speak respectfully of English philosophy. It is characteristic of Fichte's almost excessive receptiveness that in his latest published work, *Der neuere Spiritualismus* (1878), he supports his position by arguments of a somewhat occult or theosophical cast, not unlike those adopted by F. W. H. Myers in his writings for the Psychical Research Society. (H. St.)

Field, Cyrus West (1819–1892), American capitalist, founder of the first Atlantic cable, was born at Stockbridge, Mass., on the 30th of November 1819. At the age of fifteen he became a clerk in the store of Alexander T. Stewart & Co. of New York. Five years later he began to manufacture paper, and by 1853 had accumulated a sufficient fortune to retire from the business. The following year, in connexion with Peter Cooper and other capitalists, he organized the New York, Newfoundland, and London Telegraph Company. A submarine cable to Ireland was laid by this company in 1856, but it failed to work. The same year he organized the Atlantic Telegraph Company, and in 1858 this company laid a cable which transmitted messages successfully, but for only about a fortnight. In 1865 an attempt was made with the *Great Eastern* to lay another cable, but the cable parted in mid-ocean. Still another attempt was made in the following year, with the same vessel, and this time his long-continued efforts were crowned with complete success. Mr Field received many honours as a result of his achievement, among others a gold medal and a vote of thanks from the U.S. Congress. Among his other enterprises Mr Field took an important part in the development of the elevated railway system in New York City. He died at New York on 12th July 1892.

Field, Eugene (1850–1895), American poet, was born at St Louis, Missouri, 2nd September 1850. He spent his boyhood in Vermont and Massachusetts; studied for short periods at Williams and Knox Colleges and the University of Missouri, but without taking a degree; and worked as a journalist on various papers, finally becoming connected with the Chicago *News*. *A Little Book of Profitable Tales* appeared in Chicago in 1889 and in New York the next year; but Field's place in later American literature chiefly depends upon his poems of Christmas-time and childhood (of which *Little Boy Blue* and *A Dutch Lullaby* are most widely known), because of their union of obvious sentiment with fluent lyrical form. His principal collections of poems are: *A Little Book of Western Verse* (Chicago, 1889; New York, 1890); *A Second Book of Verse* (Chicago, 1892; New York, 1893); and *With Trumpet and Drum* (1892). Field died at Chicago, 4th November 1895.

Field, William Ventris, Baron (1813–——), English judge, son of Mr Thomas Flint Field of Fielden, Bedfordshire, was born on the 21st of August 1813. He was educated at Burton Grammar School in Somersetshire, and entered the legal profession as articled clerk to Messrs Terrell, Barton, & Smale, a firm of solicitors at Exeter. He was afterwards in a London office (that of Messrs Price & Bolton in Lincoln's Inn), and from 1840 to 1843 was junior partner in the firm of Thompson, Debenham, & Field, of Salter's Hill Court. In 1843, however, he ceased to practise as a solicitor, and entered at the Inner Temple, reading for the bar in the chambers of Mr T. K. Kingdon of the Western circuit. After having practised for a short time as a special pleader, Mr Field was called to the bar in 1850, and joined the Western circuit, but soon exchanged it for the Midland. He obtained a large business as a junior, and became a Queen's counsel and bencher of his inn in 1864. As a Q.C. he had a very extensive common-law practice, and had for some time been the leader of the Midland circuit, when in February 1875, on the retirement of Mr Justice Keating, he was raised to the bench as a justice of the Queen's Bench, and was knighted. Mr Justice Field was an excellent puisne judge of the type that attracts but little public attention. He was a first-rate lawyer, had a good knowledge of commercial matters, great shrewdness, and a quick intellect, while he was also painstaking and scrupulously fair. When the rules of the Supreme Court 1883 came into force in the autumn of that year, Mr Justice Field was so well recognized an authority upon all questions of practice that the Lord Chancellor selected him to sit continuously at Judges' Chambers, in order that a consistent practice under the new rules might as far as possible be established. This he did for nearly a year, and his name will always, to a large extent, be associated with the settling of the details of the new procedure, which finally did away with the former elaborate system of "special pleading." When in 1890 Mr Justice Field accepted a life peerage and retired, becoming at the same time a member of the Privy Council, his title and retirement were recognized as well earned by the work that he had done. In the House of Lords he at first took part, not unfrequently, in the hearing of appeals to that chamber, and notably delivered a carefully-reasoned judgment in the case of the Bank of England *v.* Vagliano Brothers (5th March 1891), in which, with Lord Bramwell, he differed from the majority of his brother peers. Before long, however, deafness and advancing years rendered his attendances less frequent. Lord Field married Louisa, daughter of Mr J. Smith, but his wife died in 1880.

Fields, James Thomas (1817–1881), American publisher and author, was born in Portsmouth, New Hampshire, 31st December 1817, and at the age of fourteen went to Boston as clerk in a bookseller's. Afterwards he wrote for the newspapers, and in 1835 he read a poem before the Boston Mercantile Library Association. In 1838 he became junior partner in the publishing and bookselling firm afterwards known as Ticknor & Fields. The first collected edition of De Quincey was due to his efforts. In 1862 he became editor of the *Atlantic Monthly*, which had been edited by James Russell Lowell since its commencement in 1857. In 1871 Fields retired from business and from his editorial duties, and devoted himself to literary work. Of his books the chief were the collection of sketches and essays entitled *Underbrush* (1877) and the chapters of reminiscence composing *Yesterdays with Authors* (1871), in which he recorded his personal acquaintanceship with Wordsworth, Thackeray, Dickens, Hawthorne, and others. He died in Boston, 24th April 1881.

Fife, a peninsular county of Scotland, bounded N. by the Firth of Tay, separating it from Perthshire and Forfar, S. by the Firth of Forth, separating it from the Lothians, E. by the German Ocean, and W. by parts of Kinross, Perth, and Clackmannan.

Area and Population.—The area of the county is 314,952 acres, or 492·1 square miles, with a population in 1881 of 171,931, and in 1891 of 187,346, of whom 89,135 were males and 98,211 females, the number of persons per square mile being 381, and of acres to a person 1·7. In 1881 the town population amounted to 85,973, the village to 46,576, and the rural to 39,382; and in 1891 the town population to 98,508, the village to 49,923, and the rural to 38,915. Between 1881 and 1891 the increase in population was 8·96 per cent. In 1901, the population was 218,843, of whom 105,096 were males, and 113,747 females. The following table gives the numbers of marriages, births, and deaths, with the number and percentage of illegitimate births for 1880, 1890, and 1899:—

Year.	Marriages.	Births.	Deaths.	Illegitimate Births.	
				No.	Percentage.
1880	987	5307	3099	361	6·8
1890	1181	5346	3477	291	5·4
1899	1524	5895	3334	277	4·7

The percentage of illegitimacy is considerably below the average for Scotland. In 1891 there were in the county 3453 English, 61 Welsh, 1732 Irish, and 103 foreigners.

The following are the most important towns in Fife, from the point of view of population: Kirkcaldy, Dunfermline, St Andrews, Cowdenbeath, and Leven.

Administration.—For parliamentary purposes Fife is divided into an eastern and a western division. It also includes the Kirkcaldy district of parliamentary burghs (comprising Burntisland, Dysart, Kinghorn, and Kirkcaldy) and the St Andrews district of parliamentary burghs (comprising Anstruther Eastern, Anstruther Western, Crail, Cupar, Kilrenny, Pittenweem, and St Andrews), in addition to which Dunfermline and Inverkeithing are included in the Stirling district of parliamentary burghs. The county town is Cupar.

Education.—St Andrews, the seat of the oldest university of Scotland, contains also many private boarding schools for boys and girls. There are in the county five higher class schools in receipt of government grants, and offering various facilities for education: Bell Baxter School, Cupar; High School, Dunfermline; High School, Kirkcaldy; Madras College, St Andrews; and Waid Academy, Anstruther. The grant for higher class schools for the year ending 31st March 1900 was £2446. The total accommodation in elementary schools on 31st September 1899 was 44,797, the average attendance was 31,990, and the average cost per scholar was £2 : 6 : 9¼. The amount of school rates received in 1895–96 was £31,280, in 1896–97 £32,993, and in 1898–99 £36,199, the average rate per £ on rateable value for these years being 8·10d., 8·38d., and 8·48d. respectively.

Communications.—Within recent years the railway communication has been greatly improved, especially in the eastern portion of the county, the whole of the coast towns being now connected by rail from St Andrews to Burntisland; and while the Forth Bridge has facilitated traffic both with Edinburgh and Glasgow, the Tay Bridge gives easy access to Dundee and the north. In 1898 a line for goods traffic only was opened, bisecting the eastern portion of the county from Cameron Bridge to Lochty.

Agriculture.—About four-fifths of the total area of the county is under cultivation, and of this about three-sevenths is in permanent pasture. In addition about 9000 acres are in hill pasturage, and over 24,000 acres under wood. Within the last twenty years the acreage under corn crops has considerably diminished, the decrease being mainly in the acreage under barley, which is now about a third less than in 1880; there has also been a decrease of about 2000 acres in the wheat area, but almost no decrease in that of oats, which occupy more than half of the corn crop acreage. Turnips occupy nearly three-fourths of the acreage under green crops, and potatoes about a third, while over 1000 acres are under other varieties of green crops. More attention has lately been given to dairy farming, but cattle are still kept mainly for feeding purposes. The following table gives the main divisions of the cultivated area at intervals of five years from 1880:—

Year.	Total Area under Cultivation.	Corn Crops.	Green Crops.	Clover.	Permanent Pasture.	Fallow.
1880	246,480	86,584	47,179	62,033	48,849	1835
1885	250,918	88,752	43,716	67,636	55,524	1267
1890	253,756	76,994	42,782	68,342	64,131	1409
1895	256,060	74,028	42,536	63,125	75,594	614
1900	255,398	73,282	41,118	64,341	75,878	593

The following table gives particulars regarding the principal live stock for the same years:—

Year.	Total Horses.	Total Cattle.	Cows or Heifers in Milk or in Calf.	Sheep.	Pigs.
1880	10,202	39,674	9.038	72,783	5229
1885	9,717	44,360	10 347	88,346	6713
1890	9,481	48,004	10,628	105,093	6669
1895	10,535	49,912	11,285	94,578	6532
1899	9,791	47,673	12,186	109,780	5511

Industries and Trade.—According to the report for 1898 of the Chief Inspector of Factories (1900) the total number of persons employed in factories and workshops in 1897 was 26,052, as compared with 25,871 in 1896. Of these 12,580 were employed in textile factories, 12,481 being employed in the flax, hemp, and jute industries, and nine-tenths of these in the flax or linen industry, which besides having its chief seats in Kirkcaldy and Dunfermline is prosecuted at many of the inland villages, specially those in the neighbourhood of the Eden and Leven. Non-textile factories employed 10,859 persons, of whom 2069 were employed in the manufacture of machines and 1516 in the manufacture of paper, &c. Workshops employed 2613 persons, 1514 of whom were employed in clothing industries. The total number of persons employed in connexion with mines and quarries in 1899 was 14,870. The same year 103,479 tons of sandstone were raised, 83,716 tons of limestone, and 97,355 tons of igneous rocks. The coalfield is one of the largest and richest in Scotland, and while coal mining is being prosecuted with increasing enterprise and success, there are ample possibilities of much greater development of the industry. The following table gives the tonnage and value of fireclay, coal, and iron ore in 1890 and 1899:—

Year.	Fireclay.		Coal.		Iron.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
1890	23,618	£4137	3,121,646	£1,131,597	4,100	£1845
1899	35,662	5349	4,927,489	1,847,808	25,269	9476

On account of the great extent of its sea coast and its situation between two large firths, both the salmon and deep-sea fisheries of Fife are of great importance. All the deep-sea fishing stations east of Wemyss and round by the north coast to Newburgh are included in the Anstruther district, and Wemyss and the small stations in the western portion of the south coast—which together land fish of a total value of less than a twelfth of that of the fish landed in the Anstruther district—in the Leith district. The following table gives particulars regarding the Anstruther district at intervals from 1885:—

Year.	Fishermen.	Total Persons employed.	Value of Boat Lines and Nets.	Value of Fish landed.
1890	3325	5354	£151,555	£44,671
1899	1937	2493	£156,763	£47,272

AUTHORITIES.—Chief among later works is A. H. MILLAR's *Fife, Pictorial and Historical* (2 vols. Cupar-Fife, 1895)—a very minute history of the different parishes with notices of the principal families. Other books are:—BABINGTON. *Records of the Fife Foxhounds.* Edinburgh, 1883.—G. G. *Our Old Neighbours: Folklore of Fife.* Anstruther, 1887.—SHERIFF ÆNEAS MACKAY. *Sketch of the History of Fife.* Edinburgh, 1890. *History of Fife and Kinross* (Scottish County History Series). Edinburgh, 1896.—THOMSON. *History of the Fife Light Horse.* Edinburgh, 1892.—GEDDIE. *Fringes of Fife.* Edinburgh, 1894.—PRYDE. *The Queer Folk of Fife.* Glasgow, 1897.

Figueira da Foz, a town of Portugal, at the mouth of the Mondego, in the district of Coimbra, 25 miles west from Coimbra. It is a summer seaside resort, a new villa quarter, Bairro Novo, having grown up to the north-west of the old town. It is connected with Cape Mondego by tramway. Coal is mined, and glass is manufactured. The port is a fishing station. In 1899 it was entered by a total of 322 vessels of 22,995 tons. The custom-house returns in 1899 showed a total of £67,244. The products are corn, fruit, wine, olive oil, and cork. Population, 5676.

Fiji Islands.—The Fiji archipelago comprises about 250 islands and islets, lying between 177° E. and 178° W. long., and between 15° 40′ and 22° S. lat., about 1700 miles north-east of Sydney and 1200 miles north of New Zealand. The colony includes the island of Rotuma (or Rotumah), which lies 300 miles due north, and supports a population of 2219, its people being apparently a cross between the Polynesians and Micronesians. The peculiar formation of Vitilevu, the largest of the group, gives rise to three rivers, the Rewa, Singatoka, and Ba, which are disproportionately large for an island scarcely half the size of Wales. The land is of recent geological formation, the principal ranges being composed of igneous rock, and showing traces of much volcanic disturbance. There are boiling springs in Vanualevu and Ngau, and slight shocks of earthquake are occasionally felt. With few exceptions the islands are surrounded by barriers of coral, broken by openings opposite the mouths of streams. The mean temperature of the group is 80°, but in the hill sanatorium at Nandarivatu (2000 feet) the thermometer occasionally falls below 50°. Some part of the group is usually visited by a cyclone at intervals of four or five years.

Recent Commercial History.—Fiji became a British colony in 1874. At that date the islands were suffering from commercial depression, following a fall in the price of cotton after the American civil war. Coffee, tea, cinchona, and sugar were tried in turn, with limited success. The coffee was attacked by the leaf disease; the tea could not compete with that grown by the cheap labour of the East; the sugar machinery was too antiquated to withstand the fall in prices consequent on the European sugar bounties. In 1878 the first coolies were imported from India, and the cultivation of sugar began to pass into the hands of large companies working with the most modern machinery. With the introduction of coolies the Fijians began to fall behind in the development of their country. Many of the coolies chose to remain in the colony after the termination of their indentures, and these are rapidly displacing the European country traders. The recruiting of *kanaka* labourers has, with a regular and plentiful supply of Indian coolies, practically ceased. The settlement of European land claims, and the measures taken for the protection of native institutions, caused lively dissatisfaction among the colonists, who laid the blame of the commercial depression at the door of the Government; but with returning prosperity this feeling has almost disappeared. Out of 4,953,920 acres in the colony the natives own over 4,500,000, or 45 acres a head. They are not permitted to sell their lands, but large tracts are leased to European planters at a low rental. In 1882 the capital was transferred from Levuka to Suva, on the south-east coast of Vitilevu, where there is a better harbour, and where a larger area of land was at the disposal of the Government.

Vital Statistics.—There has been a steady, if not a very rapid, decrease in the native population since 1875. The terrible epidemic of measles in that year swept away 40,000, or about one-third of the Fijians, and although measles again revisited the group in 1898, out of the 200 cases there were no deaths. There has, however, been a steady leakage, principally among young children, owing to whooping-cough, tuberculosis, and croup. Every Fijian child seems to contract *yaws* at some time in its life, through the mistaken notion on the part of the parents that it strengthens the child's physique. One per cent. of the natives is a leper. A commission appointed in 1891 to inquire into the causes of the native decrease collected much interesting anthropological information regarding native customs, and provincial inspectors and medical officers have been specially appointed to compel the natives to carry out the sanitary reforms recommended by the commission. A considerable sum has also been spent in laying on good water to the native villages. The Fijians have shown no disposition to intermarry with the Indian coolies. The European half-castes, who numbered in 1900 1258, are not prolific *inter se*, and they are subject to a scrofulous taint. The most robust cross in the islands is the offspring of the African negro and the Fijian. Probably the only hope of saving the native population lies in miscegenation with the Micronesians, the only race in the Pacific which is rapidly increasing, but the immigration of the Gilbert and Ellice islanders would have to be undertaken by the Government.

The following table shows the population by census 5th April 1891, and by vital statistics 31st December 1899:—

Class.	Census 1891.			Vital Statistics 1899.		
	Male.	Female.	Total.	Male.	Female.	Total.
Europeans	1,273	763	2,036	2,759	1,614	4,373
Half-castes .	529	547	1,076	624	634	1,258
Asiatics . .	4,998	2,470	7,468	8,875	4,407	13,282
Polynesians .	1,923	344	2,267	1,672	289	1,961
Rotumans .	1,056	1,163	2,219	1,033	1,138	2,171
Fijians . .	56,445	49,355	105,800	52,354	46,124	98,478
Others . .	143	171	314	471	679	1,150
Grand total	...	...	121,180	...	...	122,673

Constitution and Government.—There has been no change in the government since annexation. The legislative council consists of six official and six non-official members nominated by the crown, and the governor has a casting vote. The New Zealand Government made overtures in 1900 to absorb Fiji. The Aborigines Society sent a protest to the Colonial Office on 3rd April 1901, and the Imperial Government declined to sanction the proposal. As the power of the chiefs has declined, the *roko tui*, or native lieutenant-governor, has been occasionally replaced by a European resident commissioner. The native chiefs have shown considerable ability both as administrators and magistrates, but, with some exceptions, they seem unable to withstand the temptation of converting public money to their own uses.

Religion and Instruction.—The majority of the natives are Wesleyan Methodists. The Roman Catholic missionaries have about 3000 adherents; the Church of England is confined to the Europeans and *kanakas* in the towns; the Indian coolies are divided between Mahommedans and Hindus. There are public schools for Europeans and half-castes in the towns, but there is, as yet, no provision for the education of the children of settlers in the out-districts. The missions have established schools in every native village, and most natives are able to read and write their own language. The Government has besides established a native technical school for the teaching of useful handicrafts. The natives have shown themselves very slow in adopting European habits in food, clothing, and house-building. The law of custom has so far decayed as to deprive them of many safeguards to health, and the law of competition not having yet taken its place, the Fijian is left, as it were, stranded between two tides. Until the custom of *kerekere*, under which he who has is obliged to give to him who has not, is broken down, the lazy will continue to live upon the industrious, and there will be no inducement to accumulate property.

Finance.—The revenue is derived from customs, native taxation, and stamp duties. The customs tariff, formerly about 12½ per cent. *ad valorem*, was in 1897 largely increased by specific duties. The native taxes, paid in produce cultivated under European supervision, are assessed annually at about £18,000, any excess being sold to the contractor, and returned to the native in cash. In 1899 some £12,000 was thus returned, and so elaborate is the system of book-keeping, that every individual native receives his share before the close of the year in which the produce was grown. Owing to the freedom from hurricanes for the last five years there has been a steady increase in the revenue, and a surplus varying from £5000 to £7000. The actual revenue for 1898 was £94,165, the expenditure £85,741. There is a debt of £109,500 in 4½ per cent. debentures, which is being gradually paid off by a sinking fund, and a debt of £95,476 advanced by the imperial treasury without interest, which is also being paid off. A reserve of £25,000 is being formed to meet any temporary loss of revenue by hurricanes. A branch of the Bank of New Zealand is the only banking establishment in the colony. The currency and weights and measures are English.

Defence.—The armed native constabulary numbers 100 men, and there is a volunteer and cadet corps in Suva and Levuka.

Agriculture and Industries.—The principal exports are sugar and copra and bananas. The production of sugar has passed almost exclusively into the hands of one powerful company, whose plant is one of the largest in the world. As fresh areas of cocoanuts have come into bearing the export of copra has much increased. The cultivation of tea and coffee is now almost abandoned, but sufficient tobacco is grown to supply the local consumption of cigars. Soap made from cocoanut oil also supplies the local market.

Year.	Imports.	Exports.		
		Sugar.	Copra.	Total.
1890	£206,757	£244,655	£31,013	£364,532
1895	241,759	208,889	94,084	332,209
1899	263,044	340,602	77,330	481,856

Internal Communications.—Good bridle tracks now exist in all the larger islands, and macadamized roads are being pushed forward from Suva. There is a bi-weekly overland mail service by native runners, and a telephone line connects Suva with Ba and Nandi.

See Smyth. *Ten Months in the Fiji Islands.* London, 1864.—B. Seemann. *Flora Vitiensis.* London, 1865.—W. T. Pritchard. *Polynesian Reminiscences.* London, 1866.—Forbes. *Two Years in Fiji.* London, 1875.—Commodore Goodenough. *Journal.* London, 1876.—H. N. Moseley. *Notes of a Naturalist in the "Challenger."* London, 1879.—Sir A. H. Gordon. *Story of a Little War.* Edinburgh, privately printed, 1879.—J. W. Anderson. *Fiji and New Caledonia.* London, 1880.—C. F. Gordon-Cumming. *At Home in Fiji.* Edinburgh, 1881.—John Horne. *A Year in Fiji.* London, 1881.—H. S. Cooper. *Our New Colony, Fiji.* London, 1882.—S. E. Scholes. *Fiji and the Friendly Islands.* London, 1882.—Princes Albert Victor and George of Wales. *Cruise of H.M.S. "Bacchante."* London, 1886.—A. Agassiz. *The Islands and Coral Reefs of Fiji.* Cambridge, Mass., U.S., 1899. (B. H. T.)

Filey, a seaside resort and fishing village of England, stands on the north side of a bay on the Yorkshire coast, between Scarborough and Bridlington, 9 miles south-east from the former. It has firm sands, a golf-course, and mineral springs, now however neglected. Population (1901), 3004.

Finance.—The complete alteration of the English financial system involved in the thorough application of a free-trade policy was substantially accomplished in 1860. Since then the history of English finance has been one of normal growth, influenced indeed by new conditions and marked by considerable readjustments, but altogether free from revolutionary change. The repeal of the 1s. duty on corn (1869), and the abolition of the sugar duty (1874), were in fact the removal of a last trace of Protection, and a continuation of the work of simplifying the taxation of commodities, and reducing the charge on the poorer consumers, which was characteristic of the reforms of Peel and Gladstone. In tracing the financial history of the thirty years, 1870–1900, the first noticeable point is the almost continuous growth of expenditure. From being under 70 millions in 1870, it rose to nearly 87 millions in 1890; it passed the 100 million point in 1897, until in 1901, under the pressure of war, it exceeded 183 millions. The principal element in this movement was obviously the increased demands of both the army and navy. The outlay on the former, which was 15 millions in 1870, came in time of peace to exceed 20 millions. In the case of the navy the increase was from less than 10 millions to 30 millions, or over 200 per cent. The revival of international ill-feeling, the immense development in implements of war, and the higher rates of pay required, owing to the improvement in the standard of life, were, though in unequal degree, the underlying causes. Civil administration has also become more costly. The State has undertaken new tasks, and has discharged its older duties with greater vigour. Especially remarkable is the advance of expenditure on education, which was less than 2 millions in 1870, but came to 12½ millions in 1900. One item of increase is, however, rather apparent than real, viz., the post-office expenditure, for it is the necessary condition of the more than proportional increase in postal receipts. Up to 1899 a reduction is also found under the head of interest and management of debt, which only amounted to £16,200,000 in that year, as against 22½ millions in 1869—a result due in part to the repayment of principal, in part to the conversion measure of 1888. The war loans of 1900 and 1901 seriously increased this item.

Expenditure, 1870-1900.

This great increase in national expenditure has been met by a corresponding growth of revenue, which has enabled the various claims of the State to be satisfied without undue pressure on the enjoyments or the industries of the people. The great division of *taxes on commodities* (or indirect taxation) has been strictly confined to a few productive articles—spirits, beer, wines, tobacco, and tea (with its substitutes). The rates of imposition have not seriously altered—the lowering of the tea duty from 6d. to 4d. per lb, small increases on spirits and beer, with some adjustment of the tobacco duty, being the chief changes—and yet there has been an advance in receipts. The customs, indeed, have not shown much change from the average of 20 millions attained between 1865 and 1900 (their yield in 1901 was 26¾ millions). But this steady return has been secured in spite of the surrender of the sugar duty (1874), and one-third of the tea duty (1890). The South African War led to the raising of the tea duty to its old level, the reimposition of the sugar duty, and to an export duty on coal. The excise has proved more elastic. From 23½ millions in 1871–72, its return advanced to over 33 millions in 1900-1, together with 5 millions set aside for the purposes of local finance. Thus it appears that nearly 60 millions is the sum obtained by the State from taxation of commodities. From being regarded as a temporary and unsatisfactory resource, the *income tax* has gained the place of a well-established and important element in the tax system. Placed at the very low rate of 2d. in the £ in 1874, it was gradually advanced, until in 1894 what since seemed the normal peace rate of 8d. was established. The necessary result has been a great increase in yield. In 1876 the returns were just over 4 millions; for 1893 they were 13½ millions; in 1899–1900 they reached 18¾ millions. These figures show clearly that a considerable part of the burden of growing expenditure has fallen directly on the payers of income tax as such. But there has been also a rearrangement, which has affected the relations of different classes of payers. In 1870 the limit for exemption from the tax was only £100, and incomes of £200 paid the full tax without abatement. By a series of changes the exemption point has been raised to £160, while all incomes of £700 and under are allowed abatements. The practical effect is to throw by far the greater part of the burden on the possessors of incomes over £700, leaving moderate incomes unaffected by the increase. The fact that, in spite of so extensive a relief, the yield per penny now amounts to £2,300,000 is a good illustration of the growth of wealth in the United Kingdom. The war rates of 1s. (1900) and 1s. 2d. (1901) proved productive, as the yield for 1900–1 was almost 27 millions.

Revenue.

A still more remarkable feature of modern English finance is the increased rigour of the duties on succession to property—the *death duties.* Instead of the system in force in 1870, under which real property escaped the general or probate duty, which only amounted to 3 per cent., there has been since 1894 a comprehensive "estate" duty applicable to all property, and so graduated as to levy 8 per cent. on estates of 1 million. By this agency the death duties, which supplied less than 5 millions in 1870, and had not reached 10 millions in 1890, came in 1900–1 to 13 millions (besides over 4 millions for local finance). This group of taxes operates as the complement of the income tax, and taking the two together, it is evident that between 1876 and 1901 the taxation on income and property increased more than fourfold, or from 10 millions to 40 millions. Other items of the tax revenue so-called need only cursory mention. The land tax and house duty have both been recently reduced, and the more productive "stamps" have been somewhat enlarged in order to include commercial transactions, until in 1899–1900 they produced 8½ millions. The industrial departments of the post-office have yielded more than 80 per cent. of the non-tax revenue (over 16½ millions in 1899–1900), subject, however, to a heavy deduction for expenses, which reduces the net revenue to the moderate amount of 4 millions, or 1 million more than in 1872.

The avoidance of deficits or undue surpluses has been a cardinal principle of modern English finance; but the great war period, ending in 1815, bequeathed a heritage of debt, involving heavy interest payments. This charge has (as already mentioned) been reduced by (1) the substitution of terminable annuities for funded debt, (2) the establishment of a fixed annual sum for the debt service—the "new sinking fund" (1875)—which in 1899 was reduced to 23 millions, and (3) the "old sinking fund," *i.e.*, the application of actual surplus to redemption of debt—this last a resource which has in recent years been restricted by the continual introduction of late supplementary estimates. The process of reduction has varied in its rate. In 1869 the debt principal was 750 millions, in 1885 it was 740 millions, a trivial diminution of 10 millions. By 1899 more progress had been made, as the total debt was only 635 millions, or 105 millions less than in 1885. The work of redemption, which was aided by the conversion of the 3 per cent. stock into 2¾ per cent. in 1888, was, broadly speaking, nullified by the war loans of 1900 and 1901, as they added over 100 millions to the capital charge.

The chief changes in the complementary system of *local finance* since 1870 have been (1) even greater increase in expenditure than that of the State; (2) a considerable development of "non-tax" revenue derived from municipal industries; (3) a great increase in indebtedness, mainly the consequence of the preceding process; (4) the automatic growth of the share of tax-revenue assigned to local purposes. As a whole, the English financial system appears to be based on simple and intelligible principles, and to be extremely productive of revenue without great sacrifice on the part of the tax-payers. Through the movable income tax and the reserve of untaxed articles it has ample resources for emergencies, while the distribution of burdens is not seriously unjust. Its weakest points are probably the treatment of the classes of (1) the very poor, who consume taxed articles, and (2) the possessors of moderate incomes, and also the want of relation between central and local finance. (See also TAXATION.)

(For the finance generally of other countries than Great Britain, see the articles on those countries.)

AUTHORITIES.—S. DOWELL. *History of Taxation*, vol. ii. (2nd ed.). London, 1888.—S. BUXTON. *Finance and Politics*, vol. ii. London, 1888.—A. WAGNER. *Finanzwissenschaft* (Ergänzungsheft to vol. iii.), pp. 8–48. Leipzig, 1896. (C. F. B.)

Findlay, capital of Hancock County, Ohio, U.S.A., on the Blanchard river, at an altitude of 778 feet. It is a railway centre of much importance, being at the intersection of five lines—the Cincinnati, Hamilton, and Dayton; the Cleveland, Cincinnati, Chicago, and St Louis; the Findlay, Fort Wayne, and Western; the Lake Erie and Western; and the Ohio Central. About 1885 the development of a natural gas field in the neighbourhood induced a rapid growth of population and manufactures, especially of iron, steel, and glass. Population (1880), 4633; (1890), 18,553; (1900), 17,613, of whom 1051 were foreign-born, and 294 negroes.

Findlay, Sir George (1829–1893), English railway manager, was of pure Scottish descent, and was born at Rainhill, in Lancashire, on 18th May 1829. For some time he attended Halifax Grammar School, but left at the age of fourteen, and began to learn practical masonry on the Halifax railway, upon which his father was then employed. Two years later he obtained a situation on the Trent Valley railway works, and when that line was finished in 1847 went up to London. There he was for a short time among the men employed in building locomotive sheds for the London & North-Western Railway at Camden Town, and years afterwards, when he had become general manager of that railway, he was able to point out stones which he had dressed with his own hands. For the next two or three years he was engaged in a higher capacity as supervisor of the mining and brickwork of the Harecastle tunnel on the North Staffordshire line, and of the Walton tunnel on the Birkenhead, Lancashire, and Cheshire Junction Railway. In 1850 the charge of the construction of a section of the Shrewsbury and Hereford line was entrusted to him, and when the line was opened for traffic Mr Brassey, the contractor, having determined to work it himself, installed him as manager. In the course of his duties he was brought for the first time into official relations with the London & North-Western Railway, which had undertaken to work the Newport, Abergavenny, and Hereford line, and he ultimately passed into the service of that company, when in 1862, jointly with the Great Western, it leased the railway of which he was manager. In 1864 he was moved to Euston as general goods manager, in 1872 he became chief traffic manager, and in 1880 he was appointed full general manager; this last post he retained until his death, which occurred on 26th March 1893 at Edgware. Sir George Findlay was the author of a book on the *Working and Management of an English Railway*, which contains a great deal of information, some of it not easily accessible to the general public, as to English railway practice about the year 1890.

Finistère, the most westerly department of France, washed by the English Channel and the Atlantic Ocean.

Area, 2730 square miles, with 43 cantons and 293 communes. Population, 707,820 in 1886, 739,648 in 1896, and 763,193 in 1901. Births in 1899, 23,884, of which 588 illegitimate; deaths, 17,108; marriages, 6125. The schools numbered (1896) 839, with 113,000 pupils; 16 per cent. of the population was illiterate. Quimper, the capital, with 19,441 inhabitants, and Brest, a military station, with 81,948 inhabitants, are the chief towns. The area of cultivated land in 1896 amounted to 1,027,994 acres, of which 773,467 acres were plough-land. In 1899 the produce of wheat was valued at £638,000; of rye, £237,000; of barley, £180,000; of oats, £340,000; potatoes, £998,000; mangold-wurzel, £130,000; natural pastures and grass lands, £640,000. Finistère cultivates with success flax, which in 1899 returned the value of £44,000, and hemp, which produced £46,000. Its main source of prosperity, however, is the rearing of horses, which in 1899 numbered 112,270 head. Its cattle totalled 432,680; its sheep, 69,400; and its pigs, 112,430. The department is not rich in metals, and its industry is restricted to some cloth factories.

Finland, Grand Duchy of, a part of the Russian empire, situated between the Gulfs of Bothnia and Finland, and including, moreover, a large territory in Lapland. It touches at its south-eastern extremity the government of St Petersburg, includes the northern half of Lake Ladoga, and is separated from the Russian governments of Arkhangelsk and Olonets by a sinuous line which follows, roughly speaking, the water-parting between the rivers flowing into the Baltic Sea and the White Sea. In the north of the Gulf of Bothnia it is separated from Sweden and Norway by a broken line which takes the course of the valley of the Torneå river up to its sources, thus falling only 21 miles short of reaching the head of the Norwegian Lyngen-fjord; then it runs south-east and north-east down the Tana and Pasis-joki, but does not reach the Arctic Ocean, and 13 miles from the Varanger-fjord it turns southwards. Finland includes in the south-west the Åland archipelago—its frontier approaching within 8 miles from the Swedish coast—as well as the islands of the Gulf of Finland, Hogland, Tytärs, &c. Its utmost limits are: 59° 48′—70° 6′ N. lat., and 19° 2′—32° 50′ E. long. The area of Finland, in square miles, is as follows (*Atlas de Finlande*, 1899):—

Government.	Continent.	Islands in Lakes.	Islands in Seas.	Lakes.	Total.
Nyland . . .	4,062	24	210	286	4,582
Åbo-Björneborg	7,594	8	1331	400	9,333
Tavastehus . .	6,837	97	...	1,400	8,334
Viborg . . .	11,630	362	130	4,502	16,624
St Michel . .	5,652	1018	...	2,149	8,819
Kuopio . . .	13,160	643	...	2,696	16,499
Vasa	14,527	62	203	1,313	16,105
Uleåborg . .	60,348	171	94	3,344	63,957
Total . .	123,810	2385	1968	16,090	144,253

Orography.—A line drawn from the head of the Gulf of Bothnia to the eastern coast of Lake Ladoga divides Finland into two distinct parts, the lake region and the nearly uninhabited hilly tracts belonging to the Kjölen mountains, to the plateau of the Kola peninsula, and to the slopes of the plateau which separates Finland proper from the White Sea. At the head-waters of the Torneå, Finland penetrates as a narrow strip into the heart of the Kjölen highlands, where the Haldefjäll (Lappish Halditschokko) reaches 4115 feet above the sea, and is surrounded by other *fjälls*, or flat-topped summits, of from 3300 to 3750 feet of altitude. Extensive plateaus (1500–1750 feet), into which Lake Enare, or Inari, and the valleys of its tributaries are deeply sunk, and which take the character of a mountain region in the Saariselkä (highest summit 2360 feet), occupy the remainder of Lapland. Along the eastern border the dreary plateaus of Olonets reach on Finnish territory altitudes of from 700 to 1000 feet. Quite different is the character of the pentagonal space comprised between the Gulfs of Bothnia and Finland, Lake Ladoga, and the above-mentioned line traced through the Lakes Uleå and Piellis. The meridional ridges which formerly used to be traced here along the main water-partings do not exist in reality, and the country appears on the hypsometrical map in the *Atlas de Finlande* as a plateau of 350 feet of average altitude, covered with countless lakes, lying at altitudes of from 250 to 300 feet. The three main lake-basins of Näsi-järvi, Päjäne, and Saima are separated by low and flat hills only; but one sees distinctly appearing on the map a line of flat elevations running south-west to north-east along the north-west border of the lake regions from Lauhanvuori to Kajana, and reaching from 650 to 825 feet of altitude. A regular gentle slope leads from these hills to the Gulf of Bothnia (Osterbotten), forming vast prairie tracts in its lower parts.

A notable feature of Finland are the *åsar* or narrow ridges of morainic deposits, more or less reassorted on their surfaces. Some of them are relics of the longitudinal moraines of the ice-sheet, and they run north-west to south-east, parallel to the striation of the rocks and to the countless parallel troughs excavated by the ice in the hard rocks in the same direction; while the Lojo ås, which runs from Hangöudd to Vesi-järvi, and is continued farther east under the name of Salpausselkä, parallel to the shore of the Gulf of Finland, are remainders of the frontal moraines, formed at a period when the ice-sheet remained for some time stationary during its retreat. As a rule these forest-clothed *åsar* rise from 30 to 60 and occasionally 120 feet above the level of the surrounding country, largely adding to the already great picturesqueness of the lake region; railways are traced in preference along them.

Lakes and Rivers.—A labyrinth of lakes, covering 11 per cent. of the aggregate territory, and connected by short and rapid streams (*fjärden*), covers the surface of South Finland, offering great facilities for internal navigation, while the connecting streams supply an enormous amount of motive-power. The chief lakes are: Lake Ladoga, of which the northern half belongs to Finland; Saima (three and a half times larger than Lake Leman), whose outlet, the Vuoksen, flows into Lake Ladoga, forming the mighty Imatra rapids, while the lake itself is connected by means of a sluiced canal with the Gulf of Finland; the basins of Pyhä-selkä, Ori-vesi, and Piellis-järvi; Päjäne, surrounded by hundreds of smaller lakes, and the waters of which are discharged into the lower gulf through the Kymmene river; Näsi-järvi and Pyhä-järvi, whose outflow is the Kumo-elf, flowing into the Gulf of Bothnia; Uleå-träsk, discharged by the Uleå into the same gulf; and Enare, belonging to the basin of the Arctic Ocean. Two large rivers, Kemi and Torneå, enter the head of the Gulf of Bothnia, while the Uleå is now navigable throughout, owing to improvements in its channel.

Geology.—Finland is nearly entirely built up of oldest crystalline rocks. Cambrian, Silurian, Devonian, and Carboniferous deposits are only found on the coasts of the Gulf of Finland and Lake Ladoga, as also along the coasts of the Arctic Ocean (probably Devonian), and in the Kjölen. Eruptive rocks of Palæozoic age are met with in the Kola peninsula (nephelin-syenites) and at Kuusamo (syenite). The remainder of Finland is built up of the oldest known crystalline rocks belonging to the Archæozoic or Algonkian period. The eldest of them seem to be the granites of East Finland, whose disaggregation gave origin to the *Ladoga schists* and various deposits of the same period, whose primitive position was altered by subsequent vigorous foldings. Then the country came once more under the sea, and the débris of the previous formation, mixed with débris of eruptive rocks originated from many volcanoes situated then in West Finland, formed the so-called *Bothnian series.* New masses of granites protruded next from underneath, and the Bothnian deposits underwent foldings in their turn, while denudation was again at work on a grand scale. A new series of *Jatulian deposits* was formed next, and a new system of foldings followed; but these were the last in this part of the globe. The *Jotnian series* of deposits, which were formed next, remain still undisturbed. No marine deposits younger than those just mentioned—all belonging to a pre-Cambrian epoch—are found in the continental portion of Finland. The plateau character of vast portions of the surface must have been acquired during the extremely long period during which the country remained a continent. The whole of Finland is covered with Glacial and post-Glacial deposits, the former of which, representing the bottom-moraine of the ice-sheet, are covered with Glacial and post-Glacial clays (partly of lacustrine and partly of marine origin) only in the peripheral coast-region—or in separate areas in the interior depressions. Some Finnish geologists—Sederholm for one—consider it probable that during the Glacial period an Arctic sea (*Yoldia* sea) covered all southern Finland and Skånia (in Sweden), thus connecting the Atlantic Ocean with the Baltic and the White Sea by a broad channel; but no fossils from that sea have been found anywhere in Finland. On the contrary, quite certain traces of submergence under a post-Glacial Littorina sea (containing shells now living in the Baltic) are found up to 150 feet along the Gulf of Finland, and up to 260, or perhaps 330 feet, in Osterbotten. Traces of a large inner post-Glacial lake, similar to Lake Agassiz of North America, have lately been discovered. The country is still continuing to rise, but at an unequal rate; of nearly 3·3 feet in a century in the Gulf of Bothnia (Kvarken), from 1·4 to 2 feet in the south, and nearly zero in the Baltic provinces.

Climate.—Owing to the prevalence of moist west and south-west winds the climate of Finland is less severe than it is farther east in corresponding latitudes. The and country lies thus between the annual isotherms of 41° 28° Fahr., which run in a W.N.W.-E.S.E. direction. In January the average monthly temperature varies from 9° Fahr. about Lake Enare to 30° along the south coast; while in July the difference between the monthly averages is only eight degrees, being 53° in the north and 61° in the south-east. Everywhere, and especially in the interior, the winter lasts very long, and early frosts (June 12–14 in 1892) often destroy the crops. The amount of rain and snow is from 25½ inches along the south coast to 13·8 inches in the interior of southern Finland.

Vegetation.—The flora of Finland has been most minutely explored, especially in the south, and the Finnish botanists were enabled to divide the country into twenty-eight different provinces, giving the numbers of phanerogam species for each province. These numbers vary from 318 to 400 species in Lapland, from 508 to 651 in Karelia, and attain 752 species for Finland proper; while the total for all Finland attains 1132 species. Alpine plants are not met with in Finland proper, but are represented by from 32 to 64 species in the Kola peninsula.

Fauna.—The fauna has also been explored in great detail both as regards the vertebrates and the invertebrates, and specialists will find the necessary bibliographical indications in *Travaux géographiques en Finlande*, published for the London Geographical Congress of 1895.

Forests.—The chief forest trees of Finland are the Scotch fir (*Pinus sylvestris*, L.), the fir (*Picea excelsa*, Link.); two species of birch (*B. verrucosa*, Ehrh., and *B. odorata*, Bechst.), as well as the birch-bush (*B. nana*); two species of *Alnus* (*glutinosa* and *incana*); the oak (*Q. pedunculata*, Ehrh.), which grows only on the south coast; the poplar (*Populus tremula*); and the Siberian larch, introduced in culture in the 18th century. Over 6,000,000 trees are cut every year to be floated to thirty large saw-mills, and about 1,000,000 to be transformed into paper pulp. The total export of timber was valued in 1897 at 82,160,000 marks. It is estimated, however, that the domestic use of wood (especially for fuel) represents nearly five times as many cubic feet as the wood used for export in different shapes. The total area under forests is estimated at 63,050,000 acres, of which 34,662,000 acres belong to the State.

Population.—The population of Finland, which was 429,912 in 1751, 832,659 in 1800, and 1,636,915 in 1850, was on the 31st December 1895, 2,520,437, of whom there were 1,276,586 women, and 272,415 lived in towns. The distribution of population in various provinces was as follows:—

31st December 1895.	Population.	Density per sq. Mile.
Åbo-Björneborg	419,369	47
Kuopio	300,291	22
Nyland	264,243	61
St Michel	185,098	28
Tavastehus	276,010	40
Uleåborg	260,763	4
Viborg	379,115	33
Vasa	435,548	30
Total	2,520,437	20

The movement of the population varies very much from year to year in accordance with the state of crops, the number of births having varied in the years 1892–96 from 76,206 to 84,010, the number of deaths from 46,709 to 57,486, and the excess of births over deaths from 18,947 in 1892 to 37,301 in 1895. Emigration proper was estimated at about three thousand every year before 1898, but it largely increased then, owing to Russian encroachments on Finnish autonomy. In 1899 the emigrants numbered 12,357; in 1900, 10,642; in 1901, 12,659; and for 1902 the number was still larger.

The bulk of the population are Finns (2,169,000 in 1895) and Swedes (341,500). Of Russians there were only 7000, chiefly in East Finland (Karelia), and 1150 Laps. Both Finns and Swedes belong to the Lutheran faith, there being only 46,509 Greek Orthodox and Raskolniks (Nonconformists) Finns, chiefly in Karelia.

The distribution of population in different classes is as follows: Nobles, 0·1 per cent.; clergy, 0·3; burghers, 3·1; peasants, 26·1; others, 70·4. Of these different classes only the first four elect representatives to the Diet.

The chief towns of Finland are: Helsingfors, capital of Finland, and chief town of the province (*län*) of Nyland, chief seaport (73,820 inhabitants); Åbo, chief town of the Åbo-Björneborg province, important seaport (34,339); Tammerfors, manufacturing town of Tavastehus län (25,338); Viborg, chief town of province of same name, important seaport (23,026); Uleåborg, capital of province (13,770); Vasa, or Nikolaistad, capital of Vasa län (12,384); Björneborg (11,669); Kuopio, capital of province (9566); and Tavastehus, capital of province (5322).

Agriculture gives occupation to 77 per cent. of the inhabitants; however, only 117,704 persons are owners of the soil, and 92,838 out of them own less than 62½ acres, 32,711 less than 12½ acres. There are, besides, 70,444 farmers, mostly paying their rent in labour, and a large number of *Ansässige* (*inhysingar*), *i.e.*, agricultural labourers, only casually employed, and various classes of farm-servants. Efforts have lately been made by enlightened Finnish patriots to facilitate the acquisition of land by the labourers.

The crops, which are chiefly rye and oats in the south, and barley in the north, up to 68° 30′, as also some wheat, vary very much from year to year, and yielded for the twelve years 1884–95 a maximum of 14·4 bushels of all cereals per head of total population, and a minimum (in 1892) of 11 bushels. To these, from 4 to 7 bushels of potatoes per inhabitant must be added. An average crop may be taken at 4,202,000 quarters of all cereals, *i.e.*, twice as much as it was in 1861. Every year grain has, however, to be imported to the amount of about 66 ℔ per head of population. Agricultural machinery is mostly of the old type.

Dairy farming is on the increase, and the foreign exports of butter attained in 1896 nearly 13,000 tons (12 ℔ per head of rural population). There were in 1898 1,298,990 head of cattle (fifty-seven head per each 100 of rural population), 302,565 horses, 1,092,420 sheep, 214,946 swine, 114,730 reindeer, and 441,000 poultry.

Measures have been taken since 1892 for the improvement of agriculture, and the state keeps now twenty-six agronomists and instructors for that purpose. There are two high schools, one experimental station, twenty-two middle schools, and forty-eight lower schools of agriculture; besides ten horticultural schools are being created. Agricultural societies exist in each province.

Fishing is an important item of income. Over 17,000 tons of different fish (8350 tons of herring) are obtained every year. The value of exports of fish, &c., was 2,909,000 marks in 1898, but from 1,000,000 to 1,800,000 marks' worth of fish is also imported every year.

Industry is of recent origin. There are 91,055 workers, miners, and artizans engaged in all industries, in 7787 separate industrial establishments, the aggregate production of which was valued at 283,671,147 marks in 1898. The chief of them are: wood (22,522 workers, 71,216,455 marks of annual production), articles of food (10,099 workers, 54,016,941 marks), metallurgy and mechanical works (17,198 workers, 44,642,832 marks), textiles (9677 workers, 33,147,415 marks), paper (6254 workers, 22,230,147 marks), and leather (3431 workers, 15,974,617 marks).

Some gold is being obtained in Lapland, on the Ivalajoki (4·6 kilogrammes in 1898), some silver on Lake Ladoga (455 kilogrammes), copper (253 tons) and tin (21 tons) at Pitkäranta, and iron. The last is obtained partly from mines (19,145 tons of ore, 20,000 tons more imported from Sweden), but chiefly from the lakes (50,000 to 75,000 tons of ore). In 1898, 26,679 tons of cast iron (32,811 in 1897) were obtained, and while 12,722 tons of it were exported to Russia, 21,702 tons of cast iron and 23,235 tons of iron were imported from Sweden and Great Britain, the total consumption of iron having regularly risen so as to reach 43,872 tons in 1898. The textile industries are making rapid progress, and their produce, notwithstanding the high duties, is exported to Russia. The fabrication of paper pulp out of wood is also rapidly growing, the total annual production being now over 50,000 tons, out of which 38,000 tons are exported. As to the timber trade, there are no less than 120 large saw-mills (eighteen only with water-power) and 370 small ones (215 with water-power), and over 900 carpentry establishments.

Roads, Railways, Canals.—The *roads*, attaining an aggregate length of 27,500 miles, are kept as a rule in very good order. The first *railway* was opened in 1862, and the next, from Helsingfors to St Petersburg, in 1870 (cost only 113,000 marks per mile). Railways of a lighter type began to be built since 1877, and now Finland has 1560 miles of railways belonging to the state and 160 miles to private companies, the state debt contracted for that purpose being 112,430,000 marks. A new line connects Helsingfors with Åbo. The gross income from the state railways is 25,047,000, and the net income 7,544,000 marks. Finland has an extensive and well-kept system of *canals*, of which the sluiced canal connecting Lake Saima with the Gulf of Finland is the chief one. It permits ships navigating the Baltic to penetrate 270 miles inland, and is passed every year by from 4980 to 5200 vessels. Considerable works have also been made to connect the different lakes and lake-basins for inland navigation, a sum of 25,000,000 marks having been spent for that purpose.

For *postal service* Finland had in 1898 820 post-offices, the total of letters, papers, &c., transported attaining 34,000,000.

The *telegraphs* (3300 miles) chiefly belong to Russia, excepting the railway telegraphs (2970 miles). Telephones have taken a wide extension both in the towns and between the different towns of southern Finland, the telephone net of the chief society having a length of 3180 miles; the cost of the yearly subscription varies from forty to sixty marks, and is only ten marks in the smaller towns.

Commerce.—The foreign trade of Finland has been steadily growing, reaching in 1899 the following items in marks:—

	From or to Russia.	From or to Other Countries.	Totals.
Imports . .	85,100,000	165,900,000	251,000,000
Exports . .	57,300,000	130,000,000	187,300,000

The chief trade of Finland is with Russia, and next with Britain, Germany, Denmark, France, and Sweden. The main imports are: cereals and flour (44,449,000 marks), metals (22,774,000), machinery (19,334,000), textiles (19,286,000), raw cotton, wool, and twist (10,742,000). The chief articles of export are: timber and wood articles (93,490,000 marks), butter and other farm produce (28,987,000), paper and paper pulp (17,213,000), some tissues, metallic goods, leather, &c.

The ports of Finland were entered in 1898 by 8566 ships of more than nineteen tons, representing an aggregate tonnage of 1,919,000 tons; 5878 of them (862,000 tons) were Finnish. The chief ports are Helsingfors, Åbo, Viborg, Hangö, and Vasa. The commercial fleet numbered, in 1898, 1896 sailing ships (271,824 tons) and 236 steamers (41,043 tons).

Education.—Great strides have been made since 1866, when the new education law was passed, to spread education in the country. Rudimentary teaching in reading, occasionally writing, and the first principles of Lutheran faith are given in the maternal house, or in "maternal schools" (235 in number), or by ambulatory schools (951), under the control of the clergy, who make the necessary examination in the houses of every parish. This education is received by nearly all Lutheran children, *i.e.*, by 404,745 children out of 413,867 of from seven to fifteen years of age, and by 5442 out of 7763 Greek Orthodox children of the same age. All education above that level is in the hands of the Educational Department and School Boards elected in each parish, each rural parish being bound (since 1898) to be divided into a proper number of school districts and to have a school in each of them, the state contributing to these expenses 800 marks a year for each male and 600 marks for each female teacher, or 25 per cent. of the total cost in urban communes. In the towns, 12,725 boys and 13,206 girls received in 1898–99 education in such schools from 795 teachers. In the rural communes there were 1650 schools of that standard, with a staff of 1888 teachers, and with 72,991 pupils (32,769 girls). There are besides twenty-two superior folk-schools (about 8000 pupils), all due to private initiative. Of schools for teachers there are now ten (five male, five female; eight Finnish, two Swedish). Secondary education, formerly instituted on two separate lines, classical and scientific, has been reformed so as to give more prominence to scientific education, even in the classical (linguistic) lyceums or gymnasia. There are now fifteen classical and nine "modern" (scientific) gymnasia (4723 pupils), and six "elementary" schools, containing each the three or four first forms of the gymnasia (431 pupils, of whom 155 are girls). There are besides twelve gymnasia (high schools) for girls, with 1732 pupils, and ninety private secondary schools (2916 boys and 4869 girls). For higher education there is the university of Helsingfors (formerly the Åbo Academy), which had, in 1900, 2318 students (363 ladies) and 119 professors and docents. Besides the Helsingfors polytechnic there are a number of higher and lower technical, commercial, and navigation schools. Finland has several scientific societies enjoying a world-wide reputation, as the Finnish Scientific Society, the Society for the Flora and Fauna of Finland, several medical societies, two societies of literature, the Finno-Ugrian Society, the Historical and Archæological Societies, one juridical, one technical, and two geographical societies. All of these, as also the Finnish Geological Survey, the Forestry Administration, &c., issue publications well known to the scientific world. The numerous local branches of the Friends of the Folk-School and the Society for Popular Education display great activity, the former by aiding the smaller communes in establishing schools, and the latter in publishing popular works, starting their own schools (twenty-one in 1900) as well as free libraries (in nearly every commune), and organizing lectures for the people. The university students take a lively part in this work.

Finances.—The budget of Finland, in an average for the three years 1895–97, was 59,744,777 marks of revenue, to which an average of 5,850,000 marks obtained by railway loans has to be added. As to the expenditure, it attained during the same three years an average of 46,597,693 marks of ordinary expenditure, and 8,643,843 of extraordinary for new railways. The estimates of expenditure for the following three years were: ordinary, 51,863,206 marks; extraordinary, 11,388,333; total, 63,251,539 marks. The public debt (3 and 3½ per cent.) reached, on 1st January 1900, 112,432,178 marks. The expenditure of the towns was 16,122,000, and of the rural communes 5,358,000 marks. The municipal and communal debts attained the sum of 31,152,000 marks.

Government and Administration.—After the year of annexation to Russia, 1809, up till 1898, Finland was considered as a separate state, the head of which, or grand duke, is the Emperor of Russia, and which is governed by the grand duke and the Diet, composed of representatives of the four estates—nobility, clergy, burghers, and peasants (30 per cent. only of the population having the franchise). The finances, the judicial, educational, clerical, and economic administration were entirely in the hands of the Diet and the Finnish senate, nominated by the Emperor (see *Ency. Brit.*, 9th ed.). The minister of war, however, had to be the Russian war minister, and the minister of foreign affairs the Chancellor of the Russian empire. Several encroachments, however, have been made since upon that independent organization: the posts of Finland were brought under the Russian post-administration, and an Imperial decree promulgated in 1898 established the right of the Imperial power to recognize certain matters (and specially military service) as Imperial matters, and to act accordingly without the consent of the Diet, while the use of the Russian language was to be rendered obligatory in various branches of the administration and the courts. This attempt to Russify Finland led to a serious agitation in protest, but without success; and many Finns left the country rather than submit.

Ethnology, Ethnography, Archæology.—Considerable researches have been accomplished since about 1850 in these subjects, on a scale which has no parallel in any other country. The study of the prehistoric population of Finland—Neolithic (no Palæolithic finds have yet been made)—of the Age of Bronze and the Iron Age has been carried on with great zeal. At the same time the folk-lore, Finnish and partly Swedish, has been worked out with wonderful completeness (see *L'Œuvre demi-séculaire de la Société de Littérature Finnoise et le mouvement national Finnois*, by Dr E. G. Palmén, Helsingfors, 1882, and K. Krohn's Report to the London Folk-lore Congress of 1891). The work that was begun by Porthan, Z. Topelius, and especially E. Lönnrot (1802–1884), for collecting the popular poetry of the Finns, was continued by Castrén (1813–1852), Europaeus (1820–1884), and V. Porkka (1854–1889), who extended their researches to the Finns settled in other parts of the Russian empire, and collected a considerable number of variants of the Kalevala and other popular poetry and songs. In order to study the different eastern kinsfolk of the Finns, Sjögren (1792–1855) extended his journeys to North Russia, and Castrén to West and East Siberia (*Nordische Reisen und Forschungen*), and collected the materials which permitted himself and Schiefner to publish grammatical works relative to the Finnish, Lappish, Zyrian, Tcheremiss, Ostiak, Samoyede, Tungus, Buryat,

LONDON FIRE BRIGADE, HORSED ESCAPE.

LONDON FIRE BRIGADE STATION.

Karagas, Yenisei-Ostiak, and Kott languages. Ahlqvist (1826–1889), and quite a phalanx of linguists, continued their work among the Vogules, the Mordves, and the Obi-Ugrians. And finally, the researches of Aspelin (*Foundations of Finno-Ugrian Archœology*, in Finnish, and *Atlas of Antiquities*) led the Finnish ethnologists to direct more and more their attention to the basin of the Yenisei and the Upper Selenga. A series of expeditions (of Aspelin, Snellman, and Heikel) were consequently directed to those regions, especially since the discovery by Yadrintseff of the remarkable Orkhon inscriptions (see MONGOLIA), which finally enabled the Danish linguist, V. Thomsen, to decipher these inscriptions, and to discover that they belonged to the Turkish Iron Age. (See *Inscriptions de l'Iénissei recueillies et publiées par la Société Finl. d'Archéologie*, 1889, and *Inscriptions de l'Orkhon*, 1892.)

See also RUSSIA. Full bibliographical indexes of recent works as well as excellent general descriptions of Finland, will be found in *Travaux géographiques exécutés en Finlande*, published for the London Geographical Congress of 1895. Other works are *Atlas de Finlande*, with French *Texte*, published in 1899 by the Geographical Society of Finland; *Notices sur la Finlande*, published in 1900 for the Paris Exhibition; *Finland in the Nineteenth Century*, published on the same occasion; *La Constitution du Grand-Duché de Finlande; recueil de lois fondamentales*, &c.; and an excellent illustrated and detailed work *Finlandia* (1898), in which the country and its life are very well described, and the constitutional question is documentally dealt with so as to answer the arguments of the Russian imperialists (Ordin, &c.); this work contains a very complete bibliography in all branches. A good English book on the constitutional history is *Finland and the Tsars*, by JOSEPH FISHER, 2nd ed., London, 1900. (P. A. K.)

Finmark, in Norway, the regions inhabited by the Lapps, whom the Norwegians call "Finns." (See LAPLAND.)

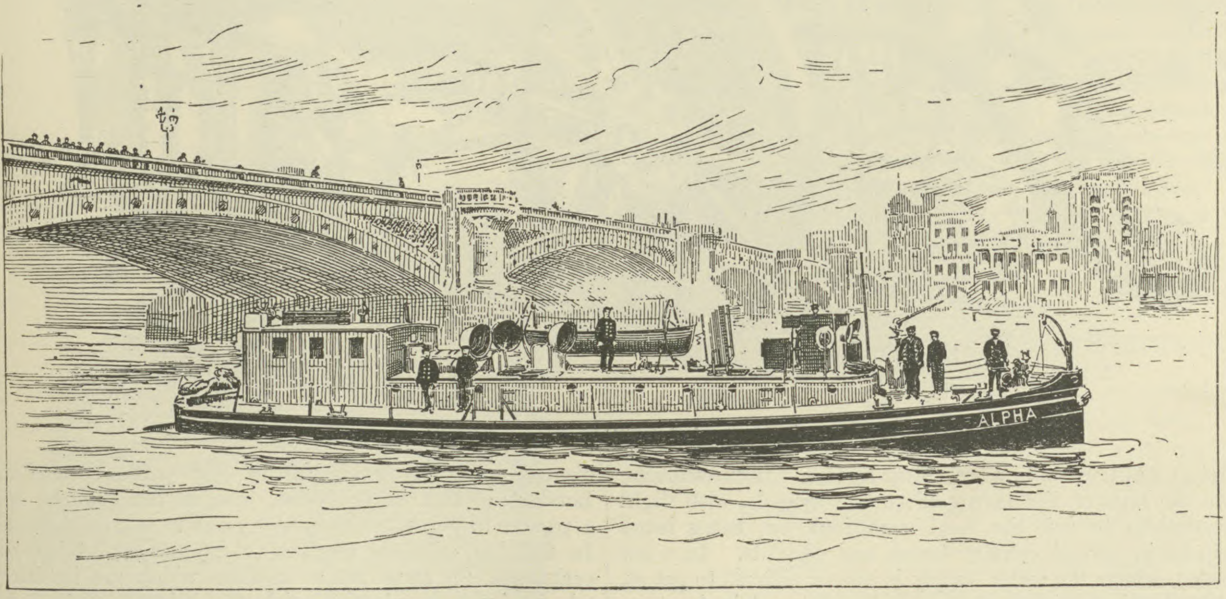
Finsterwalde, a town of Prussia, on the Schakebach, emptying into the Little Elster, 28 miles west-south-west of Cottbus by rail, in the circle of Luckau, government district of Frankfurt. The town has a Gothic church (1581), a castle, two girls' schools, cloth and cigar factories, iron-foundries, flour and saw mills, machinery factories, screws, &c. Population (1890), 8133; (1900), 10,726

FIRE AND FIRE EXTINCTION.

UNITED KINGDOM

In England it is only in recent years that the matter of fire protection on what may be termed efficient lines has been seriously considered. A committee of the House of Commons reported in July 1900 that, except in the large cities and towns, the fire arrangements, where any arrangements exist at all, were often inadequate, and that in the majority of places and districts there were practically no arrangements for protection against fire. The committee accordingly called attention to the need of legislation upon the subject.

Fire arrangements may be regarded from two points of view, *i.e.*, the saving of life, and the preservation of property; and it is possible for a force to be equipped with greater consideration to the saving of property than to the saving of life, or *vice versâ*. Roughly speaking, the appliances for life saving, such as ladders, poles, ropes, &c., are utilized more or less in saving property, as they enable firemen to get close to a fire, whether life has to be saved or not. On the other hand, in country towns, it may be argued that provision of life-saving appliances may, to a certain extent, be disregarded, inasmuch as statistics show that very few, if any, deaths result from fire. In Great Britain and Ireland the fire service is recognized as a public service, and such questions as those of payments to brigades, of the amount of pecuniary assistance (if any) that insurance companies should contribute to the cost of brigades, of the protection of the fireman's uniform under the Uniforms Act 1894, of the powers given to the officers commanding brigades, &c., will probably be matters of legislation in the near future. There is no general statute, but London and a few of the larger cities work under their special and local Acts of Parliament. The Fire Brigade Act of 1865, a comparatively short and simple statute, gives the chief officer of the London fire brigade extensive authority to act on the occasion of fire, including powers "to take any measures

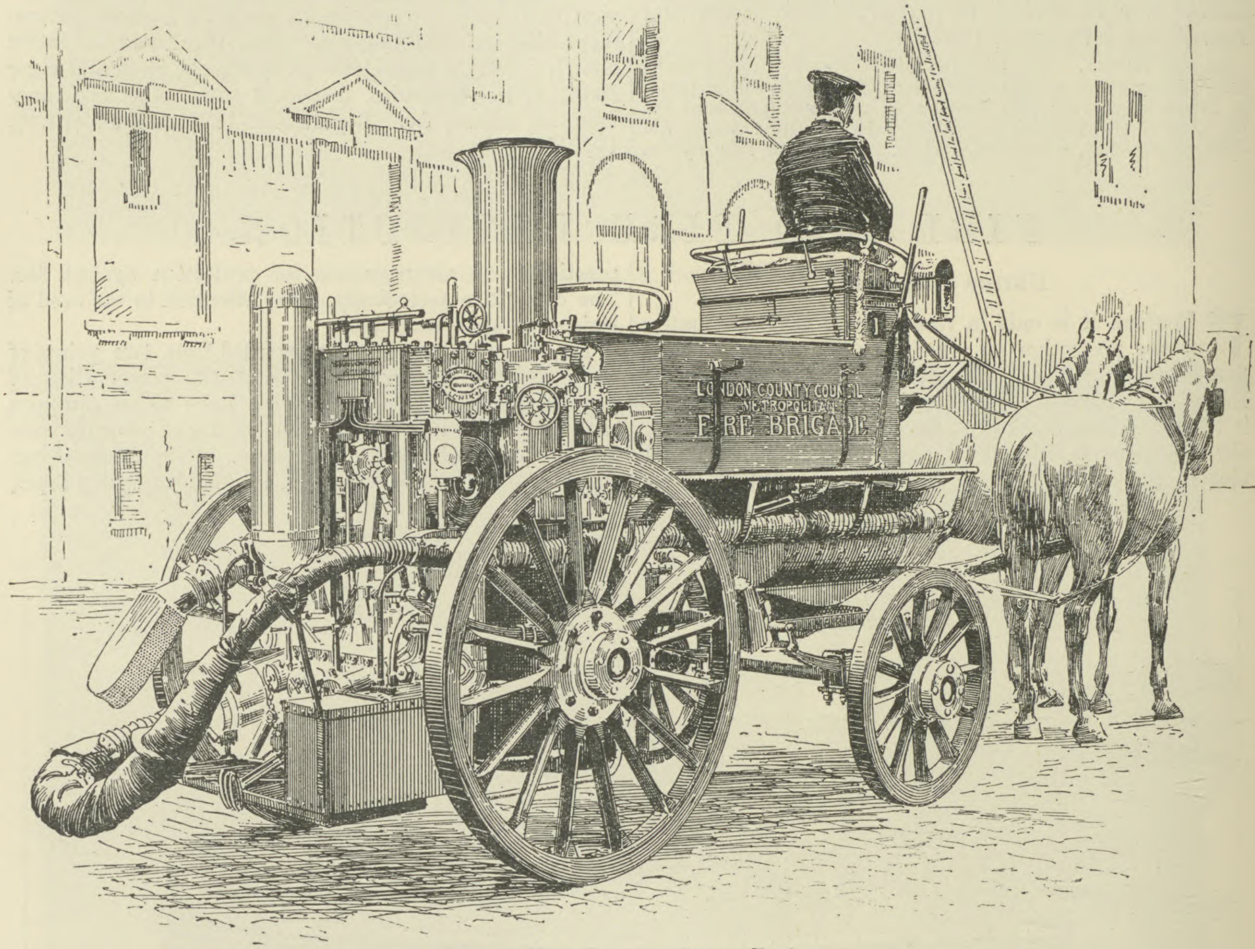


LONDON FIRE BRIGADE STEAM-FLOAT *ALPHA*.

that appear expedient for the protection of life and property."

The monthly summary for 1900 and the summary of causes of fire in 1900 (pp. 401–2) give an idea of the work done by the London fire brigade. The county of London, which is about 130 square miles in extent, contains sixty-nine stations, each commanded by an officer, and having life-saving and fire-extinguishing appliances adequate for dealing with a moderate-sized fire in that particular district. When a call is received at one of these stations (which are, generally speaking, about a mile apart) the whole strength of that station attends, and appliances are sent on from neighbouring stations to reinforce, according to the call received and the risk of the locality. In London, every machine, whether horsed-escape, fire-ladder, or steamer, is sent away as a complete unit, with a sufficiency of men, hose, &c., to get to work immediately on arrival. The London horsed-escape carries a 50-feet life-saving ladder, a coachman and four firemen, and is never sent out of the particular area for the protection of which it is provided.

The London County Council has, in recent years, spent, and continues to spend, large sums of money in improving the fire brigade, both on land and on the river, equipping it with the very best machines to suit the peculiarities of the water supply and other circumstances peculiar to London. Illustrations are given of a horsed-escape and a steam engine, and of the fire-float *Alpha*, the

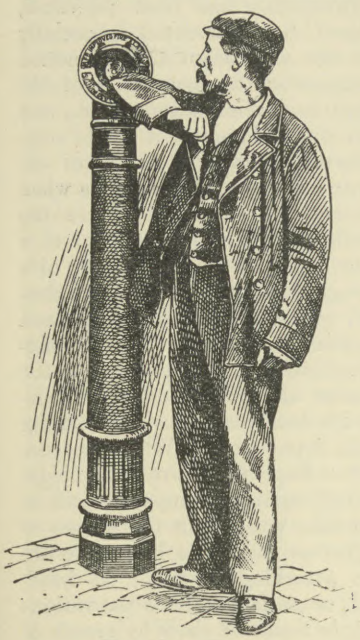


London Fire Brigade Steam Engine.

latest addition to London's river service. Improvements, on the lines of the metropolitan fire brigade, with slight variations to suit the local conditions, are being introduced in several country towns and districts. In a few cases, where the water supply is bad or difficult to get at, the chemical engine, such as is largely used in America, has been tried, but it cannot be said to have found favour generally. The smalier types of this machine, carried and worked by hand, are frequently used for indoor purposes, and it is a matter for the consideration of the householder whether these appliances, or some form of hand-pump, with buckets, afford the best "first aid" for indoor work in fire extinguishing pending the arrival of qualified firemen, who should invariably be promptly called on an outbreak of fire being discovered.

Fire-alarm posts, giving facilities for telephonic communication, of the simplest possible pattern are placed at distances varying from 300 to 800 yards throughout London, so that in few cases, save in the suburbs, has a person to run more than 400 yards to call the brigade. In addition, calls are received (*a*) by means of telephone exchanges, (*b*) from police stations which are in direct telephonic communication with the brigade, and (*c*) by persons running to fire stations. We give illustrations of the latest pattern of London alarm posts, and the method of using the telephone attachment.

One of the principal considerations with any brigade is to get the earliest possible call to a fire, and several forms of automatic alarm have been devised. Whether an electric bell be set ringing by the expansion of a thin wire under the influence of the heat produced by the fire, by the rising of mercury in a thermometer, by the melting of some particular compound at a low temperature, or by the fusing or metallic joining of the circuit wires, is a matter of choice to the occupier; but the main objects to him are (1) the reduction of his fire insurance premium, and (2) the reduction of loss to a minimum should an outbreak occur. It is possible that considerable advantage would accrue by the installation of an automatic alarm which would, at an early stage, attract the attention of the police on duty, who could verify the existence of a fire and then immediately call the brigade.



Fire-Alarm Post.

The method of insuring a deluge of water in the early stages of a fire is also proving itself, in certain cases, of advantage. This system is called the Sprinkler system, and consists of water pipes so traversing a building that on the application of heat the valve is automatically set free and the water descends in the neighbourhood of the fire. The system, devised in much the same way, of water curtain, or a stream of water striking the side of a building, doorway, or lift, has also been frequently installed, but the governing factor in these cases usually is the reduction of premium allowed to the occupier by the company which insures the premises and contents.

Fire-Alarm Post: Method of using Telephone Attachment.

Experiments have been carried out in London with a view to substituting oil for coal used in working steam engines, and some success has been met with. The practicability of substituting motor power for horses used in the traction of fire appliances is also being considered, and it is hoped that the change will result in economy, to say nothing of increased efficiency.

With a low-pressure water supply the time within which the steam, or other pumping power, can be available is a matter of the greatest importance, especially when coping with an outbreak in high buildings. For such buildings, the system of dry mains is viewed with favour. Under this system pipes to deliver water at suitable points are installed, but are not filled with water until the connexion is made to the water main or pump, as the case may be, outside the building.

The net cost to the ratepayers of the maintenance (including pensions) of the London fire brigade is about equal to a rate of $1\frac{1}{4}$d. in the pound, but in the country generally, where first-class volunteer labour can be obtained, it is quite possible to get a reasonably efficient brigade for something like a rate of a halfpenny in the pound. If this fact were generally appreciated, and districts could lay aside all municipal jealousies and freely help each other in the case of large fires, as is done by London and the larger towns, the result of the property loss would be far different.

The question has been discussed whether fire insurance companies should be legally required to contribute generally to the cost of maintaining fire brigades on some such system as obtains in London, where they pay £35 per million per annum on property insured. On the one hand, it is argued that there should be some general and fair system by which insurance companies should contribute towards the expenses of fire brigades, which in the ratio of their efficiency do so much for the benefit of the companies' shareholders; and on the other hand, it is argued that insuring is an industry of such essential benefit to the community that it is not expedient to tax it. Against the latter view, however, it is urged that if the industry be so profitable, the ratepayers should get the benefit of it, and this might lead either to municipal insurance or to the example of large railway companies, who are their own insurers, being followed by municipal authorities.

The strength of some of the principal brigades is as follows:—

London: 1216, including chief, second, and third officers and all ranks, also workshops, stores, and clerical staff.

Glasgow: 116, including chief officer, superintendent, and all ranks.

Manchester: 100, including chief officer and all ranks.

Belfast: 78, including chief officer and all ranks.

Birmingham: 65, including chief officer and all ranks.

Monthly Calls to Fire in London, 1900.

Month.	Per Centum.		Total calls in each Month.
	Serious.	Slight.	
January	6·38	93·62	409
February	3·42	96·58	352
March	3·46	96·54	428
April	1·70	98·30	387
May	2·00	98·00	392
June	3·68	96·32	345
July	3·13	96·87	432
August	1·90	98·10	360
September	5·32	94·68	331
October	2·82	97·18	379
November	2·10	97·90	337
December	4·80	95·20	377
Total	3·40	96·60	4529

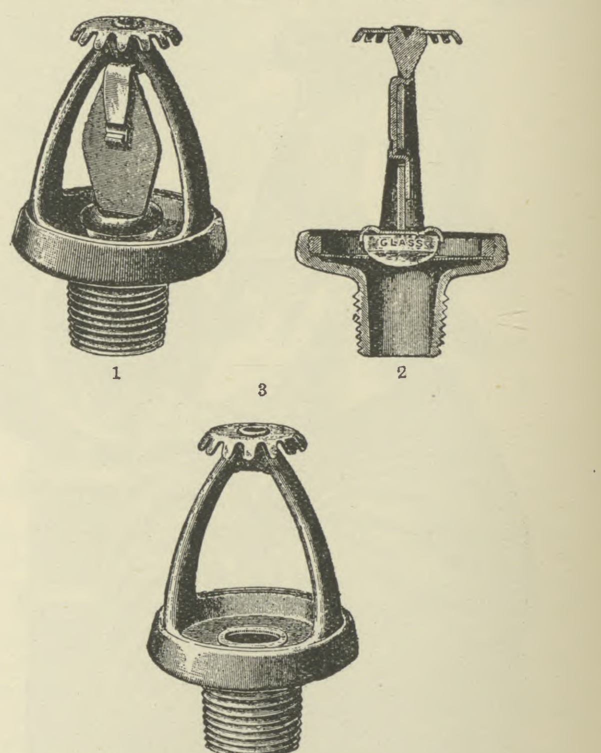
Summary of Causes of Fires, 1900.

Airing bedding	7
Airing linen	68
Bisulphide of carbon	1
Boiler, explosion of	2
Boiler, overheat of	3
Boiling over chemicals, fat, oil, pitch, spirit, tar, resin, varnish, wax, &c.	44
Burning rubbish	9
Candle	173
Candle, curtains or window blinds coming in contact with	37
Candle, decorations coming in contact with	2
Celluloid film coming in contact with flame	1
Children playing with fire	57
Children playing with lucifers	116
Children playing with gaslight	1
Coke, overheat of	3
Copper, overheat of	2
Ether	1
Electric wires, short circuit of	22
Fire, clothes coming in contact with	4
Fire, curtains coming in contact with	3
Fire-damp	1
Fire, falling on	1
Fireworks, explosion of	1
Fireworks, letting off	2
Flue blocked up	19
Flue, defect in	115
Flue, copper, defect in	3
Flue, copper, overheat of	4
Flue, furnace, defect in	1
Flue, furnace, overheat of	4
Flue, foul	21
Flue, overheat of	12
Flue, adjoining, defect in	34
Flue, adjoining, foul	3
Flue, adjoining, overheat of	4
Forge, overheat of	1
Friction of machinery	5
Fumigating	6
Furnace, overheat of	6
Gas bracket, swinging	32
Gas, escape of	98
Gas, explosion of	7
Gasfitters at work	6
Gaslight	6
Gaslighting	12
Gaslight, curtains or window blinds coming in contact with	71
Gaslight, decorations coming in contact with	6
Gaslight, goods coming in contact with	12
Gaslight, linen coming in contact with	3
Gaslight, scenery coming in contact with	1
Gas, seeking for an escape of, with light	31
Gaslight, overheat of	4
Gaslight, straw falling on	1
Gas stove	24
Gas stove, overheat of	11
Gas stove, portable	5
Gas stove, goods falling on	1
Carried forward	1130
Brought forward	1130
Gas stove, clothes coming in contact with	1
Hearth, defect in	12
Hearth, timber under	1
Hot ashes	74
Incendiarism	6
Incubator, overheat of	1
Kiln, overheat of	3
Lamp, mineral oil	45
Lamp, mineral oil, curtains or window blinds coming in contact with	18
Lamp, mineral oil, decorations coming in contact with	3
Lamp, mineral oil, clothes coming in contact with	2
Lamp, mineral oil, exploding	23
Lamp, mineral oil, upset	157
Lamp, naphtha	4
Lamp, plumber's, exploding	1
Lamp, spirit	6
Lamp, spirit, upset	2
Lighted taper	12
Light thrown down	268
Light thrown from street	34
Lightning	1
Lime slaked by rain	1
Lime slaking	2
Lucifers	7
Mineral oil upset	3
Oven, overheat of	5
Painters at work	1
Plumbers at work	1
Salvage, overheat of	2
Smokehole, overheat of	4
Smoking tobacco	13
Spark from copper fire	4
Spark from "devil"	1
Spark from fire	190
Spark from flue	11
Spark from flue adjoining	4
Spark from furnace	12
Spark from locomotive	16
Spirit upset	1
Spontaneous ignition	2
Steam pipe, overheat of	3
Still, overheat of	1
Stove, drying, overheat of	3
Stove improperly set	38
Stove, overheat of	18
Stove, adjoining, overheat of	4
Stove, ironing, overheat of	2
Stove, mineral oil	21
Stove, mineral oil, overheat of	3
Stove, mineral oil, upset	23
Stove pipe, overheat of	1
Stove, mineral oil, exploding	3
Stove, portable	3
Stove, spirit	7
Stove, spirit, upset	1
Stove, mineral oil, goods coming in contact with	1
Stove, beeswax upset on	1
Unknown	1156
Vapour of spirit coming in contact with flame	10
Watchman's fire	2
Total	3385

United States.

The freedom from great fires and conflagrations that has marked the years since 1875 in America is the more noteworthy because of the abnormal growth of large towns and cities, the great increase in number of extremely high buildings, and the development of great manufacturing establishments, all of which add enormously to the danger from fire. The fire-proof construction of buildings (see BUILDING) has been perfected, and many appliances have been invented, especially in the United States, for the prevention and extinction of fires. The fire departments in the large cities of the United States are organized on a semi-military basis, and in each city are under the entire charge of a single commissioner or board of commissioners. A "chief of department" is the executive officer on all occasions when the force is called into action. Under him are the "battalion" or "district-chiefs," each in command of a district of the city. Each engine company consists of a captain and lieutenant, engineman and assistant enginemen, and eight horsemen. Each ladder company has a captain, lieutenant, and twelve laddermen. The district-chief's driver is a telegraphist, and on reaching a fire stations himself at the nearest alarm box and opens telegraphic communication with headquarters, thus insuring instant control of the whole department. When the concentration of the force at a large fire leaves the neighbouring districts unprotected, outlying companies still in reserve are brought in and take position in the houses of those already called out, just as regiments in reserve are advanced to support the attacking column. At headquarters a covering board, or map on which the various engine houses are marked, is made to show by means of movable pegs the position of each company in action and in reserve.

Fire Prevention.—The *Automatic Sprinkler* is of conspicuous value in mills and factories, and similar buildings where the risks are great. It consists of lines of



FIGS. 1, 2, 3.—Automatic Sprinkler.

water pipes carried through the building near the ceiling, 8 or 10 feet apart. Sprinkler heads are attached on the upper side of the pipe. The main supply pipe must be large enough to give a discharge at full pressure from all of the sprinklers in the room at once. The sprinkler (Figs. 1, 2, 3) has a half-inch outlet, kept closed by a valve held in place by a device, an essential feature of which is an easily fusible solder. A fire starts and the heat quickly melts the solder; the valve is swept away by the water pressure; the half-inch stream bursts out, and striking against the deflector above is spread in a shower. Under ordinary conditions, from one to four sprinklers will extinguish the fire. In extreme cases all of the sprinklers in a room may be called into action. In the record of all of the American Associated Factory Mutual companies for the five and a half years ending 1st January 1900, it appears that of 563 fires where automatic sprinklers were called into play, 129 (60 without loss) were held by one automatic sprinkler, 88 (31 without loss) by two sprinklers, 61 (21 without loss) by three sprinklers, 44 (10 without loss) by four sprinklers, 40 (6 without loss) by five sprinklers. In the remaining 201 fires held by sprinklers (26 without loss), the sprinklers opening ranged from six to two hundred and fifty. The *Dry-Sprinkler System* is of value only where the water is liable to freeze. The pipes are filled with air under a pressure of say 10 lb. The opening of the sprinkler head by the heat allows the escape of the compressed air; the consequent loss of pressure unlocks a simple arrangement of levers and opens the water valve of the main feed pipe; the water under proper pressure then circulates through all of the sprinkler pipes.

Automatic Fire Alarm.—The system of the Boston Automatic Fire Alarm Company has been perfected during the period 1880–1901, and its efficiency proved. The essential feature is a "thermostat" or heat-detector, contained in a small round box about $2\frac{1}{2}$ inches in diameter with a perforated lid. It consists of a bent spring, made up of a strip of steel and one of brass welded together, the brass upon the outside of the curve. Its action depends on the greater expansion of the brass. One end only of the spring being fast, the heat causes the free end to bend inwards till it closes an electric circuit. These instruments are placed, usually at intervals of about 15 feet each way, upon the ceiling of a room, closet, or nook in the building, and are adjusted to act at any desired temperature, ordinarily at 130° to 150° F. These are connected with each other and with the "transmitter." The heat from even a very small fire rising to the ceiling quickly causes the thermostat to transmit the exact position of the fire to the office of the Company. The force of the fire department is usually on its way to the fire about one minute after the thermostat acts. The receiving, recording, and transmitting apparatus are the same in principle as the larger ones at the city fire alarm headquarters described below. With so sensitive an instrument a certain number of needless alarms seems inevitable, but its value is beyond question. In 1900 more than 600 buildings in Boston and 2000 in New York were equipped with these automatic fire alarms.

The *Fire Alarm System* consists (1) of street or signal boxes on a closed electric circuit, from which signals giving automatically the number of the box are sent to headquarters; (2) various receiving and recording instruments at headquarters; (3) apparatus for transmitting to the several houses of the department the number of the box signalled; and (4) a battery or other adequate source of electric power. The electric fire alarm telegraph, invented by Dr W. F. Channing and Moses G. Farmer, was first adopted in the United States at Boston in 1851. It had then 40 miles of wire in 5 circuits, 45 signal boxes, and 10 bells. In 1899 it had 1500 miles of wire, 624 signal boxes, 20 bells, 104 gongs, 90 tappers, and 35 circuits in use, with equipment for 70 circuits. During the twenty years to 1871 about twenty cities in the United States adopted the fire alarm system. By 1876 the number had increased to seventy-five. In the signal box is a clockwork (Fig. 4), which is set in motion by once pulling down the hook that projects through the inner door. This mechanism breaks and closes an electric circuit by means of a wheel, and thus telegraphs to headquarters four rounds of the number of the box. The box contains a lightning arrester, which also protects the mechanism against the high tension currents of the trolley

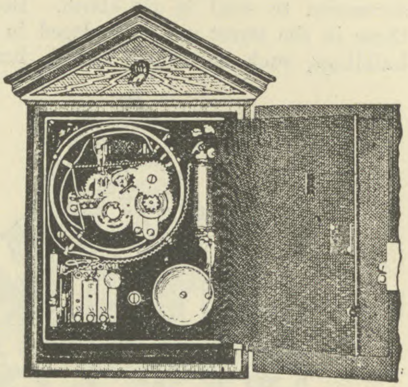


FIG. 4.—Alarm Clock.

and the electric-light wires, a telegraph key, and a call-bell for fire department and police signals. Keyless boxes (Fig. 5) have replaced the locked boxes in districts where they are less liable to be mischievously tampered with, and valuable time is thereby saved. To open the outer door the conspicuous handle is turned to the right, which rings the bell inside, and by calling attention to the fact that the box is being opened, acts as a safeguard against malicious false alarms. The alarm is given by pulling the handle projecting through the inner door, as already mentioned. When boxes are placed within short distances of each other two or more are liable to be pulled at the same moment for the

FIG. 5.—Keyless Box.

same fire. To obviate confusion in the record at headquarters, contiguous boxes are placed on different circuits, so that the number of each is recorded separately.

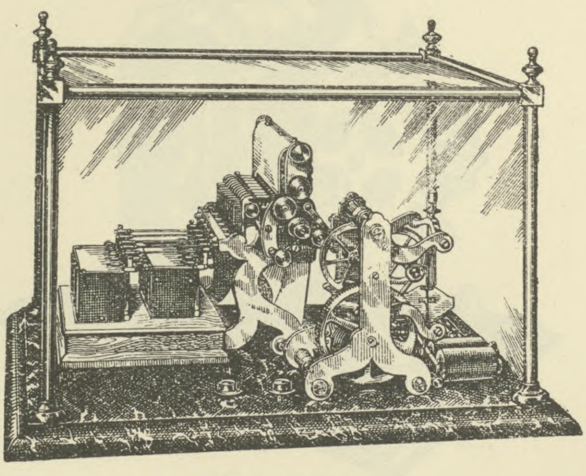


FIG. 6.—Register.

From twenty to twenty-five boxes are usually on a circuit. "Non-interference" boxes are designed to meet the same difficulty; the first box pulled is however the only one whose number is recorded. They are advisable when contiguous boxes are on the same circuit.

"Non-interference-successive" boxes contain a device which holds up all the other boxes until the first has finished its four rounds and then allows each box in succession to send in its alarm. Boxes in addition to those in the street are now placed in many large public buildings, such as school houses, hospitals, hotels and

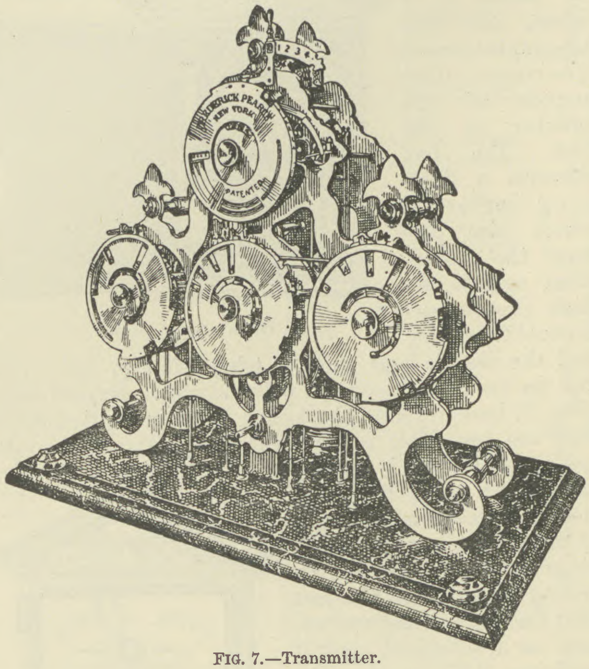


FIG. 7.—Transmitter.

theatres, and in many private buildings. Connected with each box small auxiliary boxes may be placed at various points in the buildings. At the fire alarm headquarters are appliances for transmitting the signals to the several houses of the department. The "register" (Fig. 6) receives through the relay and records the number of the

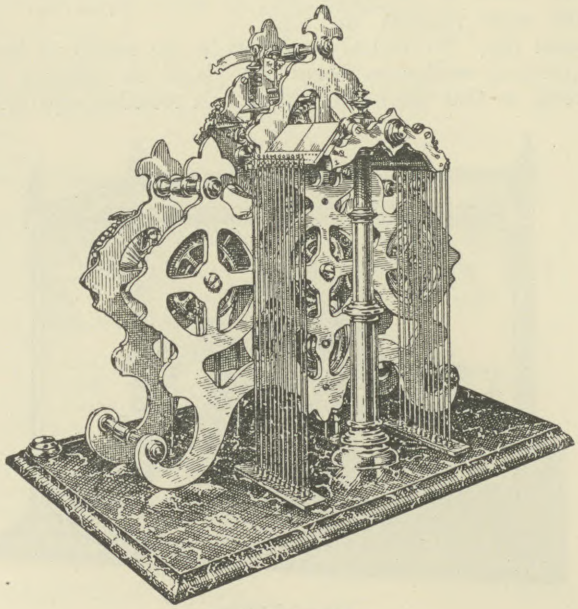


FIG. 8.—Transmitter.

alarm box upon a strip of paper that is automatically run out as soon as the box is started. Simultaneously a vibrating bell connected with the register strikes the same number. The "transmitter" (Figs. 7 and 8) is regulated by an arrangement of dials to strike upon the "tappers" in the department houses the combination of blows that makes up the number of the box. On the first intimation of an alarm the operators at headquarters take their positions, one at the receiver to observe and call out the number, and the other at the transmitter to set the dials as each figure of the number is called out. As soon as one round has been received the transmitter is released and strikes rapidly but distinctly on the tappers in each house three rounds. Before the alarm box has completed its four rounds the engines are well on their way to the fire. As soon as the tapper-transmitter stops, another similar transmitter on a different circuit strikes the alarm on the large gongs in the houses and on such public bells as may be necessary to notify the call-numbers of the suburban companies. The time consumed in sounding the alarm ranges from fifteen to thirty seconds, according as the number of the box is low or high. Electric motor generators have taken the place of the old chemical batteries to furnish the electric currents for all circuits.

Fire Engines.—The practical limit in the size of the horse-drawn engine has been reached. Engines of the first order have steam cylinders 9 inches in diameter and pumps 5½ inches in diameter with an 8-inch stroke in each. They are usually run at 120 ℔ steam pressure, and in practice seldom deliver much over 600 gallons a minute. "Self-propellers" of the latest form have double the capacity of the horse-drawn engine of a few years ago. They have steam cylinders 9½ inches in diameter and pumps 5¾ inches in diameter with an 8-inch stroke in each. At 300 revolutions the pumps will deliver 1036 gallons a minute. They stand in the houses always under a working pressure of steam. They weigh, when fully equipped, a little less than nine tons, but in spite of their great weight they are easily guided, and with an unobstructed roadway can always outstrip the horse-drawn engines. For the protection of shipping and the water front, steam fire boats are necessary. These are always under full steam, and usually lie at their regular dock. Their pumps, 10 inches in diameter with a 10-inch stroke, give at 225 revolutions 6520 gallons a minute. Such a power, the equivalent of nine average engines, makes them a most valuable part of the system.

In order to extend the radius of action, and more effectively to utilize this great power, Boston has a salt water fire system,[1] consisting of about 5000 feet of 12-inch cast-iron pipe, 1 inch thick, laid through the business district adjoining the water front. Each end of this pipe is at deep water accessible to the fire boats. At each end the pipe divides into two 10-inch pipes, each of which has a "boat connexion," with six 3½-inch outlets for attachment of hose. Each outlet has a valve opening inwards. One or both boats can connect, using 3½-inch hose in 15 to 30 feet lengths, with the twelve outlets or any less number. The maximum water pressure at the boat is 200 ℔ on the square inch. Hydrants are placed on the pipe 300 feet apart. The hydrants, known as the Bachelor Hydrant, are unusually heavy throughout, with three 3-inch outlets, each controlled by an independent valve. Each hydrant has an electrical attachment connecting with the fire boat and the headquarters of the department, so that the district chief, whose telegrapher-aid accompanies him to every fire, can control by telegraph the action of the boat, and can send and receive messages to and from headquarters. The pipe is kept full of salt water, but if it is found to be liable to excessive corrosion, it can be filled with fresh water immediately after service. One most valuable feature of this system is the concentration upon a given point of enormous streams of water drawn from an inexhaustible supply. In a test at one half mile from the water front, with one fire boat in service, two streams, each of 1500 gallons per minute, were played simultaneously through 2½-inch nozzles with a nozzle-pressure of 50 ℔, three lines of 3-inch hose being "Siamesed" for each stream. In Cleveland, Milwaukee, Detroit, and Buffalo, systems largely similar have been in successful operation for several years. The pipes in Boston are empty when not in service, at least during cold weather. The

[1] "Salt Water Fire System of Boston," by Frank A. McInnes. *Journal of the New England Water Works Association*, vol. xiii., No. 4.

FIG. 10.—Jumping Net.

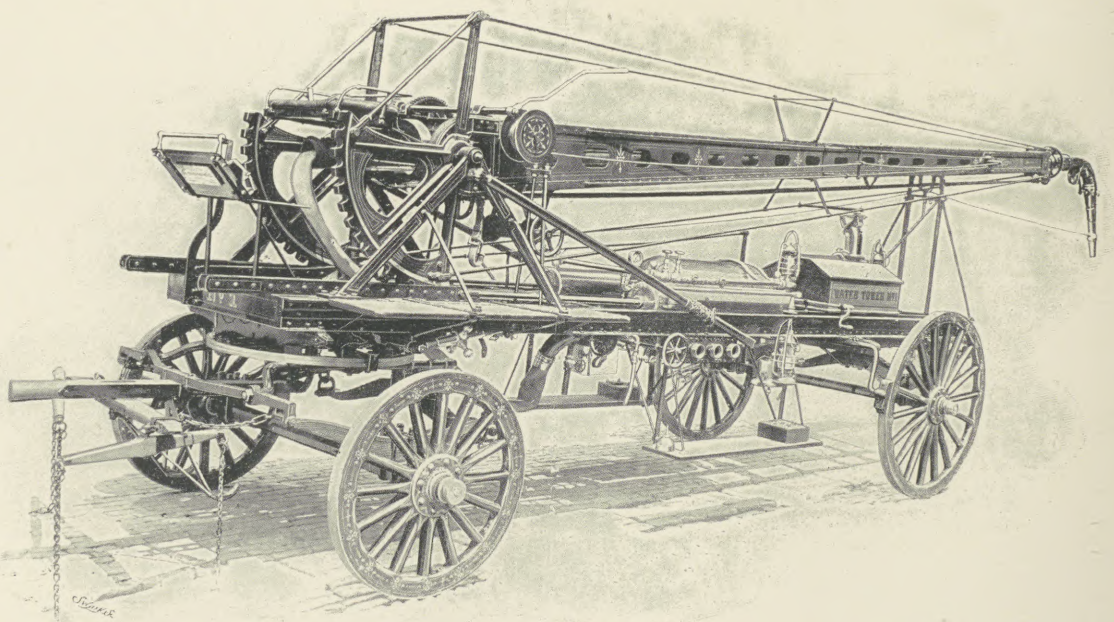


FIG. 11.—Water Tower.

elimination of the factor of frost in this way permits of shallow excavation, and probably prolongs the life of the pipe. The disadvantages are loss of time in filling the line, and the possibility of damage from imprisoned air in the operation of filling.

Chemical Engines and Portable Extinguishers[1] have proved their value in small fires, and are now largely used both in public and in private service. Of the 2130 fires in Boston reported for 1899, 19 per cent. were put out by chemical engines, and 22 per cent. by portable extinguishers. Some modifications in construction have been made, but no change in principle. The claim that the chemical ingredients are in themselves largely effective in quenching the fire has been disputed, but there is no question of the advantages of the instantly generated power. A greater development in the direction of private fire protection for hotels, theatres, and large business establishments, where a competent watchman or attendant is always assumed, is

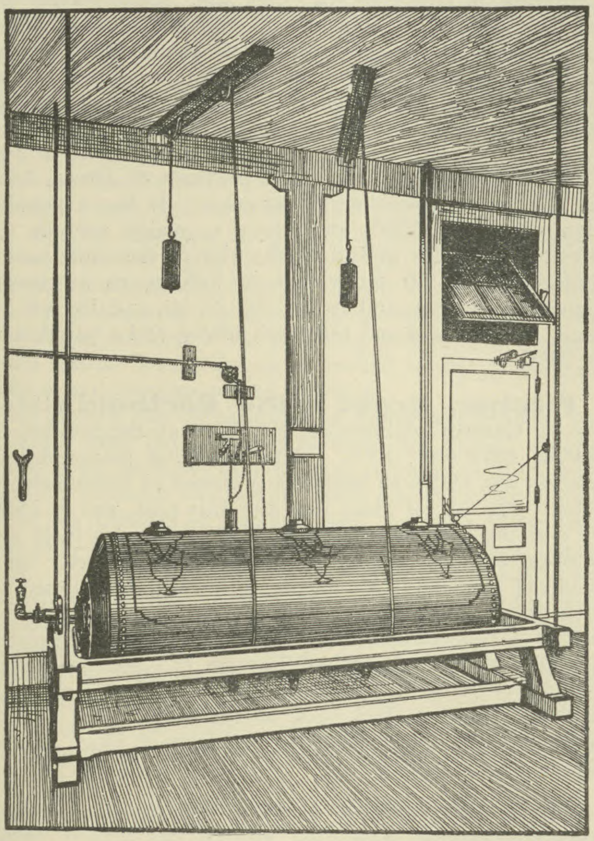


FIG. 9.—Champion Stationary Engine.

shown in the Champion Stationary Engine (Fig. 9). It is placed in the basement, and has special stand pipe connexion with one or more hose-stations on each storey. Each hose-station is covered by a small metal box with glass door. The pulling of the small handle inside releases the weights below; these invert the cylinder, and thereby cause the mixing of the chemicals and the immediate development of a heavy pressure. The process is to break the glass door, pull the handle, turn the valve, and reel off the hose, always attached, with its shut-off nozzle. The cylinder contains 500 gallons or less of the bicarbonate of soda solution. The stream is available in one minute.

Extension or "Aerial" Ladders are increasingly in use. The ladder is a permanent part of the truck which carries it, and is in two or three lengths; it is raised unextended to the proper angle by heavy screws worked by hand-cranks requiring six men; the upper lengths are then extended by a wire rope to the height desired; in use the upper end rests against the building. The details of construction and mechanism are varied by different builders, but the essential principle is the same. A line of hose is usually attached to the ladder and raised with it. The length, when fully extended, is from 90 to 100 feet. The truck carries in addition nine or ten separate ladders of different lengths. It weighs about five tons, and is drawn by three horses abreast.

Hose Waggons, drawn by two horses, have replaced the old hose reel. They carry the hosemen, 1000 feet of $2\frac{1}{2}$-inch hose, a jumping-net, two small portable chemical extinguishers, a door-opener, and the usual tools and minor pieces of apparatus.

The *Jumping Net* (Fig. 10) is made of stout tarred hemp rope, and is about 10 to 12 feet in diameter. It is essential that it be held firmly and fearlessly by a sufficient number of strong men. Firemen are drilled in its use. It has proved effective in saving life. (See Plate.)

By means of a *Water Tower* (Fig. 11, Plate) a powerful stream of water may be carried in a hose independent of the building, and delivered with full force at the height of 55 feet from the ground. The tower consists of a slender but stiff lattice iron frame, about 25 feet long, within which slides the extensible 5-inch round iron tube about 30 feet long that contains the hose. It is permanently mounted upon the waggon, lying horizontally as it is drawn to fires, and weighs all told about five tons. The waggon has an 8-foot gauge to insure a stable base. On reaching the fire the front axle is securely locked and the wheels are blocked. The tower is raised to the vertical by pressure from a carbonic acid gas-generating tank acting upon a piston with a rack geared into a quadrant at the base of the tower. The upper length, the extensible tube, is then raised, drawing up the hose with it, by a hand windlass. The tower is firmly locked. The direction of the stream from the movable pipe with its $2\frac{1}{2}$-inch nozzle can be controlled from below. The nozzle is rotated horizontally by means of an iron rod reaching from the base to the top, where it is geared into a small wheel, a part of the nozzle-pipe; it is raised to about 45° by the force of the stream, and lowered by a wire rope from below. The stout $3\frac{1}{2}$-inch hose of the tower takes its water from a chamber below, in which as many as six engine streams may be concentrated; the maximum volume and pressure are thus insured. The stream delivers upwards of 1000 gallons a minute. When a fire reaches a certain size and intensity, the ordinary $1\frac{1}{2}$- or $1\frac{3}{4}$-inch streams make little impression on it. To get sufficient concentration three or four lines of $2\frac{1}{2}$-inch hose are united or "Siamesed" into one larger one with a 3- or $3\frac{1}{2}$-inch nozzle, by means of a 3-way or 4-way brass casting to which they are coupled. Each inlet has its separate valve.

The *Gorter Battery* is convenient for concentrating as many as six ordinary streams into one. It weighs 1650 lb, and is drawn by one horse. When in action the weight is carried forward on to the shafts, which are fitted with spikes that take hold upon the ground and give the machine stability to withstand a back pressure of 1500 lb to the square inch. The nozzle is moved vertically in a ball-and-socket joint, and horizontally on a roller bearing. It throws a solid 2- to 3-inch stream 200 to 300 feet according to pressure. One man can easily control it, as the back pressure is taken up by the shafts.

Stand Pipes are used in "elevator buildings," which are too high to be commanded from the street or by dragging up the hose inside. The inside stand pipe is for use on a fire that has been promptly discovered. It is generally

[1] See *Ency. Brit.*, ninth edition, vol. ix. pp. 235–236.

connected with the city water system, and kept full of water under ordinary pressure, suitable lengths of hose ready for service being permanently attached on each floor. The outside stand pipe, from 4 to 6 inches in diameter, is for the use of the fire department; it stands empty; it

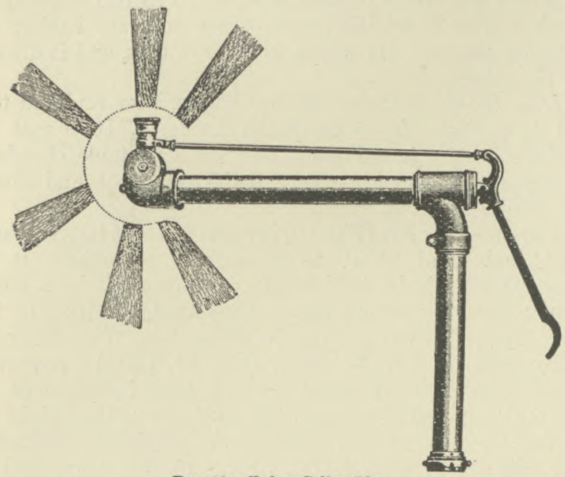


FIG. 12.—Baker Cellar Pipe.

has two or more inlets at or near the level of the sidewalk, to which hose from as many engines can be coupled, and two outlets on each storey to which short lengths of hose can be coupled and carried in through the adjacent windows. It should be placed in conjunction with a fire escape, if there is one, so that it may be easily reached by the fire-escape ladders.

The *Baker Cellar Pipe* (Fig. 12) has been found very effective in cellar fires. The pipe is passed through a hole cut in the floor over the fire; the nozzle is fitted with a ball-and-socket joint, and by means of the handle above the stream may be turned in nearly any direction. The *Bresnan Nozzle* is designed for the same use as the cellar pipe, and is perhaps equally effective; it has a revolving collar with a number of ½- and ⅝-inch outlets, so arranged as to throw streams in every direction and reach with its heavy spray every part of the cellar.

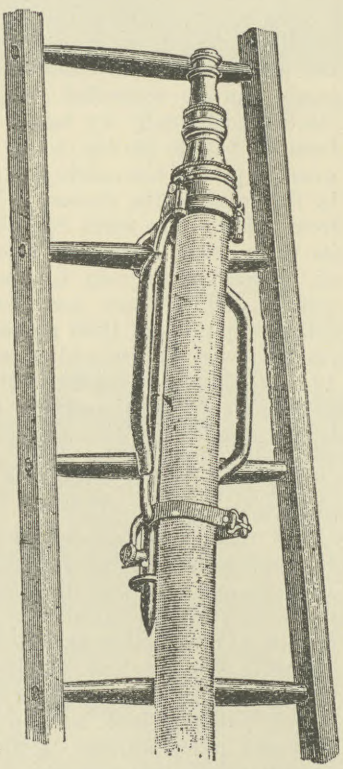


FIG. 13.—Eastman Nozzle Holder.

The *Eastman Nozzle Holder* (Fig. 13) dispenses with long play-pipes. It clasps the hose just below the nozzle, and the point, when fully drawn out, is planted in the ground and counteracts the back pressure from the nozzles, so that by means of the handles, insulated against electricity, one man can easily direct the heaviest stream. When used on a ladder, it may be hung by the hooks on the under side upon a rung or window-sill, and being pivoted at that point, the stream may be turned in any direction inside the window. The nozzle, about 10 inches long, contains in its middle length a short thin tube as a core, the diameter of which is three-fifths that of the nozzle at that point, held centrally by four wings fastened to the nozzle. The effect of this device is to correct the spiral movement of the water as it leaves the hose and to insure a smooth solid stream. By a system of electrical signals the man at the nozzle directs the action of the engine. Two insulated wires pass through the length of the hose, imbedded between two of its layers, and form an electrical circuit connecting a button on the nozzle and a bell and battery on the engine. The circuit is made continuous through the hose by the act of coupling. (A. P. R.)

Firminy, a town in the arrondissement of St Étienne, department of Loire, France, 7½ miles S.W. of St Étienne by rail. It has important coal mines and extensive manufacture of iron and steel goods, including railway material, machinery, and cannon. The mines have an annual output of about 92,000 tons, and give employment to about 4000 workmen. The principal textile industry is that of fancy woollen hosiery. Population (1881), 12,182; (1901), 16,903.

Fírúzkúh, a very small province of Persia, held in fief by the minister of arsenals. It has a population of about 5000, and pays a yearly revenue of about £400. Its capital is the city of the same name, situated about 90 miles east of Tehran, at an elevation of 6700 feet, and in 35° 46′ N. lat. and 52° 48′ E. long. It has post and telegraph offices, and a population of 2500.

Fischer, Ernst Kuno Berthold (1824–——), German philosopher, was born at Sandewalde in Silesia, 23rd July 1824. After studying philosophy at Leipzig and Halle, he became a professor at Heidelberg in 1850. His liberal ideas lost him this post, but in 1856 he obtained a professorship at Jena, where his lucid exposition and the dignity of his personal character soon rendered him highly influential. In 1872 he returned to Heidelberg. His part in philosophy has been that of historian and commentator, for which he was especially qualified by his remarkable clearness of statement. His *History of Modern Philosophy* (1852–77) is perhaps the most accredited modern book on the subject, and he has made valuable contributions to the study of Kant, Bacon, Spinoza, and Lessing.

Fish, Hamilton (1808–1893), American statesman, was born in New York city on 3rd August 1808. He graduated from Columbia College, and in 1830 was admitted to the bar, but practised for only a short time. In 1842 he was elected a Representative in Congress. In 1847 the Whigs elected him as lieutenant-governor of New York. In 1848 he defeated the Democratic candidate for the governorship. He was one of the United States Senators from New York from 1851 to 1857. In 1861 he was associated with John A. Dix, Wm. M. Evarts, Wm. E. Dodge, A. T. Stewart, and other New Yorkers, on the Union Defence Committee. As secretary of state during Grant's two administrations, 1869–77, he contributed to bring about the treaty of Washington, in May 1871, which created a basis for the arbitration of the *Alabama* claims. He was made president of the peace conference between Spain and the allied republics of Peru, Chile, Ecuador, and Bolivia. It was chiefly due to Fish's management in 1873 that the *Virginius* affair did not result in a war between the United States and Spain. He died in Garrison's, New York, on the 7th September 1893.

Fisheries.—In the last quarter of the 19th century the sea fisheries of the United Kingdom underwent a great development, principally in consequence of the application of steam power to fishing boats, and especially to trawling vessels. Necessity was in this case especially the mother of invention, for the industry of steam trawling dates its origin from a period of severe stagnation in the shipping trade in the later 'seventies. Some of the steam-tugs plying at the mouths of the Tyne and Wear resorted to trawling in the neighbourhood as an accessory occupation, and met with such success that the practice spread to other parts of the coast. The unsuitability of these "tug-trawlers" for deep-sea work necessarily placed a limit upon their operations, but the success of their experiments was more than enough to demonstrate the many advantages of steam for trawling purposes. A special type of fishing steamer, fitted with a screw instead of paddles, was soon under construction, enabling steam trawling to be prosecuted in distant as well as in home waters. Built at first of wood, but subsequently of iron, the steam trawler has undergone a continuous series of improvements, which have increased its strength, speed, storage capacity, and seaworthiness to such a pitch that it is now able to undertake the long and hazardous Icelandic voyage with remarkable regularity through winter and summer alike. The substitution of the otter or beamless trawl for the beam-trawl in 1894 also conduced to a great increase in the "catching power" of steam trawlers, especially as regards round fishes, such as cod and haddock, which swim some little distance above the actual sea-bed. The catching power of a modern steam trawler is regarded as equivalent to that of at least eight or ten deep-sea sailing trawlers.

An idea of the development of steam trawling may be gathered from the fact that in 1883 the fishing vessels sailing from the ports of Hull and Grimsby included less than 20 steamers and about 1000 sailing trawlers; in 1900 the number of steamers had increased to no less than 869, while the number of sailing trawlers had fallen to 4. In Scotland also the quantity of fish annually landed by trawlers (almost exclusively steam trawlers) has increased from 5 per cent. of the total in 1890 to 20 per cent. in 1900 (*cf.* Tables IX. and X.). In that country the development of the trawling industry and the prolongation of the herring fishery have brought about a decline of the line fishery, especially in recent years, the annual yield of the line fisheries having steadily fallen from 80,000 tons in 1890 to 38,000 tons in 1900 (*cf.* Table X.). In England and Wales it is difficult to say whether there has been any decline in the line fishery or not, owing to the absence of any discrimination between the products of the various modes of fishing in the official returns.[1] It has, however, been estimated that the number of first-class sailing liners belonging to the east coast of England fell from about 240 in 1889 to about 80 in 1898, while the number of steam liners increased from about 40 in 1889 to 100 in 1896, subsequently falling to 80 in 1898. The evidence of the Fishing Boats Register for 1893, 1899, and 1900 agrees with this estimate in showing a decrease of first-class sailing liners for the whole of England and Wales from 185 to 47, and an increase of steam liners from 56 in 1893 to 67 in 1899, falling to 63 in 1900. Thus if one steam liner be regarded as equivalent in catching power to four sailing liners, the English line fishery was probably holding its own until the year 1897, when it began to decline, apparently owing to the more lucrative character of trawl fishing. But the catch of halibut (an exclusively line-caught fish) has steadily increased throughout this period.

As regards the drift-net fishery, the supply of herrings and mackerel has been well maintained, 1897 having been a record year for mackerel on the south and east coasts of England, 1898 attaining the same distinction for herring in Scotland, while the annual catch of herrings in English waters first exceeded two million cwts. in the years 1899 and 1900. On the other hand, the conditions of the herring fishery have changed considerably during recent years. In Scotland the great summer herring fishery of the east coast has been supplemented by a winter and spring herring fishery which has attained considerable importance both on the east and west coasts, and an immense early summer fishery is now prosecuted on the west coast and in Orkney and Shetland, so that herring fishing is now followed at one part or another of the Scottish coasts during practically every month in the year. Indeed, the crews of many vessels which formerly worked at the herring and line fisheries in alternate seasons of the year now devote their energies almost entirely to the herring fishery, which they pursue in nomad fleets around all the coasts of Great Britain. Scottish crews now attend the English autumn herring fishery in far greater numbers than formerly, and with most successful results. These facts, together with the introduction of steam drift vessels, indicate a marked increase in the aggregate catching power employed in the herring fishery, and go far to explain the exceptionally heavy catches in recent years.

The yield of the Irish fisheries is still unimportant compared with that of the Scottish or English fisheries, but since 1887 a great development of the herring fishery has taken place. An increase of a less marked character is also noticeable in the records of the mackerel fishery, but it would be hazardous to draw conclusions from this feature, owing to the variable quantities of Irish mackerel which have been landed at English ports in the same period.

The total value of the sea fisheries of the United Kingdom in the year 1900, according to the official returns, was as follows:—

Fish Landed in	Excluding Shell-fish.	Including Shell-fish.
England and Wales	£6,610,000	£6,982,000
Scotland	2,326,000	2,401,000
Ireland	279,000	295,000
Total	£9,215,000	£9,678,000

No information is officially collected in England or Ireland as to the value of the vessels and gear employed in the fisheries of these countries, but as data under this head have been collected for some years past by the Fishery Board for Scotland, it is possible to frame a rough, but sufficiently correct, estimate of the total value for the United Kingdom, since the numbers and tonnage of the fishing vessels are known for all three countries.

[1] The need of a properly organized Fishery Department for the United Kingdom has often been urged. If further evidence were necessary, it might be drawn from the fact that although an Order in Council, dated 1869, provided that a Register of Sea Fishing Boats, subject to annual revision, should be *kept*, and should record among other details the "ordinary mode of fishing" of every vessel, the data under this head have never been published by the Commercial Department responsible for them; and the very existence of the data appears to have been unknown to the Board of Trade Inspectors of Sea Fisheries as late as the year 1899 (cf. *Thirteenth Annual Report of Inspectors* for 1898, p. 10). The matter was investigated the following year at the instance of the writer of this article, with the result that the annual reports of the inspectors now contain a valuable table giving authentic information on this head based on the Register. The regretable fact was, however, elicited that the "returns prior to 1893 no longer exist"—a loss which is irreparable for statistical purposes, and appears to have involved a distinct breach of the Order in Council which established the Register in the first place.

The subjoined estimate is based on the returns for 1900. It has been presumed that the average value of fishing gear per ton tonnage of fishing vessels is greater in Scotland than in England, owing to the greater proportion of trawlers among the English vessels, and the smaller cost of trawling gear as compared with nets and long lines:—

Estimate of Value of Fishing Boats and Gear employed in 1900 (the *values* are authenticated for Scotland only).

	Number.	Class of Boat.	Tons.	Value of Boats.		Value of Gear.		Grand Total.
				Per Ton.	Total.	Per Ton.	Total.	
				£	£	£	£	£
England and Wales	1,251	Steamers.	67,484	100	6,748,400	4	269,936	
	8,384	Other boats.	95,009	8	760,792	5	475,495	
					7,509,192		745,431	8,254,623
Scotland	252	Steamers.	9,320	97	904,630	4·2	39,178	
	10,973	Other boats.	108,384	7·7	831,670	6·9	749,819	
					1,736,300		788,997	2,525,297
Ireland	9	Steamers.	95	100	9,500	4	380	
	7,887	Other boats.	28,121	8	224,968	5	140,605	
					234,468		140,985	375,453
United Kingdom (total)	1,512	Steamers.			9,479,960		1,675,413	11,155,373
	27,244	Other boats.						

History.—A brief review may now be given of the history of the administration of the sea fisheries since 1877, and of the attainment of scientific and statistical information in relation thereto.

In 1878 a commission was given to Messrs Buckland and Walpole to inquire into the alleged destruction of the spawn and fry of sea-fish, especially by the use of the beam-trawl and ground-seine.

In 1882 the former Board of British White Herring Fishery was dissolved and the Fishery Board of Scotland instituted, the latter being empowered to take such measures for the improvement of the fisheries as the funds under their administration might admit of. Under the Sea Fisheries (Scotland) Amendment Act of 1885 the Board closed the Firth of Forth and St Andrews Bay against trawlers as an experiment for the purpose of ascertaining the result of such prohibition on the supply of fish on the grounds so protected. The Treasury also, by a further grant of £3000, enabled the Board to purchase the steam-yacht *Garland* as a means of carrying out regular experimental trawlings over the protected grounds. Reports on the results of these experiments have been annually published, and were summarized at the end of ten years' closure in the Board's Report for 1895. Dr Fulton's summary showed that "no very marked change took place in the abundance of food-fishes generally, either in the closed or open waters of the Firth of Forth or St Andrews Bay" as a consequence of the prohibition of trawling. Nevertheless, among flat fishes, plaice and lemon soles, which spawn off-shore, were reported to have decreased in numbers in all the areas investigated, whether closed or open, while dabs and long rough dabs showed a preponderating, if not quite universal, increase.

The results of this classical experiment point strongly to the presumptions (1) that trawling operations in the open sea have now exceeded the point at which their effect on the supply of eggs and fry for the upkeep of the flat fisheries is inappreciable; and (2) that protection of in-shore areas alone is insufficient to check the impoverishment caused by over-fishing off-shore. The importance of these conclusions as regards the future administration of our sea fisheries cannot be too strongly urged. (For critical examinations of Dr Fulton's account see M'INTOSH, *Resources of the Sea*, London, 1899, and GARSTANG, "The Impoverishment of the Sea," *Journal of the Marine Biological Association*, vol. vi., 1900.)

In 1883 a Royal Commission, under the chairmanship of the late Earl of Dalhousie, was appointed to inquire into complaints against the practice of beam-trawling on the part of line and drift-net fishermen. A small sum of money (£200) was granted to the Commission for the purpose of scientific trawling experiments, which were carried out by Professor M'Intosh.

The Report of this Commission was an important one, and its recommendations resulted in the institution of fishery statistics for England, Scotland, and Ireland (1885–87).

In 1884 the Marine Biological Association of the United Kingdom was founded for the scientific study of marine zoology and botany, especially as bearing upon the food, habits, and life-conditions of British food-fishes, crustacea and molluscs. Professor Huxley was its first President, and Professor Ray Lankester, who initiated the movement, succeeded him. A large and well-equipped laboratory was erected at Plymouth, and formally opened for work in 1888. The Fishmongers' Company contribute £200 a year to the Association, and H.M. Government now contribute a sum of £1000. The Association publishes a half-yearly Journal recording the results of its investigations.

In 1886 a Fishery Department of the Board of Trade was organized under the Salmon and Freshwater Fisheries Act of that year. The Department publishes annually a return of statistics of sea-fish landed, a report on salmon fisheries (transferred from the Home Office), and a report on sea fisheries. It consists of several inspectors under an assistant secretary of the Board; it has no power to make scientific investigations or bye-laws and regulations affecting the sea fisheries. In 1894 the administration of the Acts relating to the registration of fishing vessels, &c., was transferred to the Fisheries Department.

In 1888 the Sea Fisheries Regulation Act provided for the constitution (by Provisional Order of the Board of Trade) of local Fisheries Committees having, within defined limits, powers for the regulation of coast fisheries in England and Wales. The powers of District Committees were extended under Part II. of the Fisheries Act, 1891, and again under the Fisheries (Shell Fish) Regulation Act, 1894. Sea fisheries districts have now been created round nearly the whole coast of England and Wales.

In 1893 a Select Committee of the House of Commons took evidence as to the expediency of adopting measures for the preservation of the sea fisheries in the seas around the British Islands, with especial reference to the alleged wasteful destruction of undersized fish. They recommended the adoption of a size-limit of 8 inches for soles and plaice, and 10 inches for turbot and brill, below which the sale of these fishes should be prohibited, on the ground that these limits would approximate to those already adopted by foreign countries.

In 1899 the Agriculture and Technical Instruction (Ireland) Act transferred the powers and duties of the inspectors of Irish fisheries to the Department of Agriculture and Technical Instruction for Ireland. The Department is provided with a steam cruiser, the *Helga*, 375 tons, fully equipped for fishery research, as well as with a floating marine laboratory. Mr Holt, formerly of the Marine Biological Association, was appointed to take charge of the scientific work.

In 1900 another Select Committee of the House of Commons was appointed to consider and take evidence on the proposals of the Sea Fisheries Bill, which had been framed in accordance with the recommendations of the Select Committee of 1893, but had failed to pass in several sessions of Parliament. Owing to marked divergences of opinion on the question whether the low size-limits proposed would be effectual in keeping the trawlers from working on the grounds where small fish congregated, the Committee reported against the Bill, and urged the immediate equipment of the Government Departments with means for undertaking the necessary scientific investigations.

In May 1901 an International Conference of Representatives of the North Sea Powers met at Christiania to draw up final proposals for a scientific exploration of the North Sea in the interests of the fisheries, to be undertaken concurrently by all the countries bordering on the North Sea. The British Government was represented by Sir Colin Scott Moncrieff, K.C.M.G., C.S.I., with Professor D'Arcy Thompson, Mr W. Garstang, and Dr H. R. Mill as advisers. The proposals having been accepted by the participating Governments, the work of systematic exploration was expected to begin in the course of 1902.

Statistics.—The following tables summarize the official statistics of fish landed on the coasts of England and Wales, Scotland and Ireland, and give some information relative to the numbers of fishing-boats and fishermen in the three countries. The Irish statistics of shell-fish must throughout be treated cautiously, owing to the inadequate means at the disposal of the authorities for collecting complete statistics over large sections of the coast.

TABLE I.—Quantity and Average Landing Value of FLAT FISHES landed on the Coasts of ENGLAND and WALES (all caught with trawl-nets, except Halibut).

Year.	Quantity (in Thousands of Cwts.).					Average Price (per Cwt.).				
	Sole.	Turbot.	Brill.	Plaice.	Halibut.	Sole.	Turbot.	Brill.	Plaice.	Halibut.
						£ s.	£ s.	£ s.	£ s.	£ s.
1890	72·1	51·9	15·4	623	95	6 7	3 13	2 8	0 19	1 10
1895	**82·8**	**77·9**	19·0	**789**	114	6 16	3 17	2 11	1 1	1 15
1900	75·3	60·7	20·7	752	**136**	7 11	4 3	2 14	1 4	1 14

TABLE II.—Quantity and Average Landing Value of ROUND FISHES, caught with Trawls and Lines, landed on the Coasts of England and Wales.

Year.	Quantity (in Thousands of Cwts.).					Average Price (per Cwt.).				
	Cod.	Haddock.	Hake.	Ling.	Sundries.	Cod.	Haddock.	Hake.	Ling.	Sundries.
						s. d.	s. d.	s. d.	s. d.	s. d.
1890	363	1585	...	96	1151	13 10	9 7	...	**14 3**	14 0
1891	361	1741	140	94	854	13 9	10 2	11 10	13 8	13 9
1895	496	2433	132	**114**	1013	12 5	9 9	**16 2**	11 8	13 7
1900	**589**	**2487**	**233**	100	**1190**	**14 8**	**13 8**	15 10	12 10	14 10

TABLE III.—Quantity and Average Landing Value of SURFACE FISHES landed on the Coasts of England and Wales (caught with drift-, seine-, and stow-nets).

Year.	Quantity (in Thousands of Cwts.).				Average Price (per Cwt.).			
	Mackerel.	Herring.	Pilchard.	Sprat.	Mackerel.	Herring.	Pilchard.	Sprat.
					s. d.	s. d.	s. d.	s. d.
1889	334	1923	108	63	13 9	4 10	**6 1**	3 6
1890	**509**	1332	61	99	15 5	7 2	5 10	3 0
1891	368	1206	99	**116**	**19 7**	**8 4**	5 2	2 2
1895	375	1437	65	91	16 3	5 10	5 3	3 1
1900	321	**2425**	106	73	15 9	7 8	4 6	4 11

TABLE IV.—Quantity and Average Landing Value of SHELL-FISH landed on the Coasts of England and Wales.

Year.	Number.				Average Price.			
	Thousands.		Mills.	Cwts.	Per Hundred.			Per Cwt.
	Crabs.	Lobsters.	Oysters.	Sundries.	Crabs.	Lobsters.	Oysters.	Sundries.
					£ s.	£ s.	s. d.	s. d.
1889	5082	720	36·7	460	1 1	4 4	5 8	5 2
1890	4808	**922**	**47·6**	505	1 4	4 18	6 1	5 0
1895	4501	677	25·3	590	1 4	4 8	6 2	4 11
1900	**5177**	654	37·8	539	1 2	4 7	7 0	5 8

TABLE V.—Total Quantity of the more important Fishes and Shell-fish landed in Scotland.

Year.	In Thousands of Cwts.									Cwts.	Number (Thousands).		
	Herring.	Lemon Sole.	Flounder, Plaice, and Brill.	Halibut.	Cod.	Ling.	Haddock.	Whiting.	Skate.	Mussels.	Crabs.	Lobsters.	Oysters.
1889	3718	14·4	74·3	21·1	504	134	792	69·7	50	189	2774	576	312
1890	3980	16·6	81·3	20·2	449	170	754	75·5	54	181	2882	643	350
1895	4077	19·3	79·7	28·9	459	165	1001	43·5	59	194	2548	610	239
1900	3520	20·6	102·2	25·7	434	157	761	75·0	72	143	3128	680	796

TABLE VI.—Total Quantity of the more important Fishes and Shell-fish returned as landed on the Irish Coasts.

Year.	In Thousands of Cwts.									Number (Thousands).		
	Mackerel.	Herring.	Sole.	Turbot.	Cod.	Ling.	Haddock.	Whiting.	Hake.	Oysters.	Crabs.	Lobsters.
1890	502	85	4·5	1·4	39·6	14·8	16·4	13·5	25·3	576	228	238
1895	339	171	1·8	1·0	43·6	29·7	30·9	11·9	18·7	563	240	276
1900	278	284	3·1	1·5	33·6	11·9	12·4	11·9	16·3	236	202	286

TABLE VII.—Number of Fishing Boats on the Register for 1900 (excluding vessels navigated by oars only), compared with the average number registered in preceding periods.

Year.	England and Wales.		Scotland.		Ireland.		United Kingdom (including Isle of Man and Channel Isles).	
	1st Class.	2nd Class.	1st Class.	2nd Class.	1st Class.	2nd Class.	1st Class.	2nd Class.
1878–1882	3809	6094	3881	8365	462	3333	8503	18,160
1888–1892	3905	4151	3816	6698	443	2929	8464	14,099
1900	3176	3959	3375	6237	364	3818	7124	14,317

Note.—1st Class = boats of 15 tons and upwards; 2nd Class = boats of less than 15 tons, navigated otherwise than by oars only. In England and Wales, the Channel Isles, and Isle of Man, but not in Scotland or Ireland, undecked boats fishing within territorial limits have been exempted from compulsory registration since 1880.

TABLE VIII.—Number (A) of Men and Boys constantly Employed and (B) of other Persons occasionally Employed in Fishing.

Year.	England and Wales.		Scotland.		Ireland.		United Kingdom.	
	A	B	A	B	A	B	A	B
1890	32,503	9312	34,319	20,829	10,121	13,981	78,450	46,337
1895	32,229	8995	31,044	12,329	8,692	18,218	73,090	41,230
1900	31,589	7994	27,288	10,288	8,677	18,982	68,708	37,814

Note.—The above table takes no account of persons employed in unregistered boats, of which there are many in England and Wales.

TABLE IX.—Total Quantity of the more important Bottom Fishes[1] landed at certain Ports in the North Sea from 1891 to 1900.

Year.	Hull, Grimsby, and Boston.	N. Shields, Sunderland, Hartlepool, Scarborough, Yarmouth, Lowestoft, & Ramsgate.	Year.	Hull, Grimsby, and Boston.	N. Shields, Sunderland, Hartlepool, Scarborough, Yarmouth, Lowestoft, & Ramsgate.
	Cwts.	Cwts.		Cwts.	Cwts.
1891	1,565,165	570,818	1896	2,342,740	553,788
1892	1,639,129	579,538	1897	2,399,706	520,944
1893	1,776,338	625,283	1898	2,509,320	508,940
1894	1,971,508	575,180	1899	2,667,008	534,818
1895	2,193,998	623,743	1900	2,866,172	568,751

[1] The Bottom Fishes here included are cod, haddock, hake, ling, soles, turbot, plaice, and halibut, all of which are caught by trawls or lines. The table shows the steady increase of supplies at the ports which are the centres of the steam trawling industry (Hull, Grimsby, and Boston), and which receive the products of the Icelandic and Faröe fisheries, as contrasted with the declining character of the supplies at other ports (N. Shields, &c.), which depend exclusively on the products of the older fishing grounds in the North Sea.

TABLE X.—Catch and Value of Line-caught and Trawled Fish landed in Scotland in 1890, 1895, and 1900.

Year.	Line-caught Fish.		Trawled Fish.	
	Cwts.	£	Cwts.	£
1890	1,577,299	591,059	291,812	203,620
1895	1,479,654	548,629	531,695	291,165
1900	757,416	371,173	1,077 082	703,427

(W. GA.)

Fishery (Law of).—This subject has, (1) its International aspect; (2) its Municipal aspect; and each requires separate consideration.

On the high seas outside territorial waters the right of fishery is now recognized as common to all nations. Claims were made in former times by single nations to the exclusive right of fishing in tracts of open sea; such as that set up by Denmark in respect of the North Sea, as lying between its possessions of Norway and Iceland, against England in the 17th century, and against England and Holland in the 18th century, when she prohibited any foreigners fishing within 15 German miles of the shores of Greenland and Iceland. This claim, however, was always effectively resisted on the ground stated in Queen Elizabeth's remonstrance to Denmark on the subject in 1602, that "the law of nations alloweth of fishing in the sea everywhere even in seas where a nation hath propertie of command." The latest enunciation of this principle is to be found in the award of the Arbitration Court which decided the question of the fur-seal fishery in Bering Sea in 1894. (See Arbitration, International.) The right of nations to take fish in the sea may, however, be restrained or regulated by treaty or custom; and Great Britain has entered into Conventions with other nations with regard to fishing in certain parts of the sea. The provisions of such Conventions are made binding on British subjects by statutes.

Instances of these are the Conventions of 1818 and 1872 between Great Britain and the United States as to the fisheries on the eastern coasts of British North America and the United States within certain limits, and the award of the Bering Sea arbitration tribunal under the treaty of 1892; the Conventions between Great Britain and France in 1839 and 1867 as regards fishing in the seas adjoining these countries, the latter of which will come into force on the repeal of the former; the Convention of 1882 between Belgium, Denmark, France, Germany, Great Britain and Holland, regarding the North Sea fisheries; that of 1887 between the same parties concerning the liquor traffic in the North Sea; and the Declaration regarding the same waters made between Great Britain and Belgium for the settlement of differences between their fishermen subjects in such extra-territorial waters. At the instance of the Swedish Government the British Parliament also passed an Act in 1875 to establish a close time for the seal fishery in the seas adjacent to the eastern coasts of Greenland.

Cases have come before British Courts with regard to the whale fishery in northern and southern seas; and the customs proved to exist among the whaling ships of the nations engaged in a particular trade have been upheld if known to the parties to the action. In territorial waters, on the other hand, fishery is a right exclusively belonging to the subjects of the country owning such waters, and no foreigners can fish there except by convention.

(*a*) *Tidal Waters.*—In British territorial waters, it may be stated, as the general rule, that fishery is a right incidental to the soil covered by the waters in which that right is exercised.

The bed of all navigable rivers where the tide flows and reflows, and of all estuaries or arms of the sea, is vested in the Crown: and, therefore, in Lord Chief Justice Hale's words, "the right of the fishery in the sea and the creeks and arms thereof is originally lodged in the Crown, as the right of depasturing is originally lodged in the owner of the waste whereof he is lord, or as the right of fishing belongs to him that is the owner of a private or inland river." "But," he continues, "though the king is the owner of this great waste, and as a consequent of his propriety hath the primary right of fishing in the sea and the creeks and arms thereof, yet the common people of England have regularly a liberty of fishing therein as a public common of piscary, and may not without injury to their right be restrained of it unless in such places or creeks or navigable rivers where either the king or some particular subject hath gained a propriety exclusive of that common liberty" (*De Jure Maris*, ch. iv.).

This right extends to all fish floating in the sea or left on the seashore, except certain fish known as royal fish, which, when taken in territorial waters, belong to the Crown or its grantee, though caught by another person. These are whales, sturgeons, and porpoises; and grampuses are also sometimes added (whales, porpoises, and grampuses being "fishes" only in a legal sense). In Scotland only whales which are of large size can be so claimed; but the rights of salmon fishing in the sea and in public and private rivers, and those of mussel and oyster fishing, except in private rivers, are *inter regalia*, and are only enjoyable by the Crown or persons deriving title under it. As salmon fishery was formerly practised by nets and engines on the shore, and the mussel and oyster fisheries were necessarily carried on on the shore, the opinion was held at one time that angling for salmon was a public right, but the later decisions have established that the right of salmon fishing by whatever means is a *jus regale* in Scotland. In England, the Crown in early times made frequent grants of fisheries to subjects in tidal waters, and instances of such fisheries belonging to persons and corporations are very common at the present day: but by Magna Carta the Crown declared that "no rivers shall be defended from henceforth, but such as were in defence in the time of King Henry, our grandfather, by the same places and the same bounds as they were wont to be in his time;" and thus bound itself not to create a private fishery in any navigable tidal river. Judicial decision and commentators having interpreted this statute according to the spirit and not the letter, at the present day the right of fishery in tidal waters *primâ facie* belongs to the public, and they can only be excluded by a particular person or corporation on proof of an exclusive right to fish there not later in its origin than Magna Carta; and for this it is necessary either to prove an actual grant from the Crown of that date to the claimant's predecessor in title, or a later grant or immemorial custom or prescription to that effect, from which such an original grant may be presumed. This exclusive right of fishing may be either a franchise derived from the Crown, or may arise by virtue of ownership of the soil covered by the waters.

In Lord Hale's words: "Fishing may be of two kinds ordinarily, viz., fishing with a net, which may be either as a liberty without the soil, or as a liberty arising by reason of and in concomitance with the soil or an interest or propriety of it; or otherwise it is a local fishing that ariseth by or from the propriety of the soil,—such are *gurgites*, wears, fishing-places, *borachiæ*, *stachiæ*, which are the very soil itself, and so frequently agreed by our books. And such as these a subject may have by usage; either in gross, as many religious houses had, or as parcel of or appurtenant to their manors, as both corporations and others have had; and this not only in navigable rivers and arms of the sea but in creeks and ports and havens, yea, and in certain known limits in the open sea contiguous to the shore. And these kinds of fishings are not only for small sea-fish, such as herrings, &c., but for great fish, as salmons, and not only for them but for royal fish. . . . Most of the precedents touching such rights of fishing in the sea, and the arms and creeks thereof belonging by usage to subjects, appear to be by reason of the propriety of the very water and soil wherein the fishing is, and some of them even within parts of the seas" (*De Jure Maris*, ch. v.).

An instance of the former kind of fishery is to be found in the old case of *Royal Fishery of the River Bann* (temp. James I., Davis 655), and the modern one of *Wilson* v. *Crossfield* (1885, 1 T. L. R. 601), where a right of fishery in gross was established; but the latter kind, as Hale says, is much more common, and the presumption is always in its favour; *à fortiori* where the fishing is proved to have been carried on by means of engines or structures fixed in the soil. In England the public have not at common law, as incidental to their right of fishing in tidal waters, the right to make use of the banks or shores for purposes incidental to the fishery, such as beaching their boats upon them, landing there, or drying their nets there (though they can do so by proving a custom from which such a grant may be presumed); but statutes relating to particular parts of the realm, such as Cornwall for the pilchard fishery, give them such rights. In Scotland a right of salmon fishing separate from land implies the right of access to and use of the banks, foreshores, or beach for the purposes of the fishing; and so does white fishing by statute. But otherwise there is no right to do so, *e.g.*, in a public river for trout fishing. A similar privilege is given to Irish fishermen for the purpose of sea fishery by special statute. There is no property in fish in the sea, and they belong to the first taker; and the custom of the trade decides when a fish is taken or not, *e.g.*, in the whale fishery the question whether a fish is "loose" or not has come before English Courts.

(*b*) *Fresh Waters.*—In non-tidal waters in England and Ireland, for the reason given above, the presumption is in favour of the fishery in such waters belonging to the owners of the adjacent lands: "fresh waters of what kind soever do of common right belong to the owners of the soil adjacent, so that the owners of the one side have of common right the property of the soil, and consequently the right of fishing *usque ad filum aquae*, and the owners of the other side the right of soil or ownership and fishing unto the *filum aquae* on their side; and if a man be owner of the land on both sides, in common presumption he is owner of the whole river, and hath the right of fishing according to the extent of his land in length" (Hale, ch. i.). There is a similar presumption that the owner of the bed of a river has the exclusive right of fishery there, and this is so even though he does not own the banks; but these presumptions may be displaced by proof of a different state of things, *e.g.*, where the banks of a stream are separately owned the owner of one bank may show by acts of ownership exercised over the whole stream that he has the fishery over it all. The Crown prerogative of fishery never, it seems, extended to non-tidal waters flowing over the land of a subject, and it could not therefore grant such a franchise to a subject, nor has it any right *de jure* to the soil or fisheries of an inland lake such as Lough Neagh (*Bristow* v. *Cormican*, 1878, 3 App. Cas. 641). The public cannot acquire the right to fish in fresh waters by prescription or otherwise although they are navigable; such a right is unknown to law, because a profit *à prendre in alieno solo* is neither to be acquired by custom nor by prescription under the Prescription Act. It has been decided that the "dwellers" in a parish cannot acquire such a right, being of too vague a class; but the commoners in a manor may have it by custom; and the "free inhabitants of ancient tenements" in a borough have been held capable of acquiring a right to dredge for oysters in a fishery belonging to the corporation of the borough on certain days in each year by giving proof of uninterrupted enjoyment of it from time immemorial, on the presumption that this was a condition to which the grant made to the corporation was subject.

In Scotland the law is similar. The right to fish for trout in private streams is a pertinent of the land adjacent, and owners of opposite banks may fish *usque ad medium filum aquae;* and where two owners own land round a private loch, both have a common of fishing over it. The public cannot prescribe for it, for a written title either to adjacent lands or to the fishery is necessary. A right of way along the bank of a river or loch does not give it, nor does the right of the public to be on or at a navigable but non-tidal river. The right of salmon fishing carries with it the right of trout fishing: and eel fishing passes in the same way.

In England and Ireland private fisheries have been divided into (*a*) several (*separalis*), (*b*) free (*libera*), (*c*) common of piscary (*communis*), whether in tidal or non-tidal waters. The distinction between several and free fisheries has always been uncertain. Blackstone's opinion was that several fishery implied a fishery in right of the soil under the water, while free fishery was confined to a public river and did not necessarily comprehend the soil. He is supported by later writers, such as Woolrych and Paterson. On the other hand, the opinions of Coke and Hale are opposed to this view. "A man may prescribe to have a several fishery in such a water, and the owner shall not fish there; but if he claim to have common of fishery or free fishery the owner of the soil shall fish there" (Co. Littl. 122 A); "one man may have the river and others the soil adjacent: or one man may have the river and soil thereof, and another the free or several fishing in that river" (*De Jure Maris*, ch. i.). Lord Holt, though in one instance he distinguished them, in a later case thought that they were "all one." Later decisions have established the latter view, and it is now settled that although the owner of the several fishery is *primâ facie* owner of the soil of the waters, this presumption may be displaced by showing that the terms of the grant only convey an incorporeal hereditament, and that the words "sole and exclusive fishery" give a several fishery *in alieno solo.* In the words of Mr Justice Willes, "the only substantial distinction is between an exclusive right of fishery, usually called 'several,' and sometimes 'free,' as in 'free warren,' and a right in common with others, usually called 'common of fishery,' and sometimes 'free,' as in 'free port.' A several fishery means an exclusive right to fish in a given place, either with or without the property in the soil" (*Malcolmson* v. *O'Dea*, 1863, 10 H. L.). A common of piscary, or "a right to fish in common with certain other persons in a particular stream," is usually found in manors, the commoners of which may have the right to enjoy it to an extent sufficient for the sustenance of their tenements; but they cannot, except by immemorial special prescription, exclude the lord of the manor therefrom, and have no rights over the soil itself. Decisions also establish that a grant of "fishery" will *primâ facie* pass an exclusive fishery; a grant of soil covered by water or a lease of lands including water will pass the fishery therein; a several fishery will not merge on being resumed by the Crown; and a fishery situate within a manor is presumed to belong to the owners of adjacent land, and not to the lord. A several fishery, as already seen, being an incorporeal hereditament, can only be transferred by deed, and therefore cannot be abandoned, and so acquired by the public, even on proof that the public have, as far back as living memory, exercised the right of fishing in the *locus in quo* to the knowledge of and without interruption from the claimant of the fishery. But to establish a title to a several fishery, a "paper title," *i.e.*, one founded on documentary evidence only, is not sufficient; it must be supported by evidence of acts of ownership in recent times, for otherwise it will be presumed that a person other than the alleged owner is the real owner. If the waters of a tidal river leave their old channel and flow into another, the owner of a several fishery in the old channel cannot claim to have it in the new one; but, on the other hand, the owner of a several fishery can take advantage of a gradual encroachment by the river upon and into the land of a riparian owner, the limits of whose land are ascertained. The owner of an exclusive fishery, whether in tidal or fresh waters, has the right to take as many fish as he can, and may do so by means of fixed engines or dredging, provided that in navigable waters he does not interfere with the right of navigation, and that in navigable and other waters he does not interfere with the fishing rights of his neighbours or infringe the provisions made by old or modern statutes as to the methods of taking the fish, *e.g.*, by weirs. These were forbidden in rivers by Magna Carta and later statutes, and on the seashore by a statute of James I.; but all weirs in navigable fresh waters traceable to a date not later than 25 Edward III. are lawful, for the statutes forbidding weirs do not apply to navigable waters. It seems, however, that at common law any fixed structures put up by the owner of a fishery in his part of a river, which at all prevent the free passage of fish to the waters above or below, give the owners of fisheries therein a right of action against him. So the grantee of an exclusive fishery with rod and line in an unnavigable river can prevent any person from polluting the river higher up and so damaging the fishery. At common law there is no property in fish when enjoying their natural liberty; the taker is entitled to keep them unless they are caught from a tank or small pond; or except in the case of salmon by statute.

Modern statutes now regulate all fisheries, sea or fresh, in territorial or inland waters. As regards sea fishery in England, the Board of Trade has power by order to create sea fisheries districts, comprising any part of the sea within which British subjects have, by international law, the exclusive right of fishing, and to provide for the constitution of a local fisheries committee to regulate the sea fisheries in such district, which can make bye-laws for that purpose. It appoints fishery officers to enforce them, prescribes a close time for sea fish (which does not include salmon as defined in the Salmon Act), has summary jurisdiction over offences committed on the sea coast or at sea beyond the ordinary jurisdiction of a court of summary jurisdiction, can enforce the Sea Fisheries Acts, or regulate, protect, and develop fisheries for all or any kind of shell fish. Special provision is also made by statute for the oyster fishery and herring fishery (applicable also to Scotland), and that of mussels, cockles, lobsters, and crabs (applicable to all the United Kingdom). In Scotland the Fishery Board can constitute sea fishery districts, and boards with like powers to those in England, and has general control over the coast and deep-sea fisheries of Scotland; and there are Acts relative to herring, mussel, and oyster fisheries, and allowing the appropriation of money intended to relieve local distress and taxation towards the encouragement of sea fisheries, and marine superintendence and enforcement of Scottish sea fisheries laws. In Ireland the sea fisheries are under the direction of the Inspectors of Irish Fisheries, who have replaced the former Fishery Commissioners and Special Commissioners for Irish Fisheries; special statutes, besides the general ones applying to all the United Kingdom, deal with oyster fisheries (1845–1884), and mussel fisheries (1898); and one of 1899 appropriates £10,000 for sea fisheries under the head of technical instruction. In all three component parts of the United Kingdom there are also special statutes relative to salmon and freshwater fish: for England, the Salmon and Freshwater Fisheries Acts 1861–1891, and the Freshwater Fisheries Acts 1878 to 1886; for Scotland the chief Salmon Acts are those of 1862–1868, and for trout and freshwater fish those of 1845–1860; for Ireland, the Salmon and Trout Acts 1845–1870, and one of 1895, and the Eels Acts 1842, 1848. A similar scheme is adopted in each case, namely, fishery districts and district boards are set up which regulate the fishing by bye-laws and protect the fish by fixing a close time, and prescribing passes, licenses, inspection and the like, breaches of which are punishable by courts of summary jurisdiction. The supreme authorities in each case are—for England the Board of Trade, for Scotland the Fishery Board, and for Ireland the Inspectors of Fisheries, and in England a certain official number of conservators on such boards are appointed by the County Councils. There are special Acts dealing with the fishing in certain rivers, such as the Thames, Medway, Severn, Tweed and Esk. Throughout the United Kingdom the use of dynamite or other explosive substance to catch or destroy fish in any public fishery is prohibited, as it is also in England in any private waters subject to the Salmon and Freshwater Fisheries Acts 1878, in which it is also forbidden to use poison or other noxious substance for destroying fish. Officers in the army or marines are forbidden (under penalty) to kill fish without written leave from the person entitled to grant it. There are also provisions of the criminal law dealing with the protection of fisheries generally, as well as the provisions of the Acts already mentioned dealing with special kinds of fish.

Special provision is made by the Merchant Shipping Act 1894 for sea fishing boats (except in Scotland and the Colonies), relating to their registration, carrying official papers, carrying boats in proportion to their tonnage, the punishment of offences on board, the wages of their crews, and keeping record of all casualties, punishments and the like on board. As regards trawlers, especially in the case of those of 25 tons and upwards, a statutory form of agreement with the crew is prescribed, as well as accounts of wages and discharges; and skippers and second hands must have certificates of competency, which are granted under similar conditions to those required in the case of seagoing ships and are registered with the Board of Trade. Scottish fishing boats are regulated by a special statute of 1886 (except as regards agreements to pay crew by share of profits, dealt with by the above Act) and by the Sea Fisheries Act of 1868, which applies to all British fishing boats. Particular lights must be carried by fishing boats in navigation.

AUTHORITIES.—GREEN: *Encyclopædia of Scots Law*, Edinburgh, 1896. STEWART: *Law of Fishing in Scotland*, Edinburgh, 1869. WOOLRYCH: *Waters*, London, 1851. PATERSON: *Fishery Laws of the United Kingdom*, London and Cambridge, 1863. STUART MOORE, *Foreshore*, London, 1888. PHILLIMORE: *International Law*, London, 1879 (3rd ed.). MARTENS, *Causes Célèbres du Droit des Gens*, Leipsic, 1827. SELWYN: *Nisi Prius, Fishery*, London, 1869. (G. G. P.*)

Fiske, John (1842–1901), American historical, philosophical, and scientific writer, was born in Hartford, Connecticut, 30th March 1842, and died at Gloucester, Massachusetts, 4th July 1901. His name was originally Edmund Fiske Green, but in 1855 he took the name of a great-grandfather, John Fiske. His boyhood was spent with a grandmother in Middletown, Connecticut; and prior to his entering college he had read widely in English literature and history, had surpassed most boys in the extent of his Greek and Latin work, and had studied several modern languages. He graduated at Harvard in 1863, continuing to study languages and philosophy with zeal; spent two years in the Harvard law school, and opened an office in Boston; but soon devoted the greater portion of his time to writing for periodicals. With the exception of one year, he resided at Cambridge, Massachusetts, from the time of his graduation until his death. In 1869 he gave a course of lectures at Harvard on the Positive Philosophy; next year he was history tutor; in 1871 he delivered thirty-five lectures on the Doctrine of Evolution, afterwards revised and expanded as *Outlines of Cosmic Philosophy* (1874); and between 1872 and 1879 he was assistant-librarian. After that time he devoted himself to literary work and lecturing on history. Nearly all of his books were first given to the public in the form of lectures or magazine articles, revised and collected under a general title, such as *Myths and Myth-Makers* (1872), *Darwinism and Other Essays* (1879), *Excursions of an Evolutionist* (1883), and *A Century of Science* (1899). He did much, by the thoroughness of his learning and the lucidity of his style, to spread a knowledge of

Darwin and Spencer in America. His *Outlines of Cosmic Philosophy*, while setting forth the Spencerian system, made psychological and sociological additions of original matter, in some respects anticipating Spencer's later conclusions. Of one part of the argument of this work Fiske wrote in the preface of one of his later books (*Through Nature to God*, 1899): "The detection of the part played by the lengthening of infancy in the genesis of the human race is my own especial contribution to the Doctrine of Evolution." In *The Idea of God as affected by Modern Knowledge* (1885) Fiske discusses the theistic problem, and declares that the mind of man, as developed, becomes an illuminating indication of the mind of God, which as a great immanent cause includes and controls both physical and moral forces. More original, perhaps, is the argument in the immediately preceding work, *The Destiny of Man, Viewed in the Light of his Origin* (1884), which is, in substance, that physical evolution is a demonstrated fact; that intellectual force is a later, higher, and more potent thing than bodily strength; and that, finally, in most men and some "lower animals" there is developed a new idea of the advantageous, a moral and non-selfish line of thought and procedure, which in itself so transcends the physical that it cannot be identified with it or be measured by its standards, and may or must be enduring, or at its best immortal.

It is principally, however, through his work as a historian that Fiske's reputation will live. His historical writings, with the exception of a small volume on *American Political Ideas* (1885), an account of the system of *Civil Government in the United States* (1890), *The Mississippi Valley in the Civil War* (1900), a school history of the United States, and an elementary story of the Revolutionary war, are devoted to studies, in a unified general manner, of separate yet related episodes in American history. The volumes have not appeared in chronological order of subject, but form a nearly complete colonial history, as follows: *The Discovery of America, with some Account of Ancient America, and the Spanish Conquest* (1892, 2 vols.); *Old Virginia and her Neighbors* (1897, 2 vols.); *The Beginnings of New England; or, The Puritan Theocracy in its Relations to Civil and Religious Liberty* (1889); *Dutch and Quaker Colonies in America* (1899); *The American Revolution* (1891, 2 vols.); and *The Critical Period of American History, 1783–1789* (1888). Of these the most original and valuable is the *Critical Period* volume, a history of the consolidation of the States into a government, and of the formation of the constitution. (C. F. R.)

Fitchburg, a city of Worcester County, Massachusetts, U.S.A., in 42° 35′ N. and 71° 50′ W., on the North Branch of the Nashua river, at an altitude of 433 feet. The site is hilly, and the city is built irregularly; the waterworks, owned by the city, derive their supply by gravity from Scott brook. It is on the main line of the Fitchburg Railroad, and on a branch of the New York, New Haven, and Hartford Railroad. Its manufactures are considerable; in 1895 there were 264 establishments, with a total capital of $8,079,412, employing 6185 hands, and producing goods valued at $10,629,400. The principal items of manufacture were worsted, cotton, iron and steel goods, and paper. Population (1880), 12,429; (1890), 22,037; (1900), 31,531, of whom 10,917 were foreign-born. The death-rate in 1900 was 13·6.

FitzGerald, Edward (1809–1883), the poet of Omar Khayyám, was born, as Edward Purcell, at Bredfield House, in Suffolk, on the 31st of March 1809. His father, John Purcell, who had married a Miss FitzGerald, assumed in 1818 the name and arms of his wife's family. From 1816 to 1821 the FitzGeralds lived at St Germain and at Paris, but in the latter year Edward was sent to school at Bury St Edmunds. In 1826 he proceeded to Trinity College, Cambridge, where, some two years later, he became acquainted with Thackeray and W. H. Thompson. With Tennyson, "a sort of Hyperion," his intimacy began about 1835. In 1830 he went to live in Paris, but in 1831 was in a farm-house on the battlefield of Naseby. He adopted no profession, and lived a perfectly stationary and rustic life, presently moving into his native county of Suffolk, and never again leaving it for more than a week or two. Until 1835 the FitzGeralds lived at Wherstead; from that year until 1853 the poet resided at Boulge, near Woodbridge; until 1860 at Farlingay Hall; until 1873 in the town of Woodbridge; and then until his death at his own house hard by, called Little Grange. During most of this time FitzGerald gave his thoughts almost without interruption to his flowers, to music, and to literature. He allowed friends like Tennyson and Thackeray, however, to push on far before him, and long showed no disposition to emulate their activity. In 1851 he published his first book, *Euphranor*, a Platonic dialogue, born of memories of the old happy life at Cambridge. In 1852 appeared *Polonius*, a collection of "saws and modern instances," some of them his own, the rest borrowed from the less familiar English classics. FitzGerald began the study of Spanish poetry in 1850, when he was with Professor E. B. Cowell at Elmsett, and that of Persian in Oxford in 1853. In the latter year he issued *Six Dramas of Calderon*, freely translated. He now turned to Oriental studies, and in 1856 he anonymously published a version of the *Salámán and Absál* of Jámi in Miltonic verse. In March 1857 the name with which he has been so closely identified first occurs in FitzGerald's correspondence—"Hafiz and *Omar Khayyám* ring like true metal." On the 15th of January 1859 a little anonymous pamphlet was published as *The Rubáiyát of Omar Khayyám.* In the world at large, and in the circle of FitzGerald's particular friends, the poem seems at first to have attracted no attention. The publisher allowed it to gravitate to the fourpenny or even (as he afterwards boasted) to the penny box on the bookstalls. But in 1860 Rossetti discovered it, and Mr Swinburne and Lord Houghton quickly followed. The *Rubáiyát* became slowly famous, but it was not until 1868 that FitzGerald was encouraged to print a second and greatly revised edition. Meanwhile he had produced in 1865 a version of the *Agamemnon*, and two more plays from Calderon. In 1880–81 he issued privately translations of the two Œdipus tragedies; his last publication was *Readings in Crabbe*, 1882. From 1861 onwards FitzGerald's greatest interest had centred in the sea. In June 1863 he bought a yacht, "The Scandal," and in 1867 he became part-owner of a herring-lugger, the "Meum and Tuum." For some years, till 1871, he spent the months from June to October mainly in "knocking about somewhere outside of Lowestoft." In this way, and among his books and flowers, FitzGerald gradually became an old man. On the 14th of June 1883 he passed away painlessly in his sleep. He was "an idle fellow, but one whose friendships were more like loves." In 1885 a stimulus was given to the steady advance of his fame by the fact that Tennyson dedicated his *Tiresias* to FitzGerald's memory, in some touching reminiscent verses to "Old Fitz." This was but the signal for that universal appreciation of Omar Khayyám in his English dress, which has been one of the curious literary phenomena of recent years. The melody of FitzGerald's verse is so exquisite, the thoughts he rearranges and strings together are so profound, and the general atmosphere of poetry in which he steeps his version is so pure, that no surprise need be expressed at the universal favour which the poem has met with among critical readers. But its popularity has gone much deeper than this; it is now probably better known to the general public than any single poem of its class published since the year 1860, and its admirers have almost transcended commonsense in the extravagance of their laudation. FitzGerald married, in middle life, Lucy, the daughter of Bernard Barton, the Quaker poet. Of FitzGerald as a man practically nothing was known until, in 1889, Mr W. Aldis Wright, his intimate friend and literary executor, published his *Letters and Literary Remains* in three volumes. This was followed in 1895 by the *Letters to Fanny Kemble.* These letters constitute a fresh bid for immortality, since they discovered that FitzGerald was a witty, picturesque, and sympathetic letter-writer. One of the most unobtrusive authors who ever lived, FitzGerald has, nevertheless, by the force of his extraordinary individuality, gradually influenced the whole face of English *belles-lettres*, in particular as it was manifested between 1890 and 1900. (E. G.)

Fitzroy, a city of Victoria, Australia, in the county of Bourke, 2 miles north-east of and suburban to Melbourne, with which it is connected by rail. It has several churches, a town hall, and public recreation ground, and is well served with tramways. Population (1881), 23,118; (1901), 31,610.

Fiume, a port and municipal town in Hungary. It has a rapidly growing commercial and maritime trade. In 1900 the number of vessels entered and cleared was 21,772, of 3,365,480 tons; the value of the imports was 90·8 million, that of the exports 165 million crowns. The Government has spent in the construction of the harbour 71·7 millions of crowns, and grants yearly subventions to the Royal Hungarian Steamship Navigation Company "Adria," as well as to the other smaller shipping enterprises, the registration port of which is Fiume. Population (1900), 38,955.

Fivizzano, a town of Tuscany, Italy, in the province of Massa and Carrara, on the W. slope of the Apennines, 17 miles E.N.E. from Spezia. It has mineral springs, one sulphurous (74°·7 Fahr.), another saline (54°·5); also marble quarries, silk spinning and weaving, lime-kilns, and olive-oil mills. Population about 13,800.

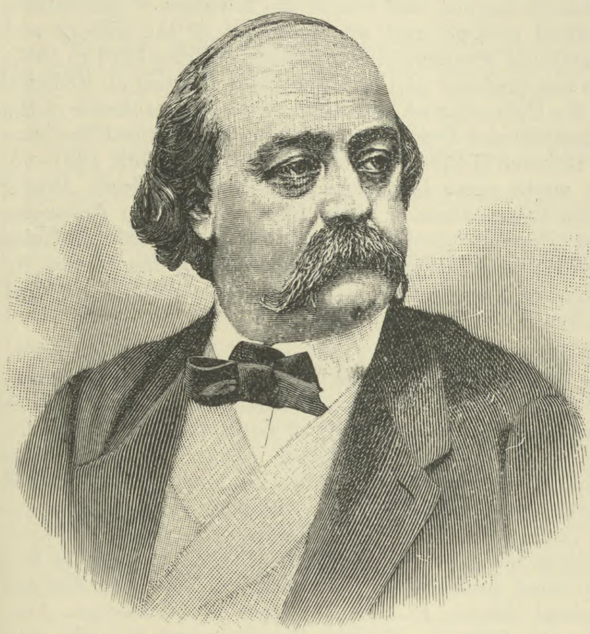
Flanders, two provinces of Belgium. I. WEST FLANDERS (Flemish, *West-Vlaanderen;* French, *Flandre occidentale*), bordering the North Sea, along a coast-line 42 miles long, France, the provinces of Hainaut and East Flanders, and the kingdom of Holland. The western part of the ancient Countship of Flanders, it was, when under the government of France, called the *département de la Lys.* Seawards, West Flanders is fringed by a line of dunes, along which, on the inland side, extend polders or alluvial lands. The subsoil of the province is sandy, but the surface has become modified in consequence of excellent cultivation. The land is a low-lying plain, except along the southern frontier, which presents a chain of hills over 300 feet high. The principal crops are cereals, flax, hemp, colza, chicory, tobacco. The live stock feeding on its good pastures numbers 200,000 head. The industries include agriculture, occupying 24 per cent. of the population, flax, cloth, table-linen, and lace, the manufacture of chicory and oils, of linen and colza, sea-fishing, employing 400 smacks and 2000 men. The coast is dotted with popular bathing-places—Ostend, Blankenberghe, Heyst, Knocke, Mariakerke, &c. The province is divided into eight administrative arrondissements. The chief towns are Bruges (with 53,000 inhabitants), the capital of the province, Ostend (38,500 inhabitants), Courtrai (33,500 inhabitants). The province has an area of 1249 square miles. The arrondissement of Courtrai is the one of densest population, 1134 to the square mile. The population of West Flanders, 696,651 in 1875, had increased by 113,793 in 1899, an increase of 16 per cent. (810,444, or 649 to the square mile).

II. EAST FLANDERS (Flemish, *Oost-Vlaanderen;* French, *Flandre orientale*), bordering on West Flanders, Hainaut, Brabant, and Antwerp, and the kingdom of Holland. The eastern part of the Countship of Flanders, established in the 9th century, was under the government of France (1795–1814) known as the *département de l'Escaut.* The land spreads out low and flat, rising a little towards the south. Muddy in the south, sandy in the north, the soil, by persistent cultivation, has been rendered fertile, more especially in the land of Waes, situated on the left of the Lower Escaut. The principal crops are cereals, flax, hemp, colza, and hops. The live stock includes 225,000 head of cattle and 200,000 pigs. More than a quarter of the population is engaged in agriculture. Other industries are the cotton manufacture, having Ghent for its principal seat; the industry in flax, thread, and cloths; the manufacture of woollen textures, pure and mixed with cotton; and roperies. The province is divided into six administrative arrondissements, having for their capitals Ghent (with 163,000 inhabitants), Eecloo (13,000 inhabitants), St Nicolas (30,300), Termonde (10,000), Alost (29,700), and Audenarde, or Oudenarde (8900). The province has an area of 1158 square miles. The arrondissement of Ghent has the greatest density of population, 1111 to the square mile. The population of the province, 868,228 in 1875, had added to that amount 166,203 by 1899 (1,034,431, or 893 to the square mile), an increase of 19 per cent.

Flatbush, formerly a township on Long Island, New York, near Brooklyn, and annexed to that city, with other parts of King's County, in 1894. (See BROOKLYN.)

Flaubert, Gustave (1821–1880), French novelist, was born at Rouen, on the 12th of December 1821. His father, in whom many traits are reproduced in "Charles Bovary," was a surgeon in practice at Rouen; his mother was connected with some of the oldest Norman families. He was educated in his native city, and did not leave it until 1840, when he came up to Paris to study law. He is said to have been idle at school, but to have been occupied with literature from the age of eleven. Flaubert in his youth "was like a young Greek," full of vigour of body and a certain shy grace, enthusiastic, intensely individual, and apparently without any species of ambition. He loved the country, and Paris was extremely distasteful to him. He made the acquaintance of Victor Hugo, and towards the close of 1840 he travelled in the Pyrenees and Corsica. Returning to Paris, he wasted his time in sombre dreams, living on his patrimony. In 1846, his mother being left quite alone through the deaths of his father and his sister Caroline, Flaubert gladly abandoned Paris and the study of the law together, to make a home for her at Croisset, close to Rouen. This estate, a house in a pleasant piece of ground which ran down to the Seine, became Flaubert's home for the remainder of his life. From 1846 to 1854 he carried on relations with the poetess, Mlle. Louise Colet; their letters have been preserved, and according to M. Faguet, this was the only sentimental episode of any importance in the life of Flaubert, who never married. His principal friend at this time was Maxime Du Camp, with whom he travelled in Brittany in 1846, and through the East in 1849.

Greece and Egypt made a profound impression upon the imagination of Flaubert. From this time forth, save for occasional visits to Paris, he did not stir from Croisset. On returning from the East, in 1850, he set about the composition of *Madame Bovary*. He had hitherto scarcely written anything, and had published nothing. The famous novel took him six years to prepare, but was at length submitted to the *Revue de Paris*, where it appeared in serial form in 1856. The Government brought an action against the publisher and against the author, on the charge of immorality, but both were acquitted; and when *Madame Bovary* appeared in book-form it met with a very warm reception. Flaubert now



GUSTAVE FLAUBERT.
(*From a photo. by P. Nadar, Paris.*)

settled down to the archæological studies which were required to equip him for *Salammbô*, which, however, in spite of the author's ceaseless labours, was not finished until 1862. He then took up again the study of contemporary manners, and, making use of many recollections of his youth and childhood, wrote *L'Éducation Sentimentale*, the composition of which occupied him seven years; it was published in 1869. Up to this time the sequestered and laborious life of Flaubert had been comparatively happy, but misfortunes began to gather around him. He felt the anguish of the war of 1870 so keenly that the break-up of his health has been attributed to it; he began to suffer greatly from a distressing nervous malady. His best friends were taken from him by death or by fatal misunderstanding; in 1872 he lost his mother, and his circumstances became greatly reduced. He was very tenderly guarded by his niece, Mme. Commonville; he enjoyed a rare intimacy of friendship with George Sand, and occasionally he saw his Parisian acquaintances, Zola, A. Daudet, Tourgenieff, the Goncourts; but nothing prevented the close of Flaubert's life from being desolate and melancholy. He did not cease, however, to work with the same intensity and thoroughness. *La Tentation de St Antoine*, which he had begun so long before as 1857, was at length completed and sent to press in 1874. In that year he was subjected to a disappointment by the failure of his drama *Le Candidat*. In 1877 Flaubert published, in one volume, *Un cœur simple*, *La légende de Julien l'Hospitalier*, and *Herodias*. After this something of his judgment certainly deserted him; he spent the remainder of his life in the toil of building up a vast satire on the futility of human knowledge and the omnipresence of mediocrity, which he left a fragment. This is the depressing and bewildering *Bouvard et Pécuchet*, which, by a curious irony, he believed to be his masterpiece. Flaubert had rapidly and prematurely aged since 1870, and he was quite an old man when he was carried off by a stroke of apoplexy at the age of only 58, on the 8th of May 1880. He died at Croisset, but was buried in the family vault in the cemetery of Rouen. A beautiful monument to him by Chapu was unveiled at the Museum of Rouen in 1890. The personal character of Flaubert offered various peculiarities. He was shy, and yet extremely sensitive and arrogant; he passed from silence to an indignant and noisy flow of language. The same inconsistencies marked his physical nature; he had the build of a guardsman, with a magnificent Viking head, but his health was uncertain from childhood, and he was neurotic to the last degree. This ruddy giant was secretly gnawn by misanthropy and disgust of life. His hatred of the "bourgeois" began in his childhood, and developed into a kind of monomania. He despised his fellow-men, their habits, their lack of intelligence, their contempt for beauty, with a passionate scorn which has been compared to that of an ascetic monk. Flaubert's curious modes of composition favoured and were emphasized by these peculiarities. He worked in sullen solitude, sometimes occupying a week in the completion of one page, never satisfied with what he had composed, violently tormenting his brain for the best turn of a phrase, the most absolutely final adjective. It cannot be said that his incessant labours were not rewarded. His private letters show that he was not one of those to whom easy and correct language is naturally given; he gained his extraordinary perfection with the unceasing sweat of his brow. One of the most severe of academic critics admits that "in all his works, and in every page of his works, Flaubert may be considered a model of style." That he was one of the greatest writers who ever lived in France is now commonly admitted, and his greatness principally depends upon the extraordinary vigour and exactitude of his style. Less perhaps than any other writer, not of France, but of modern Europe, Flaubert yields admission to the inexact, the abstract, the vaguely inapt expression which is the bane of ordinary methods of composition. He never allowed a *cliché* to pass him, never indulgently or wearily went on, leaving behind him a phrase which "almost" expressed his meaning. Being, as he is, a mixture in almost equal parts of the romanticist and the realist, the marvellous propriety of his style has been helpful to later writers of both schools, of every school. The absolute exactitude with which he adapts his expression to his purpose is seen in all parts of his work, but particularly in the portraits he draws of the figures in his principal romances. The degree and manner in which, since his death, the fame of Flaubert has extended, form an interesting chapter of literary history. The publication of *Madame Bovary* in 1857 had been followed by more scandal than admiration; it was not understood at first that this novel was the beginning of a new thing, the scrupulously truthful portraiture of life. Gradually this aspect of his genius was accepted, and began to crowd out all others. At the time of his death he was famous as a realist, pure and simple. Under this aspect Flaubert exercised an extraordinary influence over E. de Goncourt, Alphonse Daudet, and M. Zola. But even since the decline of the realistic school Flaubert has not lost prestige; other facets of his genius have caught the light. It has been perceived that he was not merely realistic, but real; that his clairvoyance was almost boundless; that he saw certain phenomena more clearly than the best of observers had done. Flaubert is a writer who must always appeal more to other authors than to the world at large, because the art of writing, the indefatigable pursuit of perfect expression, were always before him, and because he hated the lax felicities of improvization as a disloyalty to the most sacred procedures of the literary artist. (E. G.)

Flèche, La, chief town of arrondissement, department of Sarthe, France, 27 miles S.S.W. of Le Mans by rail, on a tributary of the Maine. The chief object of interest is the Prytanée, a famous school for the sons of officers, with accommodation for 600 pupils, occupying the buildings of an ancient Jesuit College. It stands in a fine park, and has a library of 20,000 volumes. In the market-place is a bronze statue of Henry IV. Starch, goloshes, sabots, and paper are manufactured. Population (1881), 6967; (1901), 10,519.

Fleetwood, a seaport and watering-place in the Blackpool parliamentary division of Lancashire, England, at the mouth of the Wyre, 8 miles north by east of Blackpool by rail. St Peter's church has been enlarged, and there are now market-buildings, and a free library and public hall. In the neighbourhood are salt works. The dock is provided with railways, and machinery for facilitating traffic; a large grain elevator has been erected. The shipping traffic is chiefly in the coasting and Irish trade. Regular communication with Scotland has been established. In 1900 the registered vessels belonging to the port were 81 sailing vessels of 5142 tons net, and 35 steamers of 4469 tons net; total, 116 vessels of 9611 tons. In 1900, 2607 vessels of 530,277 tons entered, and 2614 vessels of 548,698 tons cleared. Value of imports in the foreign and colonial trade (1900), £879,112; of exports of produce and manufactures of United Kingdom, £14,828. Area of urban district, 2510 acres. Population (1881), 6733; (1891), 9274; (1901), 12,093.

Flemington and Kensington, a borough of Victoria, Australia, in the county of Bourke, 3 miles north-west of and suburban to Melbourne, with one of the finest race-courses in the world. It has the city cattle market and abattoirs, the latter erected at a cost of about £60,000. Population (1901), 10,947.

Flensburg, a seaport town of Prussia, province of Schleswig-Holstein, at the head of the Flensburg Fjord of the Baltic, 39 miles by rail north by east from Rendsburg. It is a busy centre of trade and industry, importing coals and other commodities. In 1898 the port was cleared by 2049 vessels of 191,130 tons. The church of St Nicholas, built about 1390, was restored in 1894, and provided with a tower 295 feet high; the 13th century church of St Mary has also been provided with a tower 230 feet high. There are new law courts (1884) and a new theatre (1894). A technical school of wood-carving, a school of marine engineering, two schools of navigation, an agricultural school, and a commercial school are the principal educational adjuncts of a special character. Population (1885), 33,313; (1895), 40,840; (1900), 48,907.

Flers, a town in the arrondissement of Domfront, department of Orne, France, 37 miles, in direct line, north-west of Alençon, on the railway from Paris, and an affluent of the Noireau. There are a fine Norman church, a castle (restored) founded in the 5th century, a communal college, an industrial school, and a chamber of commerce. Manufactures are very important, and include a variety of cotton and linen fabrics, of which the annual value is about £1,500,000, also drugs and chemicals; and there are large brick and tile works, flour mills, and dyeworks. Population (1881), 9494; (1901), 13,683.

Flint, capital of Genesee County, Michigan, U.S.A., in 43° 01′ N. and 83° 41′ W., on Flint river, at an altitude of 709 feet. It is on the Grank Trunk and the Flint and Pere Marquette railways. The Michigan Institute for the Deaf and Dumb is situated here. Flint is largely a lumber town. It contains several large saw-mills, and produces much manufactured lumber. Population (1880), 8409; (1890), 9803; (1900), 13,103, of whom 2165 were foreign-born, and 257 negroes.

Flint, Austin (1812–1886), American physician, was born at Petersham, Massachusetts, 20th October 1812. He graduated at the medical department of Harvard University in 1833. He established the Buffalo *Medical Journal*, was one of the founders of the Buffalo Medical College, and was professor of the Theory and Practice of Medicine in that institution from 1847 to 1853. He was professor of the Theory and Practice of Medicine in the University of Louisville, 1852–56; professor of the Principles and Practice of Medicine and Clinical Medicine in Bellevue Hospital Medical College, New York, 1861–86. He wrote many text-books on medical subjects, among these being, *Diseases of the Heart* (1859-70); *Principles and Practice of Medicine* (1866); *Clinical Medicine* (1879); and *Physical Exploration of the Lungs by means of Auscultation and Percussion* (1882). He died in New York on 13th March 1886.

Flint, Austin (1836——), American physician, son of the foregoing, was born at Northampton, Mass., on 28th March 1836. He was educated at Harvard University and at the University of Louisville, Ky. (1854–56). He graduated at the Jefferson Medical College, Philadelphia, in 1857. In 1858 he became professor of Physiology and Microscopic Anatomy in the University of Buffalo, and in the year following professor of Physiology in the New York Medical College. In 1860 he was appointed professor of Physiology in the New Orleans Medical School; in 1861 professor of Microscopic Anatomy in Bellevue Medical Hospital; and in 1862 professor of Physiology in the Long Island College Hospital. He was better known as a teacher and writer on the subject of physiology than as a practitioner of medicine. His most exhaustive work, *Physiology of Man* (5 vols., 1866–74), never attained the popularity of his *Text-book of Human Physiology* (1876), which was for many years a standard text-book in the majority of American medical colleges. Among his other publications, the best known are, *Chemical Examination of the Urine in Disease* (1870), *Effects of Severe and Protracted Muscular Exercise* (1871), and *Service of Muscular Power* (1878).

Flintshire, a maritime county of North Wales, consists of a main and a detached portion. The main portion is bounded N.W. by the estuary of the Dee and Cheshire, and S.E., S., and S.W. by Denbigh. The detached portion, 8 miles to the S.E. of the main portion, is surrounded by Cheshire, Shropshire, and Denbigh.

Area and Population.—The area of the ancient county is 164,050 acres, or 256 square miles. Population (1881), 80,441; (1891), 77,277, of whom 38,242 were males and 39,035 females, the number of persons per square mile being 302, and of acres to a person 2·12; (1901), 81,725. The area of the administrative county, as given in the census returns of 1891, is 164,051 acres, with the same population as the ancient county; but in 1896 the part of the parish of Threapwood in Flint was transferred to Chester and in 1897 part of the parish of Llanarmon yn Yale, and part of the parish of Erbistock, were transferred to Denbigh, while part of the parish of Nannerch in Denbigh was added to Flint. The area of the registration county is 73,380 acres, with a population in 1891 of 42,565. Within this area the decrease of population between 1881 and 1891 were 7·01 per cent. The excess of births over deaths between 1881 and 1891 was 4592, but the resident population decreased by 3209.

The following table gives the number of marriages, births, and deaths, with the number and percentage of illegitimate births for 1880, 1890, and 1898 :—

Year.	Marriages.	Births.	Deaths.	Illegitimate births.	
				No.	Per cent.
1880	241	1426	877	80	5·6
1890	280	1123	848	69	6·1
1898	269	1192	762	45	3·8

In 1891 there were in the county 326 natives of Scotland, 912 natives of Ireland, and 263 foreigners, while 12,862 persons could speak English, 10,484 Welsh, and 16,879 English and Welsh.

Constitution and Government.—The county returns one member to parliament, and it also includes the Flint district of boroughs (consisting of Caergwrle, Caerwys, Flint, Holywell, Mold, Overton, Rhuddlan, and St. Asaph) and a small part of the parliamentary borough of Chester. There is one municipal borough, Flint. The urban districts are : Buckley, Connah's Quay, Holywell, Mold, Prestatyn, and Rhyl. Flintshire is in the North Wales and Chester Circuit, and assizes are held at Mold. The borough of Flint has a separate commission of the peace, but no separate court of quarter sessions. The ancient county, which is partly in the dioceses of Chester, Lichfield, and St. Asaph, contains 46 entire ecclesiastical parishes or districts and parts of eleven others.

Education.—The number of elementary schools on 31st August 1899 was 99, of which 15 were board and 84 voluntary schools, the latter including 66 National Church of England schools, 8 Roman Catholic, and 10 "British and other." The average attendance at board schools was 2297, and at voluntary schools 9877. The total school board receipts for the year ended 29th September 1899, were over £10,179. The income under the Agricultural Rates Act was over £617.

Agriculture.—About three-fourths of the total area of the county is under cultivation, and of this about three-fifths is in permanent pasture. About one-half of the acreage under corn crops is occupied by oats, wheat and barley occupying each less than a fourth. Since 1880 the corn acreage has decreased more than a fourth, the decrease being chiefly in the acreage under wheat, but partly in that under barley, while the acreage under oats has slightly increased. The principal green crops are turnips and potatoes, which occupy respectively a little less than two-sevenths and four-sevenths of the acreage. The following table gives the larger main divisions of the cultivated area at intervals from 1880 :—

Year.	Total area under cultivation.	Corn Crops.	Green Crops.	Clover.	Permanent Pasture.	Fallow.
1880	128,738	30,007	8100	17,095	70,937	2599
1885	128,346	28,763	8562	14,556	74,978	1487
1890	128,206	26,712	8217	16,879	75,131	1221
1895	126,392	23,759	8166	17,485	76,263	618
1900	126,662	22,029	7405	23,774	72,812	600

The following table gives particulars regarding the principal live stock for the same years :—

Year.	Total Horses.	Total Cattle.	Cows or Heifers in Milk or in Calf.	Sheep.	Pigs.
1880	5593	28,537	13,378	65,561	11,816
1885	5694	32,130	14,801	59,884	14,734
1890	5974	32,399	15,392	71,752	19,008
1895	6992	33,609	16,054	68,744	19,664
1900	6743	38,426	17,174	86,215	18,124

Industries and Trades.—According to the annual report for 1898 of the chief inspector of factories (1900), the total number of persons employed in factories and workshops in 1897 was 4957, as compared with 4463 in 1896. Of these 4152 were employed in non-textile factories. Hardly any fishing is carried on. The total number employed in connexion with mines and quarries in 1899 was 4192. In the same year 181,828 tons of clay were raised, and 40,283 tons of limestone. The following table gives particulars regarding the output of coal, lead, and zinc in 1890 and 1899 :—

Year.	Coal.		Lead.		Zinc.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
1890	754,149	£311,086	5222	£48,419	1117	£7449
1899	682,630	£264,519	7617	£79,095	4728	£34,693

(T. F. H.).

Floquet, Charles Thomas (1828–1896), French statesman, was born at St. Jean-Pied-de-Port (Basses-Pyrénées), on the 2nd October 1828. He studied law in Paris, and was called to the Bar in 1851. The *coup d'état* of that year aroused the strenuous opposition of Floquet, who had, while yet a student, given proof of his Republican sympathies by taking part in the fighting of 1848. He made his name by his brilliant and fearless attacks on the Government in a series of political trials, and at the same time contributed to the *Temps* and other influential journals. When the Tsar Alexander II. visited the Palais de Justice in 1867, Floquet was said to have confronted him with the cry "Vive la Pologne, monsieur !" He delivered a scathing indictment of the Empire at the trial of Pierre Bonaparte for killing Victor Noir in 1870, and took a prominent part in the Revolution of 4th September, as well as in the subsequent defence of Paris. In 1871 he was elected to the National Assembly by the department of the Seine. He opposed the measures of the Government, and formed the *Ligue d'union républicaine des droits de Paris.* He was thrown into prison, but was soon released. He became editor of the *République Française*, was chosen President of the Municipal Council, and in 1876 was elected deputy for the eleventh arrondissement by 22,000 votes out of 24,000. He took a prominent place among the extreme Radicals, and became president of the group of the "Union républicaine." In 1882 he held for a short time the post of Prefect of the Seine. In 1885 he succeeded M. Brisson as President of the Chamber. This difficult position he filled with such tact and impartiality that he was re-elected the two following years. Having approached the Russian Ambassador in such a way as to remove the prejudice existing against him in Russia since the incident of 1867, he rendered himself eligible for office ; and on the fall of the Tirard Cabinet in 1888 he became President of the Council and Minister of the Interior in a Radical ministry, which pledged itself to the Revision of the Constitution, but was forced to combat the proposals of General Boulanger. Heated debates in the Chamber culminated on 13th July in a duel between Floquet and Boulanger, in which the latter was wounded. In the following February the Government fell on the question of Revision, and in the new Chamber of November Floquet was re-elected to the presidential chair. The Panama scandals, in which he was compelled to admit his implication, dealt a fatal blow to his career : he lost the Presidency of the Chamber in 1892, and his seat in the House in 1893, but in 1894 was elected to the Senate. He died in Paris on 18th January 1896.

See *Discours et opinions de M. Charles Floquet*, edited by Albert Faivre (1885). (H. Sy.)

Florence (Italian, *Firenze ;* ancient, *Florentia*), formerly capital of the Grand Duchy of Tuscany, capital of Italy from 1864 to 1870, and now chief town of the province to which it gives its name, 120 miles north of Rome, on the river Arno. Florence is an archiepiscopal see, and headquarters of the Sixth Italian Army Corps. In 1899 the population was estimated at 216,051. The area of the city has been greatly extended by new quarters which have arisen outside the old *octroi* circle, and especially towards Porta San Gallo and Porta alla Croce. These new quarters are inhabited both by the population of the old centre of the city, which has been demolished and rebuilt, and the new inhabitants who come to Florence, especially from the surrounding province. This transformation of the city long preoccupied the municipal council and the people of Florence. The fate of the centre of Florence became a burning question, in which much interest was taken outside Florence, and especially in England. The problem at the moment of the reconstruction of the centre in

1888 appeared extremely difficult. The centre had become, from a hygienic point of view, almost uninhabitable, and was a nest of the lowest and most corrupted portion of the Florentine populace. It was necessary to execute a sanitary reform, and at the same time to respect as much as possible of the old quarter that possessed a real historical or artistic interest. The solution has been characterized by greater care for sanitary reform than for artistic and historical considerations. Unfortunately the new buildings of the centre are, as a rule, ugly, and out of keeping with the historical character of the city. The new quarters outside the gates are better in every respect, and especially the so-called *viali* or boulevards which surround the city. This part of Florence has the appearance of a quiet, well-to-do residential town. The Florentine Art Galleries, and in particular the Uffizi and the Galleria d'Arte Antica e Moderna, have undergone several improvements. In the Uffizi the pictures have been rearranged in strict chronological order. On the first floor four new rooms have been opened for the portraits of famous painters, according to epoch and nationality. A large number of the most celebrated modern painters of all countries have presented their portraits to the gallery. A new stairway has been built from these rooms to the second storey, where the great artistic collections, including that of Tuscan art, are situated. In the gallery of ancient and modern art in Via Ricasoli, by the side of the Fine Arts Academy, three new rooms have been opened. The Perugino and Botticelli rooms deserve special mention, since they contain the principal works of those great masters. The great hall on the first floor has been divided into three rooms, containing the works of the Tuscan masters from the 13th to the 18th centuries chronologically arranged and classified. In the Pitti Gallery a magnificent new stairway and a new vestibule have been constructed by royal munificence.

Florentine artistic treasures have recently been increased by the discovery of several old paintings of great importance in the churches and palazzi of the city and in the neighbouring villas. One of these paintings was a Ghirlandajo, discovered in the church of the Ognissanti. This discovery aroused great interest, both on account of the fame of the master and from the fact that among the figures in the picture is that of Amerigo Vespucci as a young man. By a coincidence the discovery was made shortly before the fourth centenary celebration of Vespucci's discovery of America. Another valuable work came to light in 1899 in the church of the Santissima Annunziata. It is a fresco by Andrea del Castagno, representing St Jerome in the desert. In the famous Villa al Gallo, once occupied by Galileo, several painted figures were discovered, and were first attributed to Botticelli, but after maturer study to Pollajolo. Further, in the Pitti storehouse a painting, also attributed to Botticelli, though possibly the work of one of his pupils, was found in 1899. The important National Library, situated near the Uffizi, has received constant attention. The library, the largest in Italy, is constantly increasing in dimensions, and at present contains nearly 1,000,000 books and pamphlets, 19,000 manuscripts, 957 parchments, 300,000 letters and autographs, 22,800 musical works, 25,000 portraits, and 1700 maps, besides prints and engravings. This enormous accumulation of valuable material outgrew the space at the disposal of the library. A number of Government commissions successively reported in favour of a new library building, for which the Florentine municipality offered the site in the centre of the city. After long delays the offer was accepted, a state subsidy granted, and the construction of the new edifice authorized.

Great care has been bestowed upon the Florentine schools and gymnasia. Besides numerous elementary schools Florence now possesses three lyceums and gymnasia, named after the three greatest Florentines—Dante, Michelangelo, and Galileo Galilei. There are, besides, technical, commercial, and professional schools; schools for female professional training, an academy of fine arts, a musical conservatory, a school of social science (founded by the late Marquis Alfieri di Sostegno for intending diplomatists), a school of recitation, and an Institute of Superior Studies. This latter institute serves as a university, although it possesses only the faculties of letters, medicine, and social science. Nevertheless in regard to philological and philosophical studies it holds the first place in Italy. The Institute of Superior Studies has, in fact, succeeded in reawakening in Italy the love for classical literature, and has taken the initiative in promoting public lectures on the Greek Theatre. The professors of the Institute have also displayed praiseworthy activity in promoting the cult of Dante and the study of the *Divina Commedia* in his native city. The influence of this Florentine initiative has been felt throughout Italy, so that the study of Dante may now be said to be more flourishing in the peninsula than ever before. A society for public art, founded in Florence and extended to other Italian cities, exercises considerable influence in the æsthetic questions connected with industries and public buildings. The development of painting, sculpture, and architecture has not kept pace with that of literature. The only really important work accomplished during recent years has been the façade of the cathedral (Sta Maria del Fiore), executed by Tuscan artificers from the designs of the architect De Fabris. During the long work the marble masons acquired a skill hardly inferior to that displayed in Renaissance structures. Begun in 1875, the façade was unveiled in 1888. In other respects Florentine art has declined, as is proved by the new buildings of the centre and by the modern monuments erected in the squares. Industries have not shown any considerable tendency to develop. Florence still feels the effect of the transfer of the capital to Rome. Local trade has increased, but manufactures on a large scale are still lacking. Florence still remains the capital of an agricultural district, and the Piazza della Signoria and the Loggie del Mercato Vecchio still serve as the rendezvous for peasants and factors. The decadence of the straw-plaiting industry in the surrounding districts has made its effects felt also in the city. Perhaps the only really important Florentine industry is represented by the porcelain works of Signor Cantagalli and by the manufactory formerly belonging to the Marchese Ginori di Doccia, but now the property of a Milanese porcelain firm, Richard & Co.

See Eugène Muntz. *Florence et la Toscane; paysages, monuments, mœurs et souvenirs historiques.* Paris. Hachette, 1901.—Perrens. *L'Histoire de Florence.*—Berenson. *The Florentine Painters of the Renaissance.*—Horner. *Walks in Florence.*—Hare. *Florence.*—Gardner. *Florence* (Dent Collection).—Conti. *Firenze Vecchia.*—Guido Carocci. *I Dintorni di Firenze; Firenze Scomparsa.*—Isidoro del Lungo. *Florentia.* Florence, 1899. (E. Co.)

Florence, capital of Lauderdale County, Alabama, U.S.A., on the northern bank of the Tennessee river, at the foot of Muscle Shoals Canal, at an altitude of 563 feet. The Southern and the Louisville and Nashville railways intersect here. It contains several minor educational institutions, the Southern Female University, the Synodical Female College, and the State Normal College. Population (1880) 1359; (1890) 6012; (1900) 6478, of whom 90 were foreign-born, and 1952 negroes.

Flores, an island of the Dutch East Indies, with an area of 5838 square miles. The coasts have deep bays and extensive rounded gulfs, where are situated the principal villages (kampongs). On the north coast are Bari, Reo, Maumer, and Geliting; on the east, Larantuka; and on the south, Sikka and Endeh. The existence of slate, chalk, and sandstone, eruptive rock, volcanoes, and heights stretching west and east, indicates a similar structure to that of the other Sunda Islands. Several volcanoes are still active. The rivers, known only at their mouths, seem to be unnavigable. The climate has a mean temperature of 77° to 80° F. and a yearly rainfall of 43 inches to 47 inches. For administrative purposes the island is divided into West Flores (Mangerai), attached to the government of Celebes, and Middle and East Flores (Larantuka and dependencies), attached to the residency of Timor. The population (250,000) live by trade, fishing, salt-making, shipbuilding, and the cultivation of rice, maize, and palms in the plain, but there is little industry.

VETH. *Geographische aanteekeningen over Flores.* Tijdschr. Aardr. Gen. i., 1876, p. 180.—KLEIAN. *Voetreis over het O. deel van Flores.* Tijdschr. Bat. Gen., 1891, p. 485.—JACOBSEN. *Reisen im O. I. Archipel.* Petermann's Mitteil, 1890, p. 103.—WICHMANN. *Bericht über eine Reise,* &c. Tijdschr. Aardr. Gen., 1891, p. 188. —HOEDT. *Verslag der reis naar de noordkust van Flores.* Tijdschr. Bat. Gen., 1893, p. 281.—KAN. *Flores.* Encyclop. v. N. I., with detailed bibliography and full description of the island.

Florianopolis, a city and port of Brazil, formerly called Desterro, capital of the State of Santa Catharina. It is situated on the island of Santa Catharina and has a population estimated at from 22,000 to 27,000. It is an agriculture centre. In 1897 the port was visited by 335 ships of 151,098 tons burden.

Florida, the most southern State of the United States of America, projecting as a peninsula between the Atlantic Ocean on the east, and the Gulf of Mexico on the west. The chief political event of late years was the framing of a new State constitution by a Convention which assembled at the capital at Tallahassee, in June 1885, with Samuel Pasco as President, and its subsequent ratification by the people. Under the former constitution the State and county officers, with few exceptions, were appointed by the governor; and the terms of the justices of the Supreme Court were for life. The new constitution made all the principal officers elective except the circuit judges, and changed the life term to a term for six years. Other fundamental changes were introduced. The governor cannot be immediately re-elected; in case of a vacancy during his term, the succession falls first upon the President of the Senate, and secondly upon the Speaker of the House of Representatives. The legislature meets biennially, and is composed of thirty-two senators and sixty-eight representatives. The legislature was authorized to make the payment of a poll-tax a prerequisite for voting, and has exercised this authority. The poll-tax cannot exceed one dollar annually, and is applied towards the support of the public schools. Authority was also given to enact laws for the correction of abuses and the prevention of unjust discrimination and excessive charges by common carriers. A Railway Commission was accordingly provided for, consisting of three members, who serve for a term of four years, and are elected by the people. The State has been Democratic in politics since 1876.

Population, Taxation, and Indebtedness.—The population of the State was, in 1880, 269,493, and in 1890, 391,422. In 1895 it was 464,639, of whom 271,561 were white and 193,078 coloured. In 1900 it was 528,542, an increase during the decade of 137,120, or 35 per cent. The total land surface is approximately 54,240 square miles, and the average number of persons to the square mile was 9·7 in 1900, as compared with 7·2 in 1890. Of the total population 275,246 were males and 253,296 females, 504.710 were native-born and 23,832 foreign-born, 297,333 white and 231,209 coloured (including 230,730 negroes, 120 Chinese, 1 Japanese, and 358 Indians). Out of 139,601 males 21 years of age and over, 30,729 were illiterate (unable to write), of whom 6558 were white and 24,171 were negroes. The death-rate of the entire State in 1900, on the basis of the deaths reported to the United States census enumerators in that year, was about 12·2. There were, in 1900, 92 incorporated cities, towns, and villages, of which only 14 had a population of over 2000, and only 4 a population of over 5000. These 4 were: Jacksonville, with 28,429 inhabitants; Pensacola, with 17,747; Key West, with 17,114; and Tampa, with 15,839. Between 1890 and 1900 the inhabitants in cities of over 8000 increased from 47,031 (12 per cent. of the total population) to 79,129 (15 per cent. of the total population), an increase considerably greater than that shown in the rural districts. In 1880 the value of real and personal property was $31,157,846; in 1899 it was $93,527,353·79. The rate of State taxation in 1880 was seven mills; in 1900 it was five mills for all State purposes. There is no floating debt, and the cash on hand belonging to the different State funds, 1st January 1901, was $370,559·46. The total bonded indebtedness is made up of 7 per cent. bonds of 1871 to the amount of $350,000, and 6 per cent. gold bonds of 1873 to the amount of $925,000, giving a total of $1,275,000. Of the bonds of 1871, on 1st January 1901, $82,300 were in the sinking fund; $255,700 were in the school, seminary, and college funds; and $12,000 were in the hands of individuals. Of the bonds of 1873, $160,200 were in the sinking fund; $586,000 were in school, seminary, and college funds; and $178,800 in the hands of individuals. The total of both issues in the hands of individuals on 1st January 1901 was thus $190,800.

Education.—In 1880 there were 1131 schools with 38,415 pupils, and the annual expenditure was $141,934·16. In 1896, out of a total average attendance of 66,135, 41,992 were whites and 24,143 were coloured. In 1900 there were 2443 schools with 108,874 pupils enrolled, and the annual expenditure was $765,777·42. The number of persons of school age (5 to 20 years inclusive) was 197,600. Two normal schools were provided for by the constitutional convention of 1885. One of these, for white teachers, has been located at De Funiak, the other, for coloured teachers, at Tallahassee. Both are in successful operation. In 1883 an institute for the deaf and blind was established at St Augustine, with separate departments for the two races. Facilities for advanced education are provided for coloured students at the following institutions: Edward Waters College, Jacksonville; Florida Baptist Institute, Jacksonville; Florida Institute, Live Oak; Cookman Institute, Jacksonville. There are three educational institutions for advanced students, which owe their origin to the liberality of Congress—the East Florida Seminary at Gainesville, the Seminary West of the Suwannce at Tallahassee, and the State Agricultural College at Lake City; the last, in 1898, had 203 students, of whom 150 were males; and fifteen instructors, of whom thirteen were men. In addition to the proceeds of the funds, and the Congressional appropriations from which these derive the larger part of their support, they are aided with annual appropriations from the State treasury. The South Florida Military and Educational Institute at Bartow is partly supported by the State, and has a curriculum equal to that of like institutions in other States. A university and two colleges have been chartered by the State; the John B. Stetson University (in 1887) at Deland, with a faculty in 1898 of twenty-five instructors, fourteen of whom were men, and 191 students, 115 of whom were men; Rollins College (in 1885) at Winter Park, with a faculty of twenty instructors; and the Methodist Conference College, Leesburg, with a faculty of seven instructors.

Religion.—The leading religious denominations are: Methodists, who in 1890 reported 70,458 communicants; Baptists, 41,647; Catholics, 16,867; Presbyterians, 4574; and Episcopalians, 4225. The total number of communicants was 141,734. There were 1971 Church organizations, with 1793 edifices, valued at $2,424,423.

Railways.—In 1880 there were 518 miles of railway, and in 1900, 3231 miles. Six daily mail trains pass each way along three trunk lines from New York, through Jacksonville and Live Oak, to their terminal points at Tampa and Miami. During the tourist season an extra train on each line furnishes the most approved conveniences and facilities of modern travel to those who visit the State. Meanwhile many millions have been expended in the improvement and extension of terminal facilities at Pensacola and Tampa. These outlays are still going on, and are rendered necessary by the increased commercial intercourse with Cuba and Porto Rico, which has resulted from the war with Spain.

Fruits.—In the closing years of the 19th century Florida was visited by a series of cold winters that did great damage, especially to the orange crops. In December 1894 the ungathered fruit was destroyed as far south as Indian River; and in the following February, when the sap was rising, the younger trees were killed to the roots, except in the most southern part of the orange belt. In February 1899 snow fell to the depth of several inches as far south as Tampa, a novel sight to the native of Florida who had never been out of his State. In spite of these vicissitudes, however, such older trees as received proper attention and cultivation recovered. Before these calamitous visitations the record shipment for one year amounted to 5,000,000 boxes. It has been urged that these cold spells are caused by the clearing of forests, which has opened a path for the blizzards from the north, and that they thus indicate a permanent change in the climate; but similar disasters occurred in the earlier days. It seems likely that in the long cycles of meteorological changes citrus fruits may again bloom and bear their golden harvests, even in the northern part of the State. In 1897, 117,910 crates of pine-apples, valued at $160,662, were shipped from the State, and 58,194 barrels of pears, valued at $65,243. The northern part of the State is famous for its water-melons, which find a ready market at the north in the early part of the season; in Jefferson County many acres are planted for the seed, which is in great demand all over the United States.

Tobacco.—The manufacture of cigars, begun at Key West, has grown to enormous proportions. The cigars there made by Cuban workmen were of such excellent quality that the name of Key West became a valuable trade mark all over the country. Factories were subsequently established at Quincy, Jacksonville, Tampa, Ocala, and other points. In 1897, 261,663,000 cigars were manufactured, with a value of $16,161,310.

Mineral Products.—The principal mineral products added to the resources of the State in late years are phosphate, fuller's earth, and kaolin. In 1897, 30,000 tons of fuller's earth, of the value of $360,000, were shipped to other markets, and 69,000 sacks of kaolin, valued at $40,800. Phosphate was discovered about 1880, but its value and importance did not attract the attention of capitalists till 1890, when mines were opened at Dunellon and other places. Florida is now one of the large phosphate-producing districts of the world. From January 1891 to January 1899, 3,433,781 tons were mined, and during the fiscal year ending 30th June 1899, 515,498 tons of the crude product, valued at $4,043,775, were shipped from the ports of Florida to foreign countries. (See SOUTH CAROLINA.)

Other Products.—In 1900 there were in the State 519,524 acres given up to Indian corn, and producing 4,156,192 bushels, valued at $2,493,715; 33,470 acres of oats, yielding 378,211 bushels, valued at $189,106; and (in 1899) 149,403 acres of cotton, yielding, during the season of 1899–1900, 41,855 bales, valued at $2,189,805. The cotton ginned from the crop of 1900 amounted to 55,696 commercial bales, of a total gross weight of 24,308,127 ℔. On the 1st of January 1900 the number and value of farm animals in Florida, according to the Year-Book of the United States Department of Agriculture, were as follows: 38,050 horses, $1,776,778; 76,074 sheep, $128,870; 8521 mules, $610,096; 113,108 milch cows, $1,888,904; 299,712 other cattle, $2,512,036. The exports of timber and lumber during the year ending 30th June 1899 were valued at more than $7,500,000. There has been a marked increase in the production of naval stores, and many new turpentine farms and stills are in successful operation. Fleets of schooners and smaller vessels and many thousand men are employed in the fisheries at the different ports of the State. Many Pensacola vessels are engaged in the snapper fisheries; they frequently sail twenty-five hundred miles in a single trip; the fish are packed in ice, and shipped to all parts of the United States. In 1890 the value of this industry was $1,339,869, and it has grown largely since then. The sponge fisheries yield a quarter of a million dollars annually.

Commerce.—Regular lines of steamers run from Jacksonville to Charleston and New York, from Tampa to Key West and Havana; from Fernandina to Brunswick, Ga.; from Key West to New York and Galveston, New Orleans, and Havana, as well as from other ports. The exports of the leading ports have increased as follows:—

	1884.	1899.
Apalachicola	$230,334	$396,436
Fernandina	169,457	2,424,296
Jacksonville	35,733	176,305
Key West	412,318	1,742,313
Pensacola	2,581,426	14,214,690
Tampa	173,496	956,235
	$3,602,764	$19,910,275

During the decade from 1890 to 1900 Congress authorized the expenditure of $5,800,000 for the improvement and maintenance of rivers and harbours.

Banks.—In 1900 there were sixteen national banks, with a capital and surplus of $1,762,600, and deposits of $6,694,036·43; twenty-two State banks, with a capital and surplus of $871,086, and deposits of $2,912,534; and one savings bank, with a capital and surplus of $25,000, and deposits of $233,341.

The mild climate of Florida through the winter months has led to the influx of large numbers of tourists, and to the erection since 1885 of mammoth hotels costing millions of dollars, especially at St Augustine, Palm Beach, Ormond, Miami, and Tampa. (S. PA.)

Floridsdorf, or FLORISDORF, chief town in the government district of the same name in Lower Austria. It was formerly a village, commune, and station on the Northern railway, about three miles from Vienna. In 1890 it had 6123 inhabitants, but in 1896 it was made the seat of the government district of the same name, some adjoining villages being incorporated. This raised the population to 23,000, and in 1900 to 36,599, chiefly German and Catholic (estimated at 6 per cent. Czech, 4 per cent. Jewish, and 1·5 per cent. Protestant). In 1866 the Austrians occupied a fortified camp at Floridsdorf in anticipation of the Prussian advance on Vienna after the battle of Sadowa. The attack was averted, however, by the conclusion of the armistice. Floridsdorf is a busy industrial centre, its principal manufactures being machinery and liqueurs.

Flotow, Friedrich Ferdinand Adolf von, FREIHERR (1812–1883), a voluminous and popular German composer of operetta, was born on his father's estate at Teutendorf, in Mecklenburg, 27th April 1812. Destined originally for the diplomatic profession, his passion for music induced his father to send him to Paris to study under Reicha. But the outbreak of the Revolution in 1830 caused his return home, where he busied himself writing chamber-music and operetta until he was able to return to Paris. There he produced *Pierre et Cathérine*, *Rob Roy*, *La Duchesse de Guise*, but made his first real success with *Le Naufrage de la Méduse* at the Renaissance Théâtre in 1838. Greater, however, was the success which attended *Stradella* (1844) and *Martha* (1847), which made the tour of the world. In 1848 Flotow was again driven home by the Revolution, and in the course of a few years he produced *Die Grossfürstin* (1850), *Indra* (1853), *Rübezahl* (1854), *Hilda* (1855), and *Albin* (1856). From 1856 to 1863 he was director (Intendant) of the Schwerin opera, but in the latter year he returned to Paris, where in 1869 he produced *L'Ombre*. From that time to the date of his death he lived in Paris or on his estate near Vienna. He died 24th January 1883. Of his concert-music only the *Jubelouvertüre* is now ever heard. His strength lay in the facility of his melodies and in their often piquant dress. (R. H. L.)

Flower, Sir William Henry (1831–1899), English biologist, was born at Stratford-on-Avon on 30th November 1831. Choosing medicine as his profession, he began his studies at University College, London, where he showed special aptitude for physiology and comparative anatomy, and took his M.B. degree at the age of twenty. He then joined the Army Medical Service, and went out to the Crimea as assistant-surgeon, receiving the medal with four clasps. On his return to England he became a member of the surgical staff of the Middlesex Hospital, London, but within a few years gave up his post there in order to succeed Quekett as curator of the Hunterian Museum of the Royal College of Surgeons of England. In 1869 he was chosen Hunterian Professor, and in 1884, on the death of Owen, was appointed to the directorship of the Natural History Museum at South Kensington. He died in London on 1st July 1899. Sir William Flower's services to science were twofold. In the first place, he made valuable contributions to structural anthropology, publishing, for example, complete and accurate measurements of no less than 1300 human skulls. As a comparative anatomist, again, he ranked high, devoting himself especially to the study of the mammalia. In the second place, he was a leading authority on the arrangement of museums. The greater part of his life was spent in their administration, and in consequence he held very decided views as to the principles upon which the specimens should be set out. He insisted on the importance of distinguishing between collections intended for the use of specialists and those designed for the instruction of the general public, pointing out that it was as futile to present to the former a number of merely typical forms as to provide the latter with a long series of specimens differing only in the most minute details. His ideas, which were largely and successfully applied to the museums of which he had charge, gained wide approval, and their influence entitles him to be looked upon as a reformer who did much to improve the methods of museum arrangement and management. In addition to numerous original papers, he was the author of several books on zoological subjects, and of one dealing with topics connected with museums; he also wrote many articles for the ninth edition of this *Encyclopædia*, that on the Mammalia being the most elaborate. (H. M. R.)

Flushing (Dutch, VLISSINGEN), a fortified seaport on the island of Walcheren, in the province of Zealand, Holland, 50 miles south-west of Rotterdam, at the mouth of the estuary of the Western Scheldt. There is regular steam communication with Queenborough. Its considerable manufacture of machinery (employing about 1000 workmen), its state railway-workshops, and its *depôt* of the Krupp iron and steel works (Essen, Prussia) contribute to its prosperity. An aqueduct conveys excellent fresh water for the ships. The navigation of the port, however, is far behind that of Rotterdam and Antwerp, the tonnage in 1899 being 1,870,000 tons, or about 7·9 per cent. of that of the kingdom. The principal imports are now grain, colonial produce, wine, wood, and manufactures for the shipping trade. Of late years Flushing has acquired considerable popularity as a bathing resort, attracting visitors even from Germany. A chamber of antiquities has been opened in the Town Hall. Population in 1900, 18,896.

Flushing (NEW YORK). See NEW YORK CITY.

Focşani, chief town of the district of Putna, Rumania, 125 miles from Bucarest, on the river Milcov, which formed the ancient frontier of the former principalities of Moldavia and Wallachia. It is the seat of a court of first instance, has 27 orthodox churches, 1 Catholic, 2 Armenian churches, and 2 synagogues, and is the headquarters of the 6th Army Corps. Focşani is a commercial centre of some importance, the chief industries being oil and soap manufacture and tannery. A large and important wine trade is also carried on. The annual fair is held on the 29th of April. There is a Chamber of Commerce. Government explorations in the vicinity of this town show it to be rich in mineral sources, such as iron, copper, coal, and petroleum. Population (1895), 21,000; (1900), 23,783, of whom 6000 were Jews. The line Focşani–Galatz is covered by a very strong line of fortifications of the most modern type.

Fogazzaro, Antonio (1842——), Italian novelist and poet, was born at Vicenza in 1842. He was a pupil of the Abate Zanella, one of the best of the modern Italian poets, whose tender, thoughtful, and deeply religious spirit has continued to animate his literary productions. He commenced his literary career with *Miranda*, a poetical romance (1874), followed in 1876 by *Valsolda*, which, republished in 1886 with considerable additions, constitutes perhaps his principal claim as a poet, which is not inconsiderable. To the classic grandeur of Carducci and D'Annunzio's impetuous torrent of melody Fogazzaro opposes a Wordsworthian simplicity and pathos, contributing to modern Italian literature wholesome elements of which it would otherwise be nearly destitute. He has, however, attained far more celebrity as a novelist. His novels, *Malombra*, *Daniele Cortis*, *Mistero del Poeta*, obtained considerable literary success upon their first publication, but did not gain universal popularity until they were discovered and taken up by French critics in 1896. The demand then became prodigious, and a new work, *Piccolo Mondo Antico*, which critics far from friendly to Fogazzaro's religious and philosophical ideas have pronounced the best Italian novel since *I Promessi Sposi*, has gone through thirty editions. Fogazzaro's conservative attitude accounts for his success with large classes of Italian society, but there is much in his delicate and graceful talent independent of the controversies of his time. His biography, with essays illustrative of his characteristics, has been written by Signor Molmenti.

Foggia, a growing town and episcopal see of Italy (Apulia), capital of the province of Foggia, an important railway centre 123 miles by rail E.N.E. from Naples. It possesses a botanical garden, a technical school (1872), and a monument to the local patriot Lanza (1784–1860), and has large ironworks and foundries, and manufactures macaroni and liquorice. Population of town (1881), 40,283; (1901), 53,351; of province (1881), 356,267; (1901), 418,510.

Foli (Foley), Allan James (1837–1899), Irish bass singer, was born at Cahir, Tipperary, 7th August 1837; originally a carpenter, he studied under Bisaccia at Naples, and made his first appearance at Catania in 1862. From the opera in Paris he was engaged by Mapleson for the season of 1865, and appeared with much success in various parts. He sang in the first performance of *The Flying Dutchman* (Daland) in England in 1870, and in the first performance of Gounod's *Redemption* in 1882. He was distinguished in opera and oratorio alike for his vigorous, straightforward way of singing, and was in great request at ballad concerts. He died 20th October 1899.

Foligno or **Fuligno,** a town and bishop's see of Italy (Umbria, province of Perugia), 25 miles S.E. from Perugia by rail. There are a picture gallery, with works by the masters of the Umbrian school, an industrial arts school (1873), and numerous private mansions of architectural interest. Population about 19,000.

Folkestone, a parish, municipal borough, and seaport in the eastern division of Kent, England, 71 miles S.S.E. of London. It is included in the parliamentary borough of Hythe. Recent erections are Established and Roman Catholic churches, a Congregational hall, a Victoria hospital, a free library and museum, the Harveian Institute (for youths), a "Home of Rest" for ladies, a convalescent home, a Masonic hall, public baths, the Victoria pier promenade, and a bronze statue of Harvey (1881). An infectious diseases sanatorium has been enlarged. Radnor park (20 acres) was opened in 1886. Several lifts facilitate intercourse between the beach and the cliffs. The port was made a customs-port in 1882. The registered shipping is unimportant, but in 1888, 1268 vessels of 209,938 tons entered, and 1760 vessels of 212,468 tons cleared, while in 1898, 2420 vessels of 483,626 tons entered, and 2388 of 478,467 tons cleared. Area of urban district, 2321 acres. Population (1881), 18,816; (1891), 23,711; (1901), 30,694.

Fond du Lac, capital of Fond du Lac County, Wisconsin, U.S.A., in 43° 47′ N. and 88° 28′ W., at the southern end of Winnebago Lake, at the mouth of Fond du Lac river, at an altitude of 770 feet. The city is regularly laid out on a level plan, is supplied with water from artesian wells, and is served by three railways, the Chicago and North-Western, the Chicago, Milwaukee, and St Paul, and the Wisconsin Central. It has extensive manufactures of lumber and agricultural implements and machines. Population (1880), 13,094; (1890), 12,024; (1900), 15,110.

Fonsagrada, a town of Spain, in the east of the mountainous province of Lugo, on the river Navia. There is trade in wheat, wine, hemp, potatoes, and fruit. Much live stock is reared in this extensive township. The industries are linen and rough frieze manufacture, and cheese and butter making. The population, which was 17,200 in 1897, shows a tendency to decrease through emigration.

Fonseca, Manoel Deodoro da (1827–1891), first President of the United States of Brazil, born at Alagoas on 5th August 1827, was the third son of Lieut.-Colonel Manoel Mendes da Fonseca (died 1859). He was educated at the military school of Rio de Janeiro, and had attained the rank of captain in the Brazilian army when war broke out in 1864 against Montevideo, and afterwards against Solano Lopez, dictator of Paraguay. His courage gained him distinction, and before the close of the war in 1870 he reached the rank of colonel, and some years later that of general of division. After enjoying several military commands, he was nominated in 1886 governor of the province of Rio Grande do Sul. In this position he threw himself heartily into politics, espoused the republican opinions then becoming prevalent, and sheltered their exponents with his authority. After a fruitless remonstrance, the Government at the close of the year removed him from his post, and recalled him to the capital as director of the service of army material. Finding that even in that post he still continued to encourage insubordination, the minister of war, Alfredo Chaves, dismissed him from office. On 14th May 1887, in conjunction with the Viscount de Pelotas, Fonseca issued a manifesto in defence of the military officers' political rights. From that time his influence was supreme in the army. In December 1888, when the Conservative Correa d'Oliveira became prime minister, Fonseca was appointed to command an army corps on the frontier of Matto Grosso. In June 1889 the ministry was overthrown, and on a dissolution an enormous Liberal majority was returned to the Chamber of Deputies. Fonseca returned to the capital in September. Divisions of opinion soon arose within the Liberal party on the question of provincial autonomy. The more extreme desired the inauguration of a complete federal system. Amongst the most vehement was Ruy Barbosa, the journalist and orator, and after some difficulty he persuaded Fonseca to head an armed movement against the Government. The insurrection broke out on 15th November 1889. The Government commander, Almeida Barreto, hastened to place himself under Fonseca's orders, and the soldiers and sailors made common cause with the insurgents. The affair was almost bloodless, the minister of marine, baron de Ladario, being the only person wounded. Fonseca had only intended to overturn the ministry, but he yielded to the insistency of the republican leaders and proclaimed a republic. A provisional government was constituted by the army and navy in the name of the nation, with Fonseca at its head. The council was abolished, and both the Senate and the Chamber of Deputies were dissolved. The emperor was requested to leave the territory of Brazil within twenty-four hours, and on 17th November was embarked on a cruiser for Lisbon. On 20th December a decree of banishment was pronounced against the Imperial family. So universal was the republican sentiment that there was no attempt at armed resistance. The provisional government exercised dictatorial powers for a year, and on 25th February 1891 Fonseca was elected President of the republic. He was, however, no politician, and possessed indeed little ability beyond the art of acquiring popularity. His tenure of office was short. In May he became involved in an altercation with Congress, and in November pronounced its dissolution, a measure beyond his constitutional power. After a few days of arbitrary rule insurrection broke out in Rio Grande do Sul, and before the close of November Fonseca, finding himself forsaken, resigned his office. From that time he lived in retirement. He died at Rio de Janeiro on 23rd August 1892.

(E. I. C.)

Fontainebleau, chief town of arrondissement, department of Seine-et-Marne, France, 9 miles S. by E. of Melun, on the railway from Paris to Lyons. The palace is now the summer residence of the President of the Republic, and a school of practical artillery is installed in a section of the buildings. The Forest of Fontainebleau covers an area of 42,500 acres. Population (1881), 9621; (1896), 10,788; (1901), 10,923, or, including military, 14,160.

Fontenay-sous-Bois, a town in the arrondissement of Sceaux, department of Seine, France, 2½ miles east of the Outer Circle of Paris, and about half a mile north-west of Fort Nogent, on the railway from Paris to Brie-Comte-Robert. It has a 16th century church, with fine Gothic arches. Population (1881), 3586; (1896), 5992; (1901), 9320.

Foochow (or FUCHAW), a treaty port in the province of Fuhkien, China. The trade of the port has declined in recent years owing to the falling off in the export of tea. In 1880 the export of this staple article of trade reached 98 million ℔, the greater part of which came to England. In 1898 the export had fallen off to 36 million ℔, of which only about a quarter came to England. The total value of the trade for 1899, as given in the customs returns, was H. taels 17,352,000 (£2,603,000). In 1880 the total of the trade was H. taels 15,758,000, equivalent at the then value of the tael to £3,832,000. The Min river on which Foochow is built has silted up to such an extent that steam-vessels for many years have been compelled to load and discharge their cargoes at a place called Pagoda anchorage, some ten miles below the city. Near this point the Chinese Government established an arsenal and ship-building yard, which between 1870 and 1880 turned out some twenty-five or thirty small gunboats. In 1884 it was partially destroyed in the attack by the French fleet on the Chinese squadron lying in the harbour, and for a number of years after that event the workshops and machinery, which had cost an immense amount of money, were allowed to stand idle and go to decay. An attempt was made after the Japanese war to revive the establishment, a staff of French engineers having again been engaged for the purpose. On the 1st August, 1895, a horrible attack was made on an English mission station near the inland city of Kucheng, 120 miles west of Foochow. Nine missionaries, of whom eight were ladies, were massacred, and only one or two escaped. Most of the ringleaders in this outrage were brought to justice. The population of Foochow is estimated at 1,000,000, and the number of foreign residents, including missionaries in the interior, at about 530.

Football.—1. *Association.* Though the rules governing the actual play have undergone singularly few, and those not very material, variations, the evolution of Association football since 1875 has brought in its train many important changes. The whole constitution of the Association itself, in the first place, has been considerably altered. What used to be a purely sporting administration controlling the game in the interests of players wholly and solely, for its own sake and as a healthy recreation, has by the force of circumstances become an unwieldy body, with many varied responsibilities involving the control of details quite outside the scope of a legislative tribunal. The institution of the Football Association Cup in 1871 may be held to have been primarily accountable for the conversion. For a time the competition was mostly limited to South of England teams. The game was then an amateur sport. Even at the most important matches spectators were comparatively few, and "gate money," enabling clubs to provide for the payment of the expenses of players on the most limited scale, was practically unknown. It was not till the entry of the Lancashire clubs into the competition that the Association Cup began to arouse any general interest. Until 1881 the final had been left entirely to southern teams. The excellent form shown by the Blackburn Rovers, who were only beaten, after a hard struggle, by the bare majority of a goal by the Old Etonians at the Oval in 1882, came as something of a revelation. The next year saw the cup won for the first time by a northern team, the Blackburn Olympic, who were able to outstay the Old Etonians and beat them after one and a half hours' play. This was the beginning of a new era. For three years in succession the Blackburn Rovers held the cup; and so complete was the ascendancy of the North that it was not till 1900 that a southern club got into the final tie, though in 1901 the cup was at last secured for the South by Tottenham Hotspur. For nineteen years the cup had remained solely in the hands of northern or Midland clubs. The early triumphs of the Lancashire teams had far-reaching effects. It soon became evident that the spirit of the amateur rules on which the cup competition was based was being violated. Attempts were made by the executive to check the illicit payment of players. When they failed, the only alternative was to recognize professionalism and bring it under adequate control. The advocates of open professionalism had to wait some time before they carried their point. Its opponents certainly did not allow it to be legalized without a stubborn fight. Gradually, however, they had to yield before the force of public opinion, and by 1890 the professional player had come to be officially recognized by the Football Association of England. For a time Scotland, Wales, and Ireland refused to acknowledge him; and the Scottish executive unsuccessfully tried to induce the English authorities to agree to his exclusion from the English elevens in international contests. As it was, they were the last to give way, and professionalism had been recognized in Wales and Ireland before Scotland perforce had to agree to it. Since 1889 the professional player has played a part, and an increasingly important part, in Association football. Up to 1902 he had been kept well under control, and the forebodings of the evil he was to do to the game had certainly not been realized. A player receiving more than his actual expenses for playing in a match is a professional, and must be registered with the Football Association as such. Even wages absolutely lost are not allowed, and no professional can revert to his old amateurism until he has been properly reinstated by the Football Association, which naturally requires to be thoroughly satisfied of the good faith of every application before it is even considered. How professionalism has developed in the years which have passed since its recognition may be gathered from the fact that in 1899–1900 no fewer than seven thousand were registered with the Football Association. This, it may be added, refers only to English players, and does not include those who are registered with Scotland, Wales, and Ireland, which may fairly be computed to number several thousands more. The development of the Association itself between 1875 and 1902 has of course corresponded with the increase in the popularity of the game itself. In 1875 the official register showed only ninety-four clubs under its direct control. In 1900 the managing body consisted of a president, four vice-presidents, a treasurer, and sixteen delegates, elected from the various districts into which the Association has been subdivided for electoral purposes. In addition to representatives of every affiliated association having jurisdiction over fifty or more clubs, varying in number according to the numerical strength of the clubs under their control, at its full strength the Council of the Football Association includes some forty or fifty persons. Such a body as this has proved very cumbersome for practical purposes, and latterly the bulk of the work has been done by a Consultative Committee, composed of the officers and twelve other delegates selected by them. Besides the Cup Competition the Association has latterly had the control of three international matches, those with Scotland, Wales, and Ireland, of the trial match North *v.* South, and during the last few years of a Second Cup Competition confined to amateurs alone. The Scottish match has been played uninterruptedly since 1872. That with Wales was not originated till seven years later, while the Irish fixture does not appear on the list until 1882. The Irish and Welsh matches, as well as that between North and South and the Amateur Cup Competition, are all of them essentially the product of the Association's work during the last quarter of the 19th century.

The whole policy of legislation in Association football of late years has been naturally to make the game faster by bringing every one into full play. The great aim accordingly has been to encourage combination and to discourage purely individual efforts. In the early days, though there was a certain amount of cohesion, a player had to rely mainly on himself. Even up to the middle of the 'seventies dribbling was looked upon as the great desideratum; it was the essential for a forward, just as long kicks were the main object of a back. The development of the game was of course bound to change all that. The introduction of passing, long or short, but long in particular, placed the dribbler pure and simple at a discount, and necessitated methods with which he was mostly unacquainted. Combined play gradually came to be regarded as the keynote to success. Instead of one full back, as was originally the case, and one half-back, the defence gradually developed by the addition first of a second half, then of a second full back, and still later of a third half-back, until it came to show, in addition to the goalkeeper of course, two full backs and three half-backs. The eight forwards who used to constitute the attack in the earliest days of the Association have been reduced by degrees, as the science of the game became understood, until they now number only five. The effect of the transition has been to put the attack and defence on a more equal footing, and as a natural consequence to make the game more open and thereby generally more interesting and attractive. Association football is indeed, from the standpoint of the spectator, a much brighter game than it was in its infancy, the result of the new methods bringing every one of the eleven players into full relief throughout the game. The players who, as a rule, make or mar the success of a side in modern football are the centre forward and the centre half-back. They are the pivot on which the attack and the defence respectively turn. Instead of close dribbling and following up, the new formation makes for accuracy of passing among the forwards, with intelligent support from the half-backs. The net result is practically the effective combination of the whole side. To do his part as it ought to be done every member of an eleven must work in harmony with the rest, and on a definite system, in all cases subordinating his own methods and personal interests to promote the general wellbeing of the side.

In its main principles the Association game itself has altered very little since 1880. The usual dimensions for a ground are 120 yards long by 80 yards wide, and the goals are still eight yards in width with a cross bar from post to post and eight feet from the ground. The game is started by a place kick from the centre of the field of play, and none of the opposite side is allowed to approach within ten yards of the ball when it is kicked off. When the ball passes over the touch line it has to be thrown in by one of the opposite side, and can be returned into the field of play in any direction. If it passes over the goal line at any time without touching one of the defending side, it has to be kicked out by the goalkeeper or one of the backs from a line marked in front of goal, the spot selected being in front of the post nearest the point where the ball left the field of play. But should it touch one of the defending side in its transit over the goal line the attacking side has the privilege of a free kick from the corner flag (a "corner kick"). This is often a great advantage, but such free kick does not produce a goal unless the ball touches one of the other players on its way to the post. Ordinarily a goal is scored when the ball goes through the post, not being thrown, knocked on, or carried. The regulation duration of a game is an hour and a half, and ends are changed at forty-five minutes. The side winning the toss has the choice of ends or kick-off, and the one obtaining the majority of goals wins. A goal cannot be scored from a free kick unless a player of the defending side wilfully handles the ball, or a player of the attacking side is intentionally tripped, charged from behind, pushed, or held by an opponent within the twelve-yards goal line. The referee in such cases has power to award a free kick within the twelve-yards line of the defending side. In a penalty kick no one but the goalkeeper is allowed to play the ball, so that the result is an almost certain goal. A player is always in play as long as there are three of the opposite side between him and the opposite goal *at the time the ball is kicked.* This rule gives much trouble to the young player, though why it should do so it is not easy to say. The rule is simple if the words in italics are remembered. The ball must not be carried, knocked, or wilfully handled under any pretence whatever, save by the goalkeeper, who is allowed to use his hands in defence of his goal, either by knocking on or throwing, within his own half of the field of play. Thus far he is entitled to go in maintaining his goal, but if he carry the ball, the penalty is a free kick. There are other infringements of the rules which also involve the penalty of a free kick, among them the serious offences of tripping, hacking, and jumping at a player. Players are not allowed to wear nails in their boots (except such as have their heads driven in flush with the leather), or metal plates, or gutta-percha, and any player discovered infringing this rule is liable to be prohibited from taking further part in a match. No player is allowed to play except in practice matches, when no gate money can be taken, from 1st May to 31st August. But in Scotland the "close season" runs from 15th May to 15th August. (C. W. A.)

2. *Rugby Union.*—From early times a rudimentary game of football had been a popular form of sport in many parts of Great Britain, and in the old-established schools football had been a regular game among the boys. In different schools there arose various developments of the original game; or rather, what, at first, must have been a somewhat rough form of horse-play with a ball began to take shape as a definite game, with a definite object and definite rules. Rugby school had developed such a game, and from football played according to Rugby rules has arisen Rugby football. It was about the middle of the 19th century that football—up till that time a regular game only among schoolboys—took its place as a regular sport among men. To begin with, men who had played the game as schoolboys formed clubs to enable them to continue playing their favourite school game, and others were induced to join them; while in other cases, clubs were formed by men who had not had the experience of playing the game at school, but who had the energy and the will to follow the example of those who had had this experience. In this way football was established as a regular game, no longer confined to schoolboys. When football was thus first started, the game was little developed or organized. Rules were very few, and often there was great doubt as to what the rules were. But, almost from the first, clubs were formed to play football according to Rugby rules—that is, according to the rules of the game as played at Rugby school. But even the Rugby rules of that date were few and vague, and indeed almost unintelligible to those who had not been at Rugby school. Still, the fact that play was according to Rugby rules produced a certain uniformity; but it was not till the establishment of the English Union, and the commencement of international matches, that a really definite code of rules was drawn up.

It is an interesting question to ask why it was that the game of Rugby school became so popular in preference to the games of other schools, such as Eton, Winchester, or Harrow. It was probably very largely due to the reputation and success of Rugby school under Dr Arnold, and this also led most probably to its adoption by other schools; for in 1860 many schools besides Rugby played football according to Rugby rules. The rapidity with which the game spread was remarkable. The Blackheath club, the senior club of the London district, was established in 1860, and Richmond, its great rival, shortly afterwards. Before 1870, football clubs had been started in Lancashire and Yorkshire; indeed the Sheffield football club dates back to 1855. Likewise, in the universities of Oxford and Cambridge, Rugby football clubs had been formed before 1870, and by that date the game had been implanted both in Ireland and South Wales; while in Scotland, before 1860, football had taken a hold. Thus by 1870 the game had been established throughout the United Kingdom, and in many districts had been regularly played for a number of years. Rapid as, in some ways, had been the spread of the game between the years 1850 and 1870, it was as nothing to what happened in the following twenty years; for by 1890 Rugby football, together with Association football, had become the great winter amusement of the people, and roused universal interest; while to-day, though there are no statistics to prove the assertion, it is no exaggeration to say that on any fine Saturday afternoon in winter there are tens of thousands of people playing football, while those who watch the game can be counted by the hundred thousand. The causes that led to this great increase in the game and interest taken in it were, undoubtedly, the establishment of the various national Unions and the international matches; and, of course, the local rivalry of various clubs, together with cup or other competitions prevalent in certain districts, was a leading factor. The establishment of the

English Union led to a codification of the rules without which development was impossible. The international matches roused patriotic enthusiasm, and club matches roused local rivalries, which have so strong a hold upon the people.

In the year 1871 the English Rugby Union was founded in London. This Union was an association of some clubs and schools which joined together and appointed a committee and officials to draw up a code of rules of the game. From this beginning the English Rugby Union has become the governing body of Rugby football in England, and has been joined by practically all the Rugby clubs in England, and deals with all matters connected with Rugby football, notably the choosing of the international teams. In 1873 the Scottish Football Union was founded in Edinburgh on the same lines, and with the same objects, while in 1880 the Welsh Football Union, and in 1881 the Irish Rugby Football Union, were established as the national Unions of Wales and Ireland, though in both countries there had been previously Unions not thoroughly representative of the country. All these Unions became the chief governing body within their own country, and one of their functions was to make the rules and laws of the game; but as this had been done to start with by the English Union, the others adopted the English rules, with amendments to them from time to time. This state of affairs had one element of weakness—viz., that since all the Unions made their own rules, if ever a dispute should arise between any of them, a deadlock was almost certain to ensue. Such a dispute did occur in 1884 between the English and Scottish Unions. This dispute eventually turned on the question of the right of the English Union to make and interpret the rules of the game, and to be the paramount authority in the game, and superior to the other Unions. Scotland, Ireland, and Wales resisted this claim, and finally, in 1889, Lord Kingsburgh and Major Marindin were appointed as a commission to settle the dispute. The result was the establishment of the International Board, which consists of representatives from each Union—six from England, two from each of the others—whose duties were to settle any question that might arise between the different Unions, and to settle the rules under which international matches were to be played, these rules being invariably adopted by the various Unions as the rules of the game.

With the establishment of the International Board, the organization of the game was complete. Still harmony did not prevail, and in 1895 occurred a definite disruption. A number of leading clubs in Yorkshire and Lancashire broke off from the English Union and formed the Northern Union, which since that date has had many accessions, and has become the leading body in the North of England. The question in dispute was the payment of players. Football was originally played by men for the sheer love of the game, and by men who were comparatively well-to-do, and who could give the time to play it; but with the increasing popularity of the game, it became the pastime of all classes of the people, and clubs began to grow rich by "drawing big gates,"—that is, large numbers of spectators, frequently many thousands in number, paid for the privilege of witnessing the match. In these circumstances the temptation arose to reimburse the player for any out-of-pocket expenses he might be put to for playing the game, and thus it became universally recognized as legitimate to pay a player's expenses to and from a match. But in the case of working men it often meant that they lost part of their weekly wage when they had to go a distance to play a match, or to go on tour with their club—that is, go off for a few days and play one or two matches in different parts of the country—and consequently the claim was made on their behalf to recoup them for their loss of wage; while at the same time rich clubs began to be willing to offer inducements to good players to join their club, and these inducements were generally most acceptable in the form of money. In Association football, professionalism—*i.e.*, the hiring and paying of a player for his services—had been openly recognized. A large section of the English Union—the amateur party—would not tolerate anything that savoured of professionalism, and regarded payments made to a player for broken time as illegitimate. The result was the formation of the Northern Union, which allowed such payments, and has practically recognized professionalism. This body has also slightly altered the laws of the game, and probably in the future the two games will be widely different. In Scotland and Ireland Rugby footballers are strongly amateur; but wherever Rugby football is the popular game of the artisan, the professional element is strong, and possibly the Northern Union will be joined by clubs in other districts of England and Wales.

Besides legislation, one of the functions of the Unions is to select international teams. On 27th March 1871 the first international match was played between England and Scotland in Edinburgh. This was a match between teams picked from English and Scottish players. These matches from the first roused widespread interest, and were a great stimulus to the development of the game. With the exception of a few years, when there were disputes between their respective Unions, all the countries have annually played one another—England having played Scotland since 1871, Ireland since 1875, and Wales since 1880. Scotland commenced playing Ireland in 1877 and Wales in 1883, while Ireland and Wales met first in 1882 and then in 1884, and since 1887 have played annually. The qualifications of a player for any country were at first vaguely considered to be birth; but they were never definitely settled, and there has been a case of a player playing for two countries. In 1894, however, the International Board decided that no player was to play for more than one country, and this has been the only pronouncement on the question; and though birth is still looked upon as the main qualification, it is not essential. Though international matches excite interest throughout the United Kingdom, the matches between two rival clubs arouse just as much excitement in their district, particularly when the clubs may be taken as representatives of two neighbouring rival towns. But when to this rivalry there is added the inducement to play for a cup, or prize, the excitement is much more intense. Among Rugby players cup competitions have never been so popular as among Association, but the competition for the Yorkshire Cup was very keen in the days before the establishment of the Northern Union, and this undoubtedly was the main cause of the popularity of the game in that county. Similarly the competition for the South Wales Cup from 1878 to 1887 did a great deal to establish the game in that country. The method of carrying on these competitions is, that all the clubs entered are drawn by lot, in pairs, to play together in the first round; the winners of these ties are then similarly drawn in pairs for the next round, until for the final round there is only one pair left, the winner of which takes the cup. An elaboration of this competition is the "League system" of the Association game. This, likewise, has not been popular with Rugby players. Still it is prevalent in many districts, especially where clubs are anxious to draw big gates. In the League system a certain number of clubs form a league to play one another twice each season; two points are counted for a win, and one for a draw. The club which at the end of the season comes out with most points wins the competition. The advantage of this system over a cup competition is, that interest is kept up during the whole season, and one defeat does not debar a club from eventually coming out first.

It is said that wherever Britons go they take their games with them, and this has certainly been the case with Rugby football, for even in India it is played. But it has not yet been firmly established out of Great Britain. In the United States of America there is a form of football—a development of football according to Rugby rules, but now totally different from Rugby football (see below). Such, too, is the case in Australia. Still, in 1888, an English team of Rugby players had a tour in Australia and New Zealand, playing matches under both Rugby and Australian rules, and in 1889 a team of New Zealand native football players, popularly called the Maoris, came over to England. In 1891 a team went to South Africa under the auspices of the Rugby Union. It is perhaps in South Africa where Rugby is most likely to flourish out of Great Britain; but even there the climatic conditions and state of the ground are against the game. In Germany the game has been established, but it has been taken up in Paris with more vigour than in any place on the Continent, and already many matches have been played between British and Parisian clubs.

The game itself is essentially a winter pastime, as two requisite conditions for its enjoyment are a cool atmosphere and a soft though firm turf. The field of play is an oblong, not more than 110 yards long nor more than 75 yards broad, and it usually approximates to these dimensions. The boundaries are marked by lines, called touch lines, down the sides, and goal lines, along the ends. The touch lines are continued beyond the goal lines for a distance of not more than 25 yards; and parallel to the goal line and behind it, at a distance of not more than 25 yards, is drawn a line called the dead ball line, joining the ends of the touch lines produced. On each goal line, at an equal distance from the touch lines, are erected two posts, termed goal posts, exceeding 11 feet in height, and as a rule generally much more—averaging perhaps from 20 to 30 feet from the ground, and placed 18 feet 6 inches apart. At a height of 10 feet from the ground they are joined by a cross bar; and the object of the game is to kick the ball over the cross bar between the upright posts, and so obtain a goal. The ball is oval in shape, and the official dimensions are—length, 11 to $11\frac{1}{4}$ inches; length circumference, 30 to 31 inches; width circumference, $25\frac{1}{2}$ to 26 inches; weight, 13 to $14\frac{1}{2}$ ounces. It is made of india-rubber inflated, and covered with a leather case. Half-way between the two goal lines there is sometimes drawn the half-way line, but more usually it is marked by flags on the touch line; and 25 yards from each goal line there is similarly marked the 25-yards line. In the original game the side that had gained the majority of goals won the match, and if no goal had been scored, or an equal number, the game was said to be left drawn; but a modification was adopted before long. A goal can be kicked from the field of play; but from the very first a try at goal could be obtained by that side one of whose players either carried the ball across his opponents' goal line and then touched it down, or touched it down, after it had been kicked across the goal line, before any of his opponents. The try at goal consisted in one of the successful side attempting to kick the ball over the bar, while the opponents had to take their stand behind their goal line. Frequently a goal was kicked; very often not. The modification, first allowed, was to count that side the winner which had gained the majority of tries, provided no goal or an equal number of goals had been scored; but a majority of one goal took precedence of any number of tries. But this, too, was afterwards abolished, and a system of points instituted by which the side with the majority of points wins.

In the game itself, not only may the ball be kicked in the direction of the opponents' goal, but it may also be carried; but it must not be thrown forward—that is, in the direction of the opponents' goal—though it may be thrown back. Thus the game is really a combination of football and handball. The main principle in the play is that any one who is onside—that is, not offside—may take part. A player is offside if he gets in front of the ball—that is, on the opponents' side of the ball, nearer the opponents' goal line; when in this position, he must not interfere with an opponent or touch the ball under penalty. The main feature of the game is the scrummage. In old days at Rugby school there was practically no limit to the numbers of players on each side, and not infrequently there would be a hundred or more players on one side. This was never prevalent in club football; twenty a-side was the usual number to start with, reduced in 1877 to fifteen a-side, the number still maintained. In the old Rugby big sides the ball got settled amidst a mass of players, and each side attempted to drive it through this mass by shoving, kicking, and otherwise forcing their way through with the ball in front of them. This, then, was the origin of the scrummage, a feature still characteristic of the game.

The game is played usually for one hour, or one hour and ten minutes, sometimes for one hour and a half. Each side defends each goal in turn for half the time of play. Play is started by one side kicking the ball off from the centre of the field in the direction of the opponents' goal. The ball is then caught by one of the other side, who either kicks it, or runs with it. In running he goes on until he is "tackled," or caught, by one of his opponents, unless he should choose to "pass" or throw it to another of his own side, who may either kick, or run, or pass as he chooses. The ball in this way is kept moving until it crosses the touch line, or goal line, or is tackled. If the ball crosses the touch line, both sides line up at right angles to the point where it crossed the line, and the ball is thrown in straight either by one of the same side whose player carried the ball across the touch line, or, if the ball was kicked or thrown out, by one of the opposite side. If the ball crosses the goal line, either a try is gained, as explained above, or if the defending side touch it down first, the other side retire to the line 25 yards from the goal line, and the defending side kick it up the field. If the ball is tackled, the player carrying the ball gets up as soon as possible, and certain players of each side, called the forwards, at once form the scrummage, by putting down their heads, and getting ready to shove against one another. They shove as soon as the ball is put down between the two front rows. In the scrummage the object is, by shoving the opponents back or otherwise breaking away with the ball in front, to carry the ball in the direction of the opponents' goal line by a series of short kicks in which the players run after the ball as fast as possible, while their opponents lie in wait to get the ball, and either by a kick or other device stop the rush. Instead, however, of the forwards breaking away with the ball, sometimes they let the ball come out of the scrummage to certain of their own side posted outside, called half-backs, who either kick or run with it, or pass it to the three-quarter-backs, and so the game proceeds until the ball is once more "dead" —that is, brought to a standstill. The scrummage appears to be an uninteresting manœuvre, and a strange relic of bygone times; but it is not merely a manœuvre in which weight and strength alone tell—it also needs a lot of dexterity in moving the ball with the feet applying the weight to best advantage, and also in outflanking the opposing side, as it were—usually termed wheeling—directing all the force to one side of the scrummage, and thus breaking away. Of the fifteen players who compose a side, the usual arrangement is that eight are called forwards, and form the scrummage; two half-backs are posted immediately outside the scrummage; and four three-quarter-backs, a little behind the halves, stretch in a line across the field, their duties being mainly to run and kick and pass, and prevent the opponents from doing the same. Behind the three-quarters comes the full back, or back, a single individual to maintain the last line of defence; his duties are entirely defensive, either to tackle an opponent who has managed to get through, or, more usually, to catch and return long kicks. As a rule the game is a lively one, for the players are rarely at rest; if there is much scrummaging, it is called a slow game, but, if much running and passing, a fast or an open game. The spectator, unless he be an expert, prefers the open game; but in any case the game is always a hard and exciting struggle, frequently with the balance of fortune swaying very rapidly from one side to the other, so that it is a matter of no surprise to find the British public so ardently attached to it.

Any one interested in the evolution of the game must be referred —if, indeed, such reference is nowadays needed—to *Tom Brown's Schooldays*, where he will find a vivid description of the old Rugby game. The ephemeral literature on Football is enormous, but there are not many good works on the game. The best is *Football: The Rugby Union Game*, by Rev. F. Marshall. In the *Encyclopædia of Sport* and in the *Badminton Library* volume on Football there are articles of more than ephemeral interest. (C. J. N. F.)

(3) *United States.*—Football in America has had a peculiar history, and one showing the great tenacity of life possessed by this sport. At first such football as was played consisted merely in kicking the ball, and the play was without system. In the years 1871–72 certain rules were formulated, but they did not correspond to those in any other country, and were not on the whole satisfactory. Some of the colleges (to which the sport, until recently, was largely confined) formed an association, and adopted these rules. In 1875 Harvard and Yale met under rules taken partly from the Rugby Union and partly from the American game. These proved unsatisfactory, and the next year Harvard and Yale adopted the Rugby Union rules in their entirety. This was the foundation of the present American game. The players found that the Rugby Union rules, while much more satisfactory than anything that had been used, depended in a great measure upon traditional understanding and interpretations. American players were unwilling to be guided by anything except written regulations, and hence it was necessary to add to and explain the rules. Annual conventions were therefore held, and the rules were amplified and from time to time altered. Other colleges joined the Association, and the game became well established in the college world. The roughness and brutality displayed in playing were strongly commented upon in the newspapers, and at that time it was difficult to say whether the game would survive or not; but in another ten years it had made great progress, and then again it became the object of further newspaper assaults, and the Harvard team, through the action of the University authorities, was withdrawn from participation. This withdrawal lasted, however, for only a year. From that time the game has been characterized by lessening tendencies to roughness, by increasing skill, and by greater satisfaction to players and spectators. For some time past it has been, perhaps, the most popular sport in the college calendar, and has drawn crowds of from 35,000 to 40,000 people at the principal games. The Association disbanded some years ago, but a Rules Committee, invited by the University Athletic Club of New York, has made the necessary changes in the rules from time to time, and these have been accepted by the country at large. In the West associations have been formed, and still exist; but the game in the East is played principally under separate agreements between the contesting universities, all playing, however, under one code of rules.

The rules provide for a field 330 feet long by 160 feet wide, upon which teams composed of eleven men each contend for a period of two thirty-five minute halves, the total score at the end of the second half determining the victor. The scoring is by goals, touch-downs, and safety touch-downs. A goal is scored when the ball is kicked through the upright goal-posts and above the cross-bar connecting the posts at a distance of 10 feet above the ground; a touch-down when the ball is carried and touched to the ground behind the goal line; a safety touch-down when the opponent is forced to carry the ball across his own goal line. The points and their values are: Goal from touch-down, 6 points; goal from field-kick, 5 points; touch-down from which no goal is kicked, 5 points; safety by opponents, 2 points. Any player when on-side can run with the ball, and his opponent may tackle him; if stopped, he must put the ball down, and a line-up or scrimmage is then formed. The ball may also be advanced by kicking. Infringement of the rules constitutes a foul, and various penalties are imposed.

Upon the above simple framework there has been built a most intricate system of play. The principle of the game is absolutely clear to the spectator, and therein lies its especial charm. There stands out boldly one cardinal object, namely, to advance the ball towards the opponent's goal. When this advance is attempted by means of kicking, the ball is usually sent as far as possible down into the opponent's territory, two or three men of the kicking side following it, and, in case it is muffed, endeavouring to secure it, or, if it be caught, to prevent the catcher from carrying it back on a run or returning the kick. The kicking game is most employed when the wind favours. It is also used to relieve the running game. A rule of the sport makes it obligatory upon the side which has failed to advance the ball five yards in three running attempts to surrender it. Hence it is usually to the advantage of the side in possession of the ball, when they have failed in two running attempts, and it looks unlikely that they would succeed in a third, to kick the ball as far as possible into the opponent's territory rather than to surrender it within a yard or so of its immediate position. The running game is more involved than the kicking game, it being the object of the captain to use all possible means to assault the opponents at points of weakness, to enable his runner to encircle the ends of the opponent's line, or to pierce that line at points where the attack can gather the most force, and the defence exhibits the least resistance. Certain signals are used which, presumably unknown to the opponents, indicate to the assaulting side just what the method of assault is to be, and thus enable the men to concentrate suddenly at the one point. This concentration is not finally brought about until after the ball has been put in play, so that the opponents have little chance to anticipate it.

The ball is handled with great accuracy, one man being selected to place the ball on the ground in a scrimmage and to snap it back with his hand to another player who delivers it, usually by a hand-pass or a short throw, to such individual as has been selected for the particular play. No man can pass the ball towards his opponent's goal, and any man is off-side and out of the play if he gets between the ball and his opponent's goal. He cannot then touch the ball until it touches an opponent, or until the man of his own side who has kicked it runs up ahead of him.

In order to measure properly the distance gained or lost the field is marked with white lines every five yards.

The officials consist of an umpire, whose principal duty it is to decide regarding fouls; a referee, who decides questions relating to the progress of the ball and the play; timekeepers and linesmen, who keep the time of the play and mark the exact progress of the ball for the benefit of the referee. The American game is far more involved and intricate than the Rugby, but offers correspondingly greater field for skilful play. Amateur athletic clubs have taken up the sport, and it is now the principal fall game throughout the United States. (W. Ca.)

Forbes, Archibald (1838–1900), British war correspondent, was the son of a Presbyterian minister in Morayshire. He was born 17th April 1838, and educated at Aberdeen University. Entering the Royal Dragoons as a private, he gained, while in the service, considerable practical experience of military life and affairs. Being invalided from his regiment, he settled in London, and adopted the journalistic profession. When the Franco-German war broke out in 1870, Forbes was sent to the front as war correspondent to the *Morning Advertiser*, and in this capacity he gained valuable information as to the plans of the Parisians for withstanding a siege. Transferring his services to the *Daily News*, his brilliant feats in the transmission of intelligence drew world-wide attention to his despatches. He was with the German army from the beginning of the campaign, and he afterwards witnessed the rise and fall of the Commune. His war correspondence in the *Daily News* was republished. Forbes afterwards proceeded to Spain, where he chronicled the outbreak of the second Carlist war; but his work here was interrupted by a visit to India, where he spent eight months upon a mission of investigation into the Bengal Famine of 1874. Then he returned to Spain, and followed at various times the Carlist, the Republican, and the Alfonsist forces. As representative of the *Daily News* he accompanied the Prince of Wales in his tour through India in 1875–76. Forbes went through the Servian campaign of 1876, and was present at all the important engagements. In the Russo-Turkish campaign of 1877 he achieved striking journalistic successes at great personal risk. Attached to the Russian army, he witnessed most of the principal operations, and remained continuously in the field until attacked by fever. His letters, together with those of his colleagues, MacGahan and Millet, were republished by the *Daily News*. On recovering from his fever, Forbes proceeded to Cyprus, in order to witness the British occupation. The same year (1878) he went to India, and in the winter accompanied the Khyber Pass force to Jelalabad. He was present at the taking of Ali Musjid, and marched with several expeditions against the hill tribes. Burma was Forbes's next field of adventure, and at Mandalay, the capital, he had several interesting interviews with King Thibaw. He left Burma hurriedly for South Africa, where, in consequence of the disaster of Isandlwana, a British force was collecting for the invasion of Zululand. He was present at the victory of Ulundi, and his famous ride of 120 miles in fifteen hours, by which he was enabled to convey the first news of the battle to England, remains one of the finest achievements in journalistic enterprise. Forbes subsequently delivered many lectures on his war experiences to large audiences. His closing years were spent in literary work. He had some years before published a military novel entitled *Drawn from Life*, and a volume on his experiences of the war between France and Germany. These were now followed by numerous publications, including *Glimpses through the Cannon Smoke*, 1880; *Souvenirs of some Continents*, 1885; *William I. of Germany: a Biography*, 1888; *Havelock*, in the "English Men of Action" Series, 1890; *Barracks, Bivouacs, and Battles*, 1891; *The Afghan Wars* (1839–80), 1892; *Czar and Sultan*, 1895; *Memories and Studies of War and Peace*, 1895, in many respects autobiographic; and *Colin Campbell, Lord Clyde*, 1896. He died 30th March 1900. (G. B. S.)

Forbes, a town in the county of Ashburnham, New South Wales, Australia, about 289 miles west from Sydney, on the Lachlan river, and with a station on the Western Railway. Its importance as a commercial centre is increasing owing to its advantageous position between the northern and southern markets. Its altitude is 1120 feet. The mean temperature for the year is 62·2° F.; that of January is 78·6°; of July, 47·3°. Population about 3500.

FORESTS AND FORESTRY.

Although most people know what a forest is, a definition of it which suits all cases is by no means easy to give. Manwood, in his treatise of the *Lawes of the Forest*, 1598, defines a forest as "a certain territory of woody grounds, fruitful pastures, privileged for wild beasts and fowls of forest, chase, and warren, to nest and abide in, in the safe protection of the king, for his princely delight and pleasure." This primitive definition has, in modern times, when the economic aspect of forests came more into the foreground, given place to others, so that forest may, in a general way, now be described as "an area which is for the most part set aside for the production of timber and other forest produce, or which is expected to exercise certain climatic effects, or to protect the locality against injurious influences."

As far as conclusions can now be drawn, it is probable that the greater part of the dry land of the earth was, at some time, covered with forest, which consisted of a variety of trees and shrubs grouped according to climate, soil, and configuration of the several localities. When the old trees reached their limit of life, they disappeared, and younger trees took their place. The conditions for an uninterrupted regeneration of the forest were favourable, and the result was vigorous production by the creative powers of soil and climate. Then came man, and by degrees interfered, until in most countries of the earth the area under forest has been considerably reduced. The first decided interference was probably due to the establishment of domestic animals; men burnt the forest to obtain pasture for their flocks. Subsequently similar measures on an ever-increasing scale were employed to prepare the land for agricultural purposes. More recently enormous areas of forest were destroyed by reckless cutting and subsequent firing in the extraction of timber for economic purposes.

It will readily be understood that the distribution and character of the now remaining forests must differ enormously. Large portions of the earth are still covered with dense masses of tall trees, while others contain low scrub, grass land, or are desert. As a general rule, natural forests consist of a number of different species intermixed; but in some cases certain species, called gregarious, have succeeded in obtaining the upper hand, thus forming more or less pure forests of one species only. The number of species differs very much. In many tropical forests hundreds of species may be found on a comparatively small area, in other cases the number is limited. Burma has several thousand species of trees and shrubs, Sind has only ten species of trees. Central Europe has about forty species, and the greater part of Northern Russia, Sweden, and Norway contains forests consisting of about half-a-dozen species. Elevation above the sea acts similarly to rising latitude, but the effect is much more rapidly produced. Generally speaking, it may be said that the tropics and adjoining parts of the earth, wherever the climate is not modified by considerable elevation, contain broad-leaved species, Palms, Bamboos, &c. Here most of the best and hardest timbers are found, such as Teak, Mahogany, and Ebony. The northern countries are rich in Conifers. Taking a section from Central Africa to North Europe, it will be found that south and north of the Equator there is a large belt of dense hardwood forest; then comes the Sahara, then the coast of the Mediterranean with forests of Cork Oak; then Italy with Oak, Olive, Chestnut, gradually giving place to Ash, Sycamore, Beech, Birch, and certain species of Pine; then Switzerland and Germany, where Silver Fir and Spruce gain ground. Silver Fir disappears in Central Germany, and the countries around the Baltic contain forests consisting chiefly of Scotch Pine, Spruce, and Birch, to which, in Siberia, Larch must be added, while the lower parts of the ground are stocked with Hornbeam, Willow, Alder, and Poplar. Australia, again, has its own particular flora of Eucalypts, of which nearly 200 species have been distinguished, as well as Wattles. Some of the Eucalypts attain an enormous height, a tree 472 feet high having been measured. Apart from a limited number of broad-leaved species, the Conifers have become the most important timber trees in the economy of man. They are found in greatest quantities in the countries around the Baltic and in North America. An endless variety of different types of forest are found in different parts of the earth.

Utility of Forests.—In the economy of man and of nature forests are of direct and indirect value, the former chiefly through the produce which they yield, and the latter through the influence which they exercise upon climate, the regulation of moisture, the stability of the soil, the healthiness and beauty of a country, and allied subjects. The *indirect* utility will be dealt with first. A piece of land bare of vegetation is, throughout the year, exposed to the full effect of sun and air currents, and the climatic conditions which are produced by these agencies. If, on the other hand, a piece of land is covered with a growth of plants, and especially with a dense crop of forest vegetation, it enjoys the benefit of certain agencies, which modify the effect of sun and wind on the soil and the adjoining layers of air. These modifying agencies are as follows: (1) The crowns of the trees intercept the rays of the sun, and the falling rain obstructs the movement of air currents, and reduces radiation at night; (2) the leaves, flowers, and fruits, augmented by certain plants which grow in the shade of the trees, form a layer of mould, or humus, which protects the soil against rapid changes of temperature, and greatly influences the movement of water in it; and (3) the roots of the trees penetrate into the soil in all directions, and bind it together. The effects of these agencies have been observed from ancient times, and widely differing views have been taken of them. Of late years, however, more careful observations have been made at so-called parallel stations, that is to say, one station in the middle of a forest, and another outside at some distance from its edge, but otherwise exposed to the same general conditions, and in this way the following results have been obtained: (1) Forests reduce the temperature of the air and soil to a moderate extent, and render the climate more equable; (2) they increase the relative humidity of the air, and reduce evaporation; (3) they tend to increase the precipitation of moisture. As regards the actual rainfall, their effect in low lands is *nil* or very small; in hilly countries it is probably greater, but definite results have not yet been obtained, owing to the difficulty of separating the effect of forests from that of other factors. (4) They help to regulate the water supply, produce a more sustained feeding of springs, tend to reduce violent floods, and render the flow of water in rivers more continuous; (5) they assist in preventing denudation, erosion, landslips, avalanches, the silting up of rivers and low lands, and the formation of sand dunes; (6) they reduce the velocity of air currents, protect adjoining fields against cold or dry winds, and afford shelter to cattle, game, and useful birds; (7) they may, under certain conditions, improve the healthiness of a country, or help in its defence; (8) they increase the beauty of a country, and produce a healthy æsthetic influence upon the people.

The direct *utility* of forests is chiefly due to their produce, the capital which they represent, and the work which they provide. The principal produce of forests consists of timber and firewood. Both are necessaries for the daily life of the people. In modern times iron and other materials have to a considerable extent replaced timber, while coal, lignite, and peat compete with firewood; nevertheless wood is still indispensable, and likely to remain so. This is borne out by the statistics of the most civilized nations. Whereas the population of Great Britain and Ireland during the period 1880–1900, increased by about 20 per cent., the imports of timber, during the same period, increased by 45 per cent.; in other words, every head of population in 1900 used more timber than twenty years earlier. Germany produced in 1880 about as much timber as she required; in 1899 she imported upwards of 4,600,000 tons, valued at £14,000,000, and her imports are rapidly increasing, although the yield capacity of her own forests is much higher now than it was formerly. Wood is now used for many purposes which formerly were not thought of. The manufacture of the wood pulp annually imported into Britain consumes at least 2,000,000 tons of timber. A texture closely resembling silk is now actually made of wood. The variety of other, or minor, produce yielded by forests is very great, and much of it is essential for the well-being of the people and for various industries. The yield of fodder is of the utmost importance in countries subject to periodic droughts; in many places field crops could not be grown successfully without the leaf-mould and brushwood taken from the forests. As regards industries, attention need only be drawn to such articles as commercial fibre, tanning materials, dye-stuffs, lac, turpentine, resin, caoutchouc, guttapercha, &c. Great Britain and Ireland alone import every year such materials to the value of more than £8,000,000.

The *capital* employed in forests consists chiefly of the value of the soil and growing stock of timber. The latter is, ordinarily, of much greater value than the former wherever a sustained annual yield of timber is expected from a forest. In the case, for instance, of a Scotch Pine forest, the value of the growing stock is, under the abovementioned condition, from three to five times that of the soil. The rate of interest yielded by capital invested in forests differs, of course, considerably according to circumstances, but on the whole it may, under proper management, be placed equal to that yielded by agricultural land; it is lower than the agricultural rate on the better classes of land, but higher on the inferior classes. Hence the latter are specially indicated for the forest industry, and the former for the production of agricultural crops. Forests require *labour* in a great variety of ways, such as (1) general administration, formation, tending, and harvesting; (2) transport of produce; and (3) industries which depend on forests for their prime material. The labour indicated under the first head differs considerably according to circumstances, but its amount is always smaller than that required if the land is used for agriculture. Hence forests provide additional labour only if they are established on surplus lands. Owing to the bulky nature of forest produce its transport forms a business of considerable magnitude, the amount of labour being perhaps equal to half that employed under the first head. The greatest amount of labour is, however, required in the working up of the raw material yielded by forests. In this respect attention may be drawn to the chair industry in and around High Wycombe in Buckinghamshire, where more than 20,000 labourers are employed in converting the Beech, grown on the adjoining chalk hills, into chairs and tools of many patterns. Complete statistics for Great Britain are not available under this head, but it may be mentioned that in Germany the people employed in the forests amount to 2·3 per cent.; those employed on transport of forest produce, 1·1 per cent.; labourers employed on the various wood industries, 8·6 per cent.; or a total of 12 per cent. of the population of the country. An important feature of the work connected with forests and their produce is that a great part of it can be made to fit in with the requirements of agriculture; that is to say, it can be done at seasons when field crops do not require attention. Thus the rural labourers or small farmers can earn some money at times when they have nothing else to do, and when they would probably sit idle if no forest work were obtainable.

Whether, or how far, the utility of forests is brought out in a particular country depends on its special conditions, such as (1) the position of a country, its communications, and the control which it exercises over other countries, such as colonies; (2) the quantity and quality of substitutes for forest produce available in the country; (3) the value of land and labour, and the returns which land yields if used for other purposes; (4) the density of population; (5) the amount of capital available for investment; (6) the climate and configuration, especially the geographical position, whether inland or on the border of the sea, &c. No general rule can be laid down, showing whether forests are required in a country, or, if so, to what extent; that question must be answered according to the special circumstances of each case. The subjoined table shows the forests of various European states:—

Countries.	Area of Forests, in Acres.	Percentage of Total Area of Country under Forest.	Percentage of Forest Area belonging to the State.	Forest per Head of Population, in Acres.
1. Sweden	48,000,000	44	27	8·9
2. Norway	17,000,000	21	12	8·4
3. Russia, including Finland	516,000,000	40	61	5·9
4. Bosnia and Herzegovina	6,790,000	53	70	4·9
5. Bulgaria	10,650,000	45	...	3·2
6. Spain	20,960,000	17	84	1·3
7. Hungary	22,420,000	28	16	1·3
8. Austria proper	23,990,000	32	7	1·0
9. Servia	2,390,000	20	...	1·0
10. Rumania	5,030,000	17	47	1·0
11. Greece	2,030,000	16	80	·9
12. Luxembourg	190,000	30	...	·9
13. Switzerland	2,100,000	20	4	·7
14. Germany	34,490,000	26	33	·7
15. France	23,530,000	18	12	·6
16. Italy	10,110,000	14	4	·3
17. Denmark	600,000	6	24	·2
18. Great Britain	3,030,000	4	3	·1
19. Belgium	1,250,000	17	5	·1
20. Portugal	770,000	3	8	·1
21. Holland	570,000	7	...	·1
22. Turkey	6,180,000	8	...	...
	758,080,000	31	...	2

These data exhibit considerable differences, since the percentage of the forest area varies from 3 to 53; and Russia, Sweden, and Norway may as yet have more forest than they require for their own population. On the other hand, Great Britain and Ireland, Denmark, Portugal, Holland, and even Belgium, France, and Italy have not a sufficient forest area to meet their own requirements; at the same time, they are all sea-bound countries, and importation is easy, while most of them are under the influence of moist sea winds, which reduces to a subordinate position the importance of forests for climatic reasons.

Intimately connected with the area of forests in a country is the state of ownership—whether they belong to the state, corporations, or to private persons. Where, apart from the financial aspect and the supply of work, forests are not required for the sake of their indirect effects, and where importation from other countries is easy and assured, the Government of the country need not, as a rule, trouble itself to maintain or acquire forests. Where the reverse conditions exist, and especially where the cost of transport over long distances becomes prohibitive, a wise administration will take measures to assure the maintenance of a suitable proportion of the country under forest. This can be done either by maintaining or constituting a suitable area of state forests, or by exercising a certain amount of control over corporation and even private forests. Such measures are more called for in continental countries than in those which are sea-bound, as is proved by the above statistics.

The subjoined table shows the net imports and exports of European countries (average data, calculated from the returns of recent years, whenever available):—

Countries.	Quantities in Tons.		Values in £ sterling.	
	Imports.	Exports.	Imports.	Exports.
Great Britain and Ireland	9,290,000	..	22,190,000	..
Germany	4,600,000	..	14,820,000	..
France	1,230,000	..	3,950,000	..
Belgium	1,020,000	..	4,100,000	..
Denmark	470,000	..	1,250,000	..
Italy	420,000	..	1,250,000	..
Spain	210,000	..	1,180,000	..
Holland	180,000	..	720,000	..
Switzerland	170,000	..	590,000	..
Portugal	60,000	..	200,000	..
Bulgaria	50,000	..	50,000	..
Greece	35,000	..	130,000	..
Servia	15,000	..	15,000	.
Rumania	..	60,000	..	180,000
Norway	..	1,040,000	..	1,870,000
Austria-Hungary, with Bosnia & Herzegovina	..	3,670,000	..	10,800,000
Sweden	..	4,460,000	..	7,930,000
Russia with Finland	..	5,900,000	..	8,900,000
Total	17,750,000	15,130,000	50,445,000	29,680,000
Net Imports	2,620,000	..	20,765,000	..

Supply of Timber—Imports and Exports.—The only timber-exporting countries of Europe are Russia, Sweden, Norway, Austria-Hungary, and Rumania; all the others either have only enough for their own consumption, or import timber. Great Britain and Ireland import now upwards of 9,000,000 tons a year, Germany about 4,600,000 tons, and Belgium about 1,000,000 tons. Holland, France, Portugal, Spain, and Italy are all importing countries, and so are Asia Minor, Egypt, and Algeria. The west coast of Africa exports hardwoods, and imports coniferous timber. The Cape and Natal import considerable quantities of Pine and Fir wood. Australasia exports hardwoods and a little Kauri Pine from New Zealand, but imports far larger quantities of light Pine and Fir timber. British India and Siam export Teak and small quantities of fancy woods. The West Indies and South America export hardwoods, and import Pine and Fir wood. The United States of America will not much longer be a genuine exporting country, since it imports already almost as much timber from Canada as it exports. Canada exports considerable quantities of timber. The Dominion has still a forest area of 1,250,000 square miles, equal to 38 per cent. of the total area, and giving 165 acres of forest for every inhabitant. Although only about one-third of the forest area can be called regular timber lands, Canada possesses an enormous forest wealth, with which she might supply permanently nearly all other countries deficient in material, if the governing bodies in the several provinces would only determine to stop the present fearful waste caused by axe and fire, and to introduce a regular system of management. As matters stand, the resources of the most valuable timber of Canada, the White or Weymouth Pine (*Pinus Strobus*), are nearly exhausted, the great stores of Spruce in the eastern provinces are being rapidly destroyed, and the forests of Douglas Fir in the western provinces have been attacked for export to the United States and elsewhere.

Taking the remaining stocks of the whole earth together, it may be said that a sufficient quantity of hardwoods is available, but the only countries which are able to supply coniferous timber for export on a considerable scale are Russia, Sweden, Norway, and Canada. As these countries have practically to supply the rest of the world, and as the management of their forests is far from satisfactory, the question of supplying light Pine and Fir timber, which form the very staff of life of the wood industries, must become a very serious matter before many years have passed. Unmistakable signs of the coming crisis are everywhere visible to all who wish to see, and it is difficult to overstate the gravity of the problem, when it is remembered, for instance, that 87 per cent. of all the timber imported into Great Britain consists of light Pine and Fir, and that most of the other importing countries are similarly situated. In some of these countries little or no room exists for the extension of wood land, but this statement does not apply to Great Britain and Ireland, which contain upwards of 12,000,000 acres of waste land, and 12,500,000 acres of mountain and heath land used for light grazing. One-fourth of that area, if put under forest, would produce all the timber now imported, which can be grown in Britain, that is to say, about 95 per cent. of the total. The subjoined table shows the movements of timber within the greater part of the British Empire, based on a few years' average :—

Countries.	Annual Average during the Years 1890–94.		Annual Average during the Years 1895–99.	
	Imports, value in £.	Exports, value in £.	Imports, value in £.	Exports, value in £.
Great Britain and Ireland . . .	17,595,000	..	22,190,000	..
New South Wales .	467,000	..	311,000	..
Victoria . . .	831,000	..	231,000	..
South Australia . .	250,000	..	198,000	..
Ceylon	..	22,000	21,000	..
Mauritius . . .	41,000	..	37,000	..
Natal	99,000	..	176,000	..
Cape of Good Hope .	160,000	..	416,000	..
Jamaica . . .	57,000	..	55,000	..
Barbadoes . . .	65,000	..	33,000	..
Trinidad . . .	41,000	..	40,000	..
British Guiana . .	41,000	..	27,000	..
Queensland . . .	..	11,000	..	5000

Forest Management.—In early times there was practically no forest management. As long as the forests occupied considerable areas, their produce was looked upon as the free gift of nature, like air and water; men took it, used it, and even destroyed it without let or hindrance. With the gradual increase of population and the consequent reduction of the forest area, proprietary ideas developed; people claimed the ownership of certain forests, and proceeded to protect them against outsiders. Subsequently the law of the country was called in to help in protection, leading to the promulgation of special forest laws. By degrees it was found that mere protection was not sufficient, and that steps must be taken to enforce a more judicious treatment, as well as to limit the removal of timber to what the forests were capable of producing permanently. The teaching of general science and of political economy was brought to bear upon the subject, so that now forestry has become a special science. This is recognized in many countries, amongst which Germany stands first, closely followed by France, Austria, Denmark, and Belgium. Of non-European countries the palm belongs to British India, and then follow Ceylon, the Cape of Good Hope, and Japan. The United States of America has also turned its attention to the subject. (See separate section below.) Most of the British colonies are, in this respect, as yet in a backward state, and the matter has still to be fought out in Great Britain and Ireland, though many writers have urged the importance of the question upon the public and the Government. There can be no doubt that all civilized countries must, sooner or later, adopt a rational and systematic treatment of their forests. The progress made in this direction up to 1889 was described in the article Forests in the 9th edition of this work (*Ency. Brit.*, vol. ix.). The following additional remarks furnish later information and statistics.

The British Empire.

Great Britain and Ireland. — The forests of Great Britain and Ireland, in spite of the large imports of timber, have not been appreciably extended up to the present time because (1) the rate at which foreign timber has been laid down in Britain is very low, thus keeping down the price of home-grown timber; (2) foreign timber is preferred to home-grown material, because it is of superior quality, while the latter comes into the market in an irregular and intermittent manner; (3) nearly the whole of the waste lands are private property. As regards prices, it can be shown that the lowest point was reached about the year 1888, in consequence of the remarkable development of means of communication, that prices then remained fairly stationary for some years, and that about 1894 a slow but steady rise set in. This was due to the gradual approach of the coming crisis in the supply of coniferous timber to the world. It can be shown that even with present prices the growing of timber can be made to pay, provided it is carried on in a rational and economic manner. Improved sylvicultural methods must be applied, so as to produce a better class of timber, and the forests must be managed according to well-arranged working plans, which provide for a regular and sustained out-turn of timber year by year, so as to develop a healthy and steady market for locally-grown material. Unfortunately the private proprietors of the waste lands are in many cases not in a financial position to plant. Starting forests demands a certain outlay in cash, and the proprietor must forego the income, however small, hitherto derived from the land until the plantations begin to yield a return. In these circumstances the State may well be expected to help in one or all of the following ways:—(1) The equipment of forest schools, where economic forestry, as elaborated by research, is taught; (2) management of the Crown forests on economic principles, so as to serve as patterns to private proprietors; (3) advances should be made to landed proprietors who desire to plant land, but are short of funds, just as is done in the case of improvements of agricultural holdings; and (4) the State might acquire surplus lands in certain parts of the country, such as congested districts, and convert them into forests. Action in these directions would soon lead to substantial benefits. The income of landed proprietors would rise, a considerable sum of money now sent abroad would remain in the country, and forest industries would spring up, thus helping to counteract the ever-increasing flow of people from the country into the large towns, where only too many must join the army of the unemployed. Even within a radius of 50 miles of London 700,000 acres of land are unaccounted for in the official agricultural returns. In Ireland more than 3,000,000 acres are waiting to be utilized, and it is well worth the consideration of the Irish Land Commissioners, whether the lands remaining on their hands, when buying and breaking up large estates, should not be converted into State forests. Such a measure might become a useful auxiliary in the peaceful settlement of the Irish land question. No doubt success depends upon the probable financial results. There are at present no British statistics to prove such success; hence, by way of illustration, it may be stated what the results have been in the kingdom of Saxony, which, from an industrial point of view, is comparable with England. That country has 432,085 acres of State forests, of which about one-eighth are stocked with broad-leaved species, and seven-eighths with conifers. Some of the forests are situated on low lands, but the bulk of the area is found in the hilly parts of the country up to an elevation of 3000 feet above the sea. The average price realized of late years per cubic foot of wood amounts to 5d., and yet to such perfection has the management been brought by a well-trained staff, that the mean annual net revenue, after meeting all expenses, comes to 21s. an acre all round. There can be no doubt that, under the more favourable climate of Great Britain, even better results can be obtained, especially if it is remembered that foreign supplies of coniferous timber must fall off, or, at any rate, the price per cubic foot rise considerably.

British India.—The history of forest administration in India is exceedingly instructive to all who take an interest in the welfare of the British Empire, because it places before the reader an account of the gradual destruction of the bulk of the natural forests, a process through which most other British colonies are now passing, and then it shows how India emerged triumphantly from the self-inflicted calamity. As far as information goes, India was, in the early times, for the most part covered with forest. Subsequently settlers opened out the country along fertile valleys and streams, while nomadic tribes, moving from pasture to pasture, fired alike hills and plains. This process went on for centuries. With the advent of British rule forest destruction became more rapid than ever, owing to the increase of population, extension of cultivation, the multiplication of herds of cattle, and the universal firing of the forests to produce fresh crops of grass. Then railways came, and with their extension the forests suffered anew, partly on account of the increased demand for timber and firewood, and partly on account of the fresh impetus given to cultivation along their routes. Ultimately, when failure to meet the requirements of public works was brought to notice, it was recognized that a grievous mistake had been made in allowing the forests to be recklessly destroyed. Already in the early part of the 19th century sporadic efforts were made to protect the forests in various parts of the country, and these continued intermittently; but the first organized steps were taken about the year 1855, when Lord Dalhousie was governor-general. At that time conservators of forests were appointed in Bombay, Madras, and Burma. Soon afterwards other appointments followed, and in 1864 an organized State department, presided over by the Inspector-General of Forests, was established. Since then the Indian Forest Department has steadily grown, so that it has now become of considerable importance for the welfare of the people, as well as for the Indian exchequer.

The first duty of the Department was to ascertain the position and extent of the remaining forests, and more particularly of that portion which still belonged to the State. Then a special forest law was passed, which was superseded in 1878 by an improved Act, which provided for the legal formation of State forests; the determination, regulation, and, if necessary, commutation of forest rights; the protection of the forests against unlawful acts, and the punishment of forest offences; the protection of forest produce in transit; the constitution of a staff of forest officers, provision to invest them with suitable legal powers, and the determination of their duties and liabilities. The officers who administered the Department in its infancy were mostly botanists and military officers. Some of these became excellent foresters. In order to provide a technically trained staff arrangements were made in 1866 by Sir Dietrich Brandis, the first Inspector-General of Forests, for the training of young Englishmen at the French Forest School at Nancy and at similar institutions in Germany. In 1876 the students were concentrated at Nancy, and in 1885 an English forest school for India was organized in connexion with the Royal Indian Engineering College at Cooper's Hill. The imperial forest staff of India consists of—officers not specially trained before entering the Department, 43; officers trained in France and Germany, 53; officers trained at Cooper's Hill, 102—total, 198.

In 1878 a forest school was started at Dehra Dun, North-Western Provinces, for the training of natives of India as executive officers on the provincial staff. Since then similar schools, though on a smaller scale, have been established at Poona in Bombay and at Tharrawaddy in Burma. A school for Madras will, no doubt, soon follow. Up to date 553 officers of this class have been appointed. In addition, there are about 12,000 subordinates, foresters, and forest guards, who form the protective staff.

The progress made since 1864 is really astonishing. According to the latest available returns, the areas taken under the management of the Department are—reserved State forests, or permanent forest estates, 79,311 square miles; other State forests, 34,606 square miles; or a total of 113,917 square miles, equal to 13 per cent. of the area over which they are scattered. At present, therefore, the average charge of each member of the controlling staff comprises 350,000 acres; that of each executive officer, 130,000 acres; and that of each protective official, 6000 acres. It is the intention to increase the executive and protective staff considerably, in the same degree as the management of the forests becomes more detailed. Of the above-mentioned area the Forest Survey Branch, established in 1872, has up to date surveyed and mapped about 25,000 square miles, and the Survey of India 24,000, or a total of about 49,000 square miles. From 1864 onwards efforts were made to introduce systematic management into the forests, based upon working plans, but as the management had been provincialized, there was no central or continuous control. This was remedied in 1884, when a central Working Plans Office, under the Inspector-General of Forests, was established. This officer has since then controlled the preparation and execution of the plans, a procedure which has led to most beneficial results. Plans referring to about 15,000 square miles are now in operation, and after a reasonable lapse of time there should not be a single forest of importance which is not worked on a well-regulated plan, and on the principle of a sustained yield. While the danger of overworking the forests is thus being gradually eliminated, their yield capacity is increased by suitable sylvicultural treatment and by fire protection. Formerly most of the important forests were annually or periodically devastated by jungle fires, sometimes lighted accidentally, in other cases purposely. Now, 29,000 square miles of forest are actually protected against fire by the efforts of the Department, and it is the intention gradually to extend protection to all permanent State forests. Grazing of cattle is of great importance in India; at the same time it is liable to interfere seriously with the reproduction of the forests. To meet both requirements careful and minute arrangements have been made, according to which at present 32,106 square miles are closed to grazing;

41,001 square miles are closed only against the grazing of goats, sheep, and camels; while 40,810 square miles are open to the grazing of all kinds of cattle. The areas closed in ordinary years form a reserve of fodder in years of drought and scarcity. During famine years they are either opened to grazing, or grass is cut in them and transported to districts where the cattle are in danger of starvation. The service rendered in this way by a wise forest administration should not be underrated, since one of the most serious calamities of a famine—the want of cattle to cultivate the land—is thus if not avoided, at any rate considerably reduced.

The financial results of forest administration in India have been as follows:—

Period	Mean Annual Net Revenue. Rupees.	Percentage of Increase during Period.
1865–70 . .	1,372,733	...
1870–75 . .	1,783,248	30
1875–80 . .	2,224,687	25
1880–85 . .	3,385,745	52
1885–90 . .	5,066,671	50
1890–95 . .	7,370,572	45

The revenue since 1886 has been considerably increased by the annexation of Upper Burma, still the progress made in the rest of India is highly satisfactory. The highest percentage of increase occurred in the period 1880–85. Apart from the net revenue, large quantities of produce are given free of charge, or at reduced rates, to the people of the country. Thus in 1896–97 the net revenue amounted to Rs.7,811,360, while the produce given free to the people was valued at Rs.3,446,500, making a total benefit derived from the State forests during that year equal to Rs.11,257,860. The sales during the same year mounted up to 55 million cubic feet of timber, 150 million cubic feet of fuel, and 172 million bamboos. The receipts from the sale of other forest produce came to 5 million rupees, out of a total gross revenue of Rs.17,856,510.

These results are highly creditable to the Government of India, which has led the way towards the introduction of rational forest management into the British Empire, thus setting an example which ought to be followed by all the British colonies. Above all, action is most urgently needed in Canada, where an enormous State property is threatened by destruction. Apart from India, Ceylon and Cape Colony are perhaps the only colonies where real and substantial progress has been made.

References.—SCHLICH. *A Manual of Forestry.* London, 1889–96. Volumes i., ii., and iii. by W. Schlich, volumes iv. and v. by W. R. Fisher; second edition of volume i., 1896, of volume ii., 1897.—BADEN-POWELL. *Forest Law.* London, 1893. —BROWN. *The Forester.* Latest edition by Nisbet, Edinburgh and London, 1894.—PUTON. *Traité d'Économie Forestière.* Paris, 1888.—BROILLIARD. *Le Traitement des Bois.* Paris, 1894.—GAYER. *Der Waldbau.* Berlin, 1889.—LOREY. *Forstwissenschaft.* Tübingen, 1888.—ROSSMÄSSLER. *Der Wald.* Leipzig, 1881.

(W. SCH.)

UNITED STATES.

The Forest Regions.—According to Mr Henry Gannett, of the U.S. Geological Survey, the wooded area of the United States, exclusive of Alaska, is 1,094,496 square miles, or 37 per cent. of the total area of the country. It is divided by the great treeless region east of the Rocky Mountains into two grand divisions, which may be called the Eastern and the Western forests. The Eastern forest is characterized by the predominance, on the whole, of broad-leafed trees, the comparative uniformity of its general types over wide areas, and its naturally unbroken distribution. In the Western forest conifers are conspicuously predominant, the individual species often reach enormous and even unequalled dimensions, the forest is frequently interrupted by treeless areas, and the transitions from one type to another are often exceedingly abrupt. Both divisions are botanically and commercially rich in species.

The Eastern forest may conveniently be subdivided into three members:—

(1) The Northern forest, marked by great density and large volume of standing timber, and a comparative immunity, in its virgin condition, from fire. The characteristic trees are Maples, Birches, and Beeches among the hardwoods, and White Pine, Spruce, and Hemlock among conifers.

(2) The Southern forest is on the whole less dense than the Northern, and more frequently burned over. Among its characteristic trees are Oaks, Gums, the Longleaf and other Pines, Bald Cypress, and White Cedar.

(3) The Interior Hardwood forest, which differs comparatively little from adjacent portions of the Northern and Southern forests except in the absence of the conifers, which form the determining (but not the predominant) factors in their composition. Among its trees are the Chestnuts, Hickories, Ashes, and other hardwoods already mentioned.

The Western division has two members:—

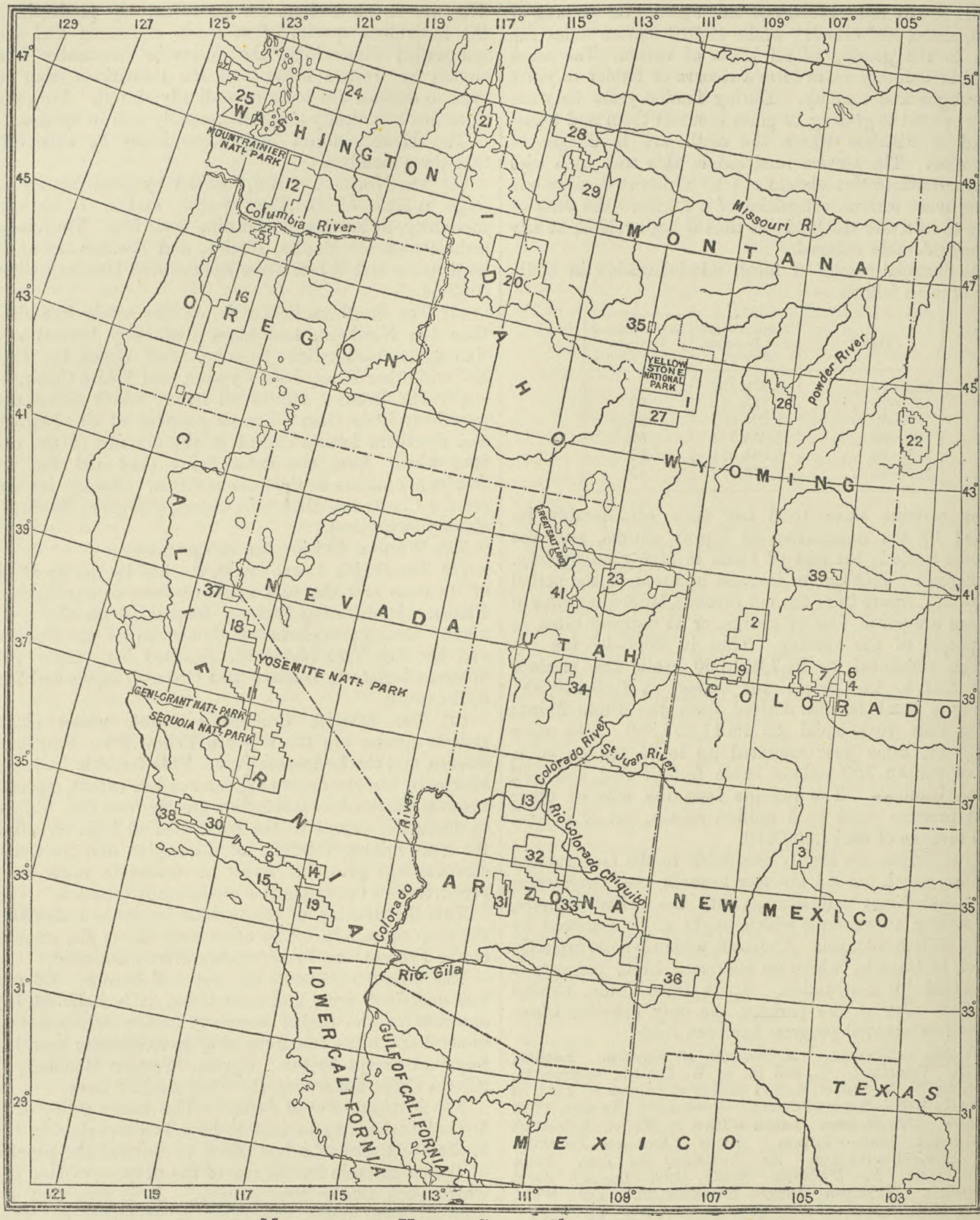
(1) The Pacific Coast forest, marked by the great size of its trees and the vast accumulations of merchantable timber. Devastating fires are frequent, especially to the north. Among its characteristic species are the Redwood and the Big Tree (*Sequoia*), the Red Fir, Sugar Pine, Western Hemlock, Western Red Cedar (*Thuja*), and Tideland Spruce.

(2) The Interior Coniferous forest, whose characteristic species are the Western Yellow Pine, Engelmann Spruce, and the Lodgepole Pine. This forest is frequently broken by treeless areas of greater or less extent, especially towards the south, and it suffers greatly from fire. Subarid in character, except to the north and at high elevations, the vast mining interests of the region and its treeless surroundings give this forest an economic value out of proportion to the quantities of timber it contains.

This distribution of the various forests is indicated in the map on p. 435. The other map shows the situation of the Federal forest reserves hereafter mentioned.

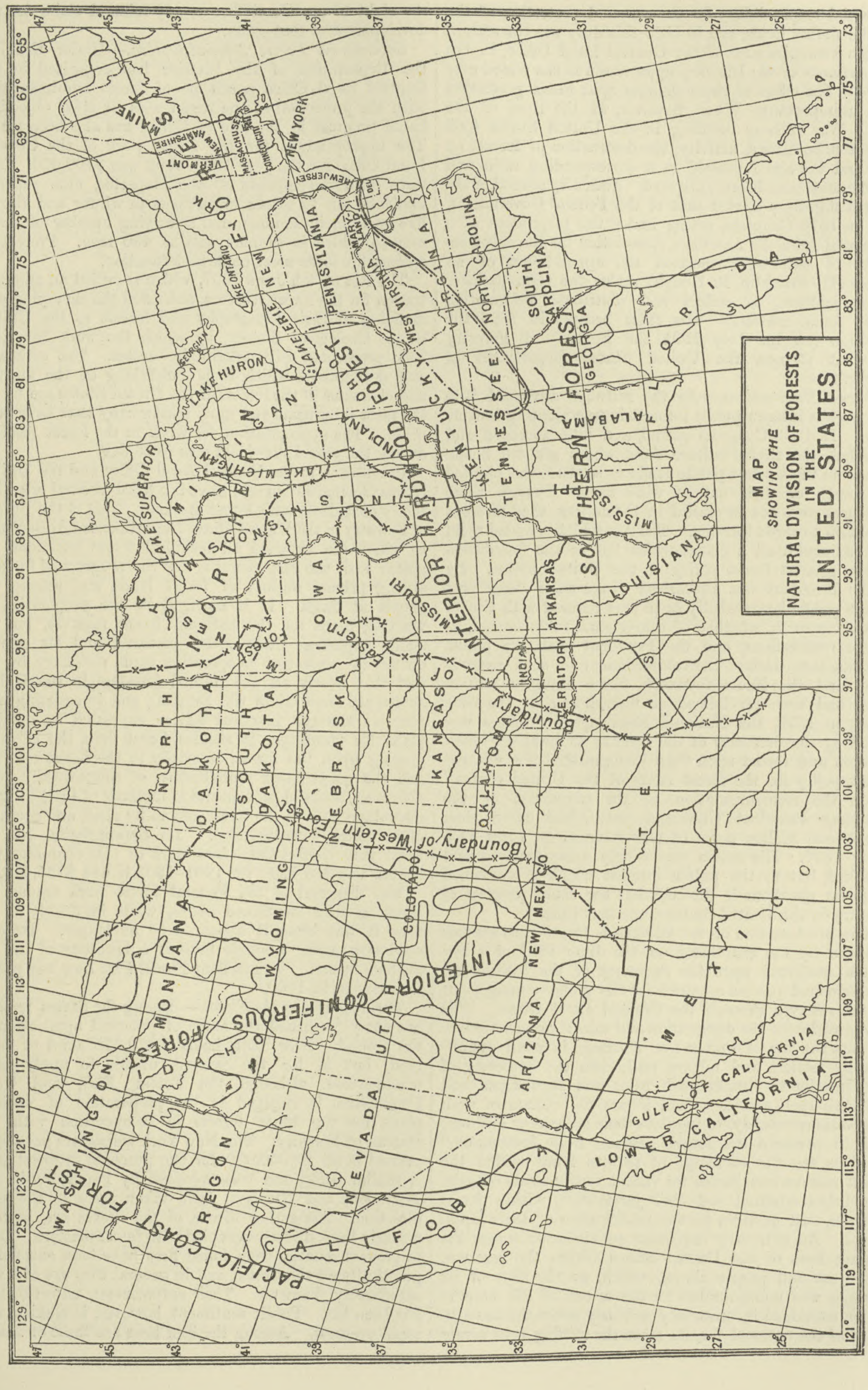
The forests of Alaska are not well known. Of great but undefined area, and containing, it is believed, large amounts of the timber necessary to the development of mineral and other resources, they have hitherto been little impaired except by fire. Spruce, Western Hemlock, and Alaska Cedar are among the characteristic trees.

The National Forest Policy.—The forest policy of the United States may be said to have had its origin in 1799 in the enactment of a law which authorized the purchase of timber suitable for the use of the navy, or of land upon which such timber was growing. It is true that laws were in force under the early governments of Massachusetts, New Jersey, and other colonies providing for the care and protection of forest interests in various ways, but these laws were distinctly survivals of tendencies acquired in Europe, and for the most part of little use. It was not until the apparent approach of a dangerous shortage in certain timber supplies became known that the first real step in forest policy was taken by the United States. Successive laws passed from 1817 to 1831 strove to give larger effect to the original enactment, but without permanent influence towards the preservation of the Live Oak (*Quercus virginiana* Mill.), which was the object in view. A long period of inaction followed these early measures. In 1831 the solicitor of the Treasury assumed



Map showing United States Forest Reserves.

No.	Acres.	States.	Names.	No.	Acres.	States.	Names.	No.	Acres.	States.	Names.
1	1,239,040	Wyo.	Yellowstone Park	15	109,920	Cal.	Trabuco Cañon	29	2,926,080	Mont.	Lewis and Clarke
2	1,198,080	Colo.	White R. Plateau	16	4,577,120	Oregon	Cascade Range	30	1,644,594	Cal.	Pine Mt. & Zaca Lake
3	430,880	N. Mex	Pecos River	17	18,560	,,	Ashland	31	423,680	Ariz.	Prescott
4	184,320	Colo.	Pike's Peak	18	691,200	Cal.	Stanislaus	32	975,360	,,	San Francisco Mts.
5	142,080	Oregon	Bull Run	19	737,280	,,	San Jacinto	33	1,658,880	,,	Black Mesa
6	179,200	Colo.	Plum Creek	20	4,147,200	Idaho & Mont.	Bitter Root	34	67,840	Utah	Fish Lake
7	683,520	,,	South Platte	21	645,120	Idaho & Wash.	Priest River	35	40,320	Mont.	Gallatin
8	555,520	Cal.	San Gabriel	22	1,211,680	S. Dak. & Wyo.	Black Hills	36	2,327,040	N. Mex.	Gila River
9	858,240	Colo.	Battlement Mesa	23	875,520	Utah	Uintah	37	136,335	Cal.	Lake Tahoe
10	403,640	Alaska	Afognak	24	3,426,400	Wash.	Washington	38	145,000	,,	Santa Ynez
11	4,096,000	Cal.	Sierra	25	1,466,880	,,	Olympic	39	56,320	Wyo.	Crow Creek
12	2,027,520	Wash.	Mount Rainier	26	1,147,840	Wyo.	Big Horn	40	57,120	Okla. T.	Wichita
13	1,851,520	Ariz.	Grand Cañon	27	829,440	,,	Teton	41	86,400	Utah	Payson
14	737,280	Cal.	San Bernardino	28	1,382,400	Mont	Flathead		46,398,369		


MAP
SHOWING THE
NATURAL DIVISION OF FORESTS
IN THE
UNITED STATES
NORTHERN FOREST
HARDWOOD FOREST
SOUTHERN FOREST
INTERIOR
INTERIOR CONIFEROUS FOREST
PACIFIC COAST FOREST
Boundary of Eastern Forest
Boundary of Western Forest
MAINE
NEW HAMPSHIRE
VERMONT
MASSACHUSETTS
CONNECTICUT
NEW YORK
NEW JERSEY
PENNSYLVANIA
MARYLAND
DEL.
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
ALABAMA
MISSISSIPPI
LOUISIANA
TENNESSEE
KENTUCKY
OHIO
INDIANA
ILLINOIS
MICHIGAN
WISCONSIN
MINNESOTA
IOWA
MISSOURI
ARKANSAS
TEXAS
INDIAN TERRITORY
OKLAHOMA
KANSAS
NEBRASKA
SOUTH DAKOTA
NORTH DAKOTA
MONTANA
WYOMING
COLORADO
NEW MEXICO
ARIZONA
UTAH
NEVADA
IDAHO
WASHINGTON
OREGON
CALIFORNIA
MEXICO
GULF OF CALIFORNIA
LOWER CALIFORNIA
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE ERIE
LAKE ONTARIO

a partial responsibility for the care and protection of the public timber lands, and in 1855 this duty was transferred to the Commissioner of the General Land Office, in the Department of the Interior, upon whom it has rested ever since. The effect of these changes upon forest protection was unimportant. When, however, at the close of the Civil War railway building in the United States took on an unparalleled activity, the destruction of forests by fire and the axe increased in a corresponding ratio, and public sentiment became alarmed. Action by several of the States slightly preceded that of the Federal Government, but in 1876 Congress, acting under the inspiration of a memorial from the American Association for the Advancement of Science, authorized the appointment of an officer (Dr Franklin B. Hough) under the Commissioner of Agriculture, to collect and distribute information upon forest matters. His office became in 1886 the Division (on 1st July 1901 the Bureau) of Forestry in what is now the United States Department of Agriculture.

Forest Reservations.—As the railways advanced into the treeless interior public interest in tree-planting became keen. In 1873 Congress passed, and later amended and repealed, the timber-culture Acts, which granted homesteads on the treeless public lands to settlers who planted one-fourth of their entries with trees. Though these measures were not successful in themselves, they directed attention towards forestry. The Act which repealed them in 1891 contained a clause which lies at the foundation of the present forest policy of the United States. By it the President was authorized to set aside "any part of the public lands wholly or in part covered with timber or undergrowth, whether of commercial value or not, as public reservations, and the President shall, by public proclamation, declare the establishment of such reservations and the limits thereof." Some eighteen million acres had been proclaimed as reservations at the time when, in 1896, the National Academy of Sciences was asked by the Secretary of the Interior to make an investigation and report upon "the inauguration of a rational forest policy for the forest lands of the United States." Upon the recommendation of the committee of the Academy President Cleveland established more than twenty-one million acres of new reserves on 22nd February 1897. His action was widely misunderstood and attacked, but to the public interest which it awakened in forest questions is directly due the rapid progress of forestry in the United States since that time.

The proclamation of the Cleveland forest reserves was followed by the enactment on 4th June 1897 of a law which conferred upon the Secretary of the Interior all the principal powers required for the proper management of the reserves through the General Land Office. This law provides for the designation and sale of mature timber, permits the use of timber free of charge in small quantities by settlers and miners, authorizes the Secretary of the Interior to "make such rules and regulations and establish such service as will insure the objects of such reservations, namely, to regulate their occupancy and use, and to preserve the forests thereon from destruction," provides for the exchange of private lands within the forest reserve boundaries for vacant public lands outside, establishes criminal and civil jurisdiction within forest reserves, and provides for the modification of their boundaries. An extremely important provision continues the mining laws of the United States within the reserves. This just and proper clause, which, at the time of its passage, was indispensable for the success of the measure which contained it, must very seriously affect the management of the national forests, since the mining laws confer the right to use the timber on any mineral claim for the development of that claim.

Government Forest Administration.—Under this law the Department of the Interior has organized in the General Land Office a scheme of forest administration with the protection of the reserves as its chief objective. Some progress in the sale of timber has also been made. The appropriation for the forest work of the General Land Office for the year 1901–1902 was $300,000. The force employed consists of one inspector, nine superintendents, ten to fifteen supervisors in winter and thirty-five to forty in summer, and a varying number of forest rangers, which in summer attains 430 men. Protection against fire is its most important function.

The Act of 4th June 1897, which provided an administration for the forest reserves, entrusted the surveying and mapping of their topography and forests to the United States Geological Survey, by which the work has since been prosecuted with admirable success. The estimates and descriptions which it is publishing of the amount and character of the forests of the United States are by far the most intelligent and most trustworthy that have been made. The appropriation for work in the forest reserves during the year 1901–1902 was $125,000.

In addition to the General Land Office and the United States Geological Survey, there is a third Federal organization which deals with forest matters. This is the Bureau of Forestry in the United States Department of Agriculture, to which are assigned all technical forest questions, together with the responsibility for the progress of forestry among private owners of forest lands and among the people at large. It is engaged in the preparation of working plans for the national forest reserves, for the single important State forest preserve, and for private owners (a method of co-operation made necessary by the fact that nearly all the trained foresters in the United States are members of the Bureau), and in assisting tree-planters through practical advice expressed in detailed plans for planting. It studies forest fires, the effect of grazing upon the forest, especially in the forest reserves, and the growth and reproduction of commercially valuable trees, seeks improvements in methods of lumbering, of advantage both to the forest and to its yield, and conducts other forest investigations. Its appropriation for the fiscal year 1898–1899, when work of this character was begun, was $28,520; for 1901–1902 it was $185,440.

The dispersal of the Federal forest work among the three agencies mentioned above, while inevitable at the time it was brought about, is so no longer. Its consolidation under a single head is a necessity of the immediate future. An excellent Forest Fire Law was passed in Congress in 1900.

Forestry among the States.—Among the States, forestry has not yet reached the stage of practical application on the ground. New York holds 1,370,928 acres of forest land, but is for the present unable to apply forest management, although the Forest, Fish, and Game Commission is engaged in the preparation of working plans for the State forests in co-operation with the Bureau of Forestry. The New York legislature has appropriated in all $2,000,000 for the purchase of forest land. A similar policy has been adopted by Pennsylvania, and Minnesota and Michigan have taken steps in the same direction. Altogether fifteen of the States are, or have recently been, directly occupied with forest matters. Laws to prevent damage from forest fires have been enacted by practically all the States, and in general they are of a very satisfactory character. Their enforcement, unfortunately, has been lax. Public sentiment, however, is making very rapid progress. Among the best laws are those of Maine, New Hampshire, Minnesota, New York, Pennsylvania, and Wisconsin. The New York law, for example, provides for the appointment of one or more fire wardens in each town of the counties in which damage by fire is especially to be feared. In other counties supervisors of towns are *ex-officio* fire wardens. A chief fire warden has general supervision of their work. The wardens, half of the cost of whose services is paid by the State, receive compensation only for the time actually employed in fighting fires. They may command the service of any citizen to assist them. Setting fire to woods or waste lands belonging to the State or to another, if such fire results in loss, is punishable by a fine not exceeding $250, or imprisonment not exceeding one year, or both, and damages are provided for the person injured. Since fire is beyond question the most dangerous enemy of forests in the United States, the measures taken against it are of vital importance.

Forest Associations.—Public sentiment in favour of the protection of forests is now widespread and increasingly effective throughout the United States. As the general understanding of the objects and methods of forestry becomes clearer, the tendency, formerly very marked, to confound ornamental tree-planting and botanical matters with forestry proper is rapidly growing less. At the same time, the number and activity of associations dealing with forest matters is increasing with notable rapidity. There are now some twenty-two such associations in the United States, of which the American Forestry Association is the oldest and most influential. Its objects are, first, to bring about a wiser and more conservative treatment of the forest resources of the country, and to promote educational, legislative, and other measures to that end; and secondly, the diffusion of knowledge regarding the conservation, management, and renewal of forests, the methods of reforesting waste lands, the proper utilization of forest products, the planting of trees for ornament, and cognate subjects of arboriculture. This association has been influential in preparing the groundwork of popular interest in forestry, and especially in advocating and securing the adoption of the federal forest reservation policy, the most important step yet taken by the national Government. The Association is growing rapidly in membership and influence. It publishes as its organ a monthly magazine called *The Forester.* The Pennsylvania Forestry Association has been instrumental in placing that State in the forefront of forest progress. Its organ is a bi-monthly publication called *Forest Leaves.* Other States which have associations or societies of special influence in forest matters are California, Massachusetts, Minnesota, Colorado, and Oregon. Arbor Day, instituted in Nebraska in 1872 as a means of interesting children in the planting of trees, has spread until it is now observed in every State and Territory. It continues to serve an admirable purpose.

Forest Instruction.—Elementary instruction in forestry has already made noteworthy progress, especially in State agricultural colleges, of which thirty-eight offer instruction in forest subjects. The University of Minnesota and Berea College, Kentucky, deserve special mention among the institutions which do not attempt to graduate fully trained foresters; of these there are ten in addition to the agricultural colleges. The Biltmore Forest School, in North Carolina, offers a one-year course in technical forestry, and the New York State College of Forestry, organized in 1898 as a part of Cornell University, offers a four-years' undergraduate technical course modelled on German lines and leading to a degree. A tract of thirty thousand acres in the Adirondack Mountains serves as an experimental forest in connexion with the college. The Yale Forest School, which was opened as a department of Yale University in September 1900, offers a two-years' post-graduate course, with abundant field-work both in the Adirondacks and in Pennsylvania and Connecticut. A summer school of forestry, specially adapted to the training of forest rangers, and for advanced and special students, is conducted at Grey Towers, Milford, Pennsylvania, by the professors of the Yale Forest School.

Forestry on Private Lands.—The practice of forestry among private owners is of old date. One of the earliest instances was that of Jared Eliot, who, in 1730, began the systematic cutting of timber land to supply charcoal for an iron furnace at Old Salisbury, Connecticut. The successful planting of waste lands with timber trees in Massachusetts dates from about ten years later. But such examples were comparatively rare until recent times. At present the intelligent harvesting of timber with a view to successive crops, which is forestry, is much more common than is usually supposed. Among farmers it is especially frequent. It was begun among lumbermen by the late E. S. Coe, of Bangor, Maine, who made a practice of restricting the cut of Spruce from his forests to trees 10, 12, or sometimes even 14 inches in diameter, with the result that much of his land yielded, during his life, a second crop as plentiful as the first. Many owners of Spruce lands have followed his example, but until very recently without improving upon it. Systematic forestry on a large scale among lumbermen was begun in the Adirondacks during the summer of 1898 on the lands of Dr W. S. Webb and Hon. W. C. Whitney, of a combined area of over 100,000 acres, under the superintendence of the then Division of Forestry. In these forests Spruce, Maple, Beech, and Birch predominate, but the Spruce alone is at present of the first commercial importance. The treatment is a form of the selection system. Under it a second crop of equal yield would be ripe for the axe in thirty-five years. Spruce and Pine are the only trees cut. The work had been executed, at anyrate up to the year 1902, with great satisfaction to the owners and the lumbering contractors, as well as to the decided benefit of the forest. The lumbering is regulated by the following rules, and competent inspectors are employed to see that they are rigidly carried out:—(1) No trees shall be cut which are not marked. (2) All trees marked shall be cut. (3) No trees shall be left lodged in the woods, and none shall be overlooked by the skidders or haulers. (4) All merchantable logs which are as large as 6 inches in diameter at the small end must be utilized. (5) No stumps shall be cut more than 6 inches higher than the stump is wide. (6) No Spruce shall be used for bridges, corduroy, skids, slides, or for any purpose except building camps, dams, or booms, unless it is absolutely necessary on account of lack of other timber. (7) All merchantable Spruce used for skidways must be cut into logs and hauled out. (8) Contractors must not do any unnecessary damage to young growth in lumbering; and if any is done, they must discharge the men who did it.

These are perhaps the most notable instances of forestry in the United States. Their example is decidedly the most useful and effective one among lumbermen, especially in the Spruce regions of New England and New York, but neither one was the first case of systematic forestry under regular working plans. The first instance was begun in 1891 on about 4000 acres of forest land, forming part of the estate of George W. Vanderbilt, at Biltmore, North Carolina. The working plan has been extended until now it covers nearly 100,000 acres. A professional forester, with a corps of trained rangers under him, is in charge of the work. Protection against fire and the planting of groves, wood-lots, and wind-breaks by individual initiative also deserve mention among private activities in forestry. The latter, in spite of the repeal of the timber-culture laws, is prosecuted on a large scale over considerable portions of the treeless West.

American Practice.—The conditions under which forestry is practised in Europe and in America differ so widely that rules which are received as axiomatic in the one must often be rejected in the other. Among these conditions in America are the highly developed and specialized methods and machinery of lumbering, the greater facilities for transportation and consequent greater mobility of the lumber trade, the vast number of small holdings of forest land, and the enormous supply of low-grade wood in the timbered regions. High taxes on forest properties, cut-over as well as virgin, notably in the north-western pineries, and the firmly established habits of lumbermen, are factors of great importance. From these and other considerations it follows that such generally accepted essentials of European methods of forestry as a sustained annual yield, a permanent force of forest labourers, a permanent road system, and the like, are in most cases utterly inapplicable in the United States at the present day. Methods of forest management, to find acceptance, must there conform as closely as possible to existing methods of lumbering. Rules of marked simplicity, the observance of which will yet secure the safety of the forest, must open the way for more refined methods in the future. For the present a periodic or irregular yield, temporary means of transport, constantly changing crews, and an almost total ignorance of the sylviculture of all but a very few of the most important trees—all combine to enforce the simplest sylvicultural treatment and the utmost concentration of purpose on the two main objects of forestry, which are the production of a net revenue and the perpetuation of the forest. Such concentration has been followed in practice by complete success.

The forests with which the American forester deals are rich in species, usually endowed with abundant powers of reproduction, and, over a large part of their range, greatly dependent for their composition and general character upon the action of forest fires. Except in its most obvious manifestations, the sylvicultural character of the larger number even of the commercially valuable trees is unknown. Of these there may be said to be in round numbers a hundred out of a total forest flora of about 500 species, but many trees not yet of importance in the lumber trade will become so hereafter, as has already happened in many cases. In a forest thus constituted and in existing circumstances the attention of the forester must be concentrated upon the growth and reproduction usually of a single species, and never of more than a very few. Thus the sylvicultural problems which must be solved in the practice of forestry in America are fortunately less complicated than the presence of so many kinds of trees in forests of such diverse types would naturally seem to indicate.

Special Problems.—It is probable that forest fires have had more to do with the character and distribution of forests in America than any other modifying factor except rainfall. With an annual range over thousands of square miles, in many portions of the United States they occur regularly year after year on the same ground. Trees whose thick bark or abundant seeding gives them peculiar powers of resistance, frequently owe their exclusive possession of vast areas purely to the action of fire. On the economic side fire is equally potent. The probability, or often the practical certainty, of fire after the first cut, commonly determines lumbermen to leave no merchantable tree standing. The prevalence of forest fires is thus one of the most effective barriers to the introduction of forestry. Excessive taxation of timber land is another of almost equal effect. Because of it lumbermen hasten to cut, and afterwards often to abandon, lands which they cannot afford to hold. This evil, which only the progress of public sentiment can control, is especially prevalent in certain portions of the White Pine belt. A third problem of crucial importance to the Western forests, but of a different kind, relates to grazing in the national forest reserves. Much of the early opposition to their establishment came from the grazing interests. Now that the maintenance of the reserves is no longer in question, the discussion hinges chiefly upon the admission of sheep within the reserve boundaries. The trend of public sentiment is against it, but their complete exclusion is both undesirable and unlikely, since there are doubtless considerable portions of the reserves where moderate grazing will do no harm. This question has been officially referred to the Bureau of Forestry, and a thorough investigation is in progress.

Lumbering.—The importance of the lumber trade to the prosperity and progress of the United States is difficult to estimate. According to the census of 1890, which was the latest available at the time of writing, the capital invested in logging operations was $60,442,226, the number of employees engaged, 174,152, and their wages, $38,991,794; saw-mills represented an invested capital of $121,562,226, and employed 286,197 persons, whose wages were $87,784,433. The industries dependent on the forest ranked next to agriculture in their contribution to the national wealth. For 1899 the total consumption of wood for the United States is roughly estimated at 18,307,000,000 cubic feet, divided approximately as follows:—Lumber market and manufactures, 2,250,000,000 cubic feet; fuel, 15,000,000,000 cubic feet; railroad ties, 27,000,000 cubic feet; fencing, 30,000,000 cubic feet; other items, 1,000,000,000 cubic feet. For purposes of comparison, 110 cubic feet may be taken as approximately equal to 1000 board feet. All the operations of the lumber trade in the United States are controlled, and to no small degree determined, by the peculiar unit of measure which has been adopted. This unit, the *board foot*, is generally defined as a board 1 foot long, 1 foot wide, and 1 inch thick, but in reality it is equivalent to 144 cubic inches of manufactured lumber in any form. To purchase logs by this measure one must first know about what each log will yield in 1-inch boards. For this purpose a scale or table is used, which gives the contents of logs of various diameters and lengths in board feet. Under such a standard the purchaser pays for nothing but the saleable lumber in each log, the inevitable waste in slabs and sawdust costing him nothing.

The principal lumber tree of the United States is still the White Pine (*Pinus strobus* L.), usually known in Europe as the Weymouth Pine. It has an average height of 110 feet when mature, and an average diameter of somewhat less than 3 feet. Throughout the Northern subdivision of the Eastern forest it is, or has been, commercially the most important factor. At present it has largely disappeared as an element of the standing forests of New England, New York, and Pennsylvania, and from large portions of its western (and more important) range as well. Trustworthy estimates of the amount of White Pine left standing are not available, but it may be accepted that the first grade of virgin timber is very nearly gone. Of late years the size of the merchantable log has rapidly decreased, until at present much of the White Pine brought to the mill is less than ten inches in diameter. A striking and instructive example of the widespread decline of White Pine as a lumber tree, and its gradual replacement by trees formerly of little moment, is afforded by the official figures of production on the

Penobscot river in Maine, which is still called the Pine Tree State. In 1851 the cut of White Pine was 144 million feet, of Spruce 48 million, of Hemlock 11 million. Thirty years later the Pine cut had sunk to 23 million, the Spruce had risen to 118 million, and the Hemlock had surpassed the Pine by a million feet. In 1900 the cut of Pine was less than 23 million, that of Spruce was 102 million, and that of Hemlock 17 million. It is certain that a similar decline in White Pine production will become general. The following table gives the cut of the north-western pineries (on the headwaters of the Mississippi) for the years 1873 to 1900 inclusive :—

1873 . .	3,993,780,000	1887 . .	7,757,916,784
1874 . .	3,751,306,000	1888 . .	8,388,716,460
1875 . .	3,968,553,000	1889 . .	8,183,050,755
1876 . .	3,879,046,000	1890 . .	8,597,659,352
1877 . .	3,595,333,496	1891 . .	7,879,948,349
1878 . .	3,629,472,759	1892 . .	8,594,222,802
1879 . .	4,806,943,000	1893 . .	7,326,263,782
1880 . .	5,651,295,000	1894 . .	6,821,516,412
1881 . .	6,768,856,749	1895 . .	7,050,669,235
1882 . .	7,552,150,744	1896 . .	5,725,763,035
1883 . .	7,624,789,786	1897 . .	6,233,454,000
1884 . .	7,935,033,054	1898 . .	6,155,300,000
1885 . .	7,053,094,555	1899 . .	6,056,508,000
1886 . .	7,425,368,443	1900 . .	5,485,261,000

Already very many of the White Pine lumbermen and mill-men have removed to the Southern States and the Pacific Coast, driven away by the exhaustion of their supplies. White Pine, as a rule, is cut in the summer and autumn, skidded (dragged to convenient places and piled along the roads) by horses in the early winter, hauled on sleds over ice-coated temporary roads to the banks of streams in the late winter and early spring, and finally driven (floated) down to the booms (chains of floating logs firmly anchored to hold the "drive") near the mill. The mill machinery, as well as the tools and appliances used in felling the trees, and in the various stages of transport from the stump to the mill, and from the mill to the consumer, are usually of the first grade of practical utility.

Second to the White Pine, among the coniferous lumber trees of the Northern forest, is the Spruce (*Picea rubens* Sargent), now, however, used for the most part in the manufacture of paper pulp, for which purpose Poplar (chiefly *Populus tremuloides* Michx. and *P. grandidentata* Michx.) and several other woods are also employed, but on a less gigantic scale. The total consumption of wood for paper in the United States in 1900 approached closely to the equivalent of one billion board feet, of which amount from 10 to 15 per cent. was imported from Canada.

The hardwood product of the country, including fuel, is enormous, but no accurate figures are available. Derived from each of the great divisions of the Eastern forest, and consumed in vast quantities for domestic purposes, its grand total can only be surmised. It is known, however, that Michigan, Wisconsin, and Minnesota, which are the principal sources of White Pine, produced in 1900 more than 900 million board feet of hardwood. Their output has doubled since 1896.

The most widely known lumber tree of the Southern forest is the Longleaf Pine (*Pinus palustris* Mill.), mistakenly called Pitch Pine in Europe, whose timber is probably superior in strength and durability to that of any other member of the genus *Pinus*. The average size of the mature Longleaf Pine is 90 feet in height and 20 inches in diameter. Other important lumber trees are the Shortleaf, Loblolly, and Cuban Pines, the Bald Cypress, and the White Cedar (*Chamæcyparis thyoides* (L.) B.S.P.) among the conifers, and the Yellow or Tulip Poplar and various oaks among broad-leafed trees. Except for the wire cable logging of the Cypress and other swamp trees, the transportation of logs is, on the whole, less highly specialized here than in the Northern forest. The more valuable timber as a rule is in the lower and more level regions, and the proportion of carriage by rail is consequently greater.

Satisfactory statistics of the standing timber or the lumber product of the Southern forest are not available. The report of the Yellow Pine Clearing House gives the total cut of the various southern lumber Pines by 136 firms in eight States during 1900 at 1,878,831,109 board feet, but these figures are incomplete. The production of naval stores as it is carried on in the forests of Longleaf Pine is rapidly destructive to the standing timber, and is directly responsible for disastrous fires. It supplies, however, an important item in the revenue from the Southern forest. In 1900 the value of the exports to foreign countries, in spite of a notable shrinkage, was $13,030,232. The domestic consumption is very large.

In the Pacific Coast forest the principal lumber trees, among many of great importance, are Red Fir, sometimes called Douglas Fir (*Pseudotsuga taxifolia* (Lam.) Britton), in Oregon and Washington, and Redwood in California. The average sizes of these trees when mature are approximately, for the Red Fir, 200 feet high and 4 feet in diameter, and for the Redwood, 225 feet high and 8 feet in diameter. The annual lumber product of the Coast is difficult to state in exact figures. That of Washington for 1900 exceeded one billion board feet, that of Oregon was 898,160,000, while the Redwood product of three counties in California for the same year exceeded 200 million feet. The timber standing in these States, according to Mr Henry Gannett, is in Washington, upon the present basis of estimate, 114,778 million feet B.M. (board measure), in Oregon 234,653 million feet, in California (Redwood only) 97,505 million feet. California has great bodies of timber outside the Redwood belt.

Logging in the Pacific Coast forest is usually by wire cable. The logs are skidded partly by cables operated by donkey engines, which drag themselves through the forest wherever they are required, partly by stationary donkeys of larger size, the cables of which are often more than half a mile in length. The final journey to the mill is commonly by rail. Extreme skill in the handling of enormous weights and powerful machinery is a conspicuous characteristic of lumbering in Washington, Oregon, and especially in California, where the logs of Redwood and of Big Tree are often more than 10 feet in diameter. Flumes for the transportation of manufactured lumber by water are frequent in this region, where some of them attain a length of 40 miles. Mills of great size, built on piles over tide-water, and so arranged that their product is delivered directly from the saws and dry kilns to the lumber vessels moored alongside, supply a rapidly growing coastwise and foreign trade. Certain products of the Coast forest, notably Cedar shingles and Fir timbers, have already made their way overland into the markets of the central and eastern States.

The most important lumber trees of the Interior Coniferous forest are the Western Yellow Pine, the Red Fir, and the Engelmann Spruce. The Red Fir, here extremely variable in size and value, reaches in this forest average dimensions of perhaps 70 feet in height and 2 feet in diameter, the Western Yellow Pine 90 feet by 3 feet, and the Engelmann Spruce 60 feet by 2 feet. Mining, railroad, and domestic uses chiefly absorb the annual timber product, which is considerable in quantity, and of vast importance to the local population.

For the twelve months ending with December 1900, the United States imported wood and manufactures of wood to the value of $20,156,641. The corresponding value of exports for the same period was $52,636,808.

AUTHORITIES.—EMERSON. *Trees and Shrubs of Massachusetts.* Boston, 1875.—F. B. HOUGH. *Elements of Forestry.* Cincinnati, 1882.—R. B. HOUGH. *American Woods.* Lowville, N.Y., 1888–1897.—SARGENT. *Silva of North America.* Boston, 1891-97.—LEMMON. *Handbook of West American Cone-bearers.* San Francisco, 1895.—BRUNCKEN. *North American Forests and Forestry.* New York, 1900.—PINCHOT. *Biltmore Forest.* Chicago, 1893. *The Adirondack Spruce.* New York, 1898.—PINCHOT AND GRAVES. *The White Pine.* New York, 1896. Also the following bulletins and circulars of the Bureau of Forestry, Washington:—MOHR, *Timber Pines of the Southern United States,* 1896; COVILLE, *Forest Growth and Sheep Grazing,* 1898; ROTH, *Timber,* 1895, and *Forestry Conditions and Interests of Wisconsin,* 1898; SUDWORTH, *Nomenclature of the Arborescent Flora of the United States,* 1897, and *Check List of the Forest Trees of the United States,* 1898; SPAULDING, *The White Pine,* 1899; PINCHOT, *A Primer of Forestry,* 1899; GRAVES, *Practical Forestry in the Adirondacks,* 1899; HOSMER AND BRUCE, *A Forest Working Plan for Township 40,* 1901; *Forest Influences,* 1893; *Forest Fire Legislation,* 1896. Also the following bulletins of the N.C. Geological Survey, Raleigh:—ASHE, *Forests, Forest Lands, and Forest Products of Eastern North Carolina,* 1894, and *Forest Fires,* 1895; PINCHOT AND ASHE, *Timber Trees and Forests of North Carolina,* 1897; together with RIDGEWAY, *Trees of White and Wabash River Valley* (U.S. National Museum), Washington, 1882; SARGENT, *Report on the Forests of North America,* Washington, 1884; *Report of the Forest Commission of the National Academy of Sciences,* Washington, 1897; FERNOW, *Forestry for Farmers* (Department of Agriculture, Farmer's Bulletin, No. 67), Washington, 1898; PINCHOT, *Survey of Forest Reserves,* Washington, 1898; GREEN, *Forestry in Minnesota,* Delano, Minn., 1898 (Minn. Forestry Association); PINCHOT, *Forest Fires and Wood Production in Southern New Jersey,* Trenton, 1899 (Report of State Geologist for 1898); FERNOW, *Report on the Forestry Investigations of the U.S. Department of Agriculture,* Washington, 1899; GANNETT, *Forest Reserves,* Washington, 1899 and 1900 (Nineteenth and Twentieth Annual Reports of U.S. Geological Survey). (G. P.)

Forfar, a royal and parliamentary burgh (Montrose group) of Forfarshire, Scotland, is 14 miles N.N.E. of Dundee by rail. The manufactures include jute, linen, and iron-founding. The parish church was renovated in 1900. Recent erections are a United Free church, an Episcopal church, and a Baptist chapel. Population of royal burgh (1881), 13,579; (1901), 12,061.

Forfarshire, or ANGUS, a maritime county of East Scotland, bounded N. by Aberdeen and Kincardine, E. by the German Ocean, S. by the Firth of Tay, and W. by Perthshire.

Area and Population.—In 1891, 568½ acres of the Perthshire parish of Caputh were added to three Forfarshire parishes, and the whole parish of Fowlis Easter and the Perthshire part of the parish of Liff, Benvie and Invergowrie, were transferred to Forfar; and to Perth from Forfar, part of Alyth, Coupar-Angus, and Kettins. The Kincardine part of the parish of Edzell was transferred to the Kincardine parish of Fettercairn. The area of the county, according to the latest official estimate, is (excluding foreshore) 562,162 acres, or about 878 square miles. The population was in 1881, 266,360; in 1891, 277,788; in 1891, on the above area, 277,735, of whom 125,414 were males and 152,321 females; in 1901, 284,078. On the old area, taking land only (560,186 acres, or 875·3 square miles), the number of persons to the square mile in 1891 was 317, and the number of acres to the person 2·0. In the registration county the population increased between 1881 and 1891 by 4·3 per cent. Between 1881 and 1891 the excess of births over deaths was 31,815, and the increase of the resident population 11,443. The following table gives particulars of births, deaths, and marriages in 1880, 1890, and 1899:—

Year.	Deaths.	Marriages.	Births.	Percentage of Illegitimate
1880	5705	1818	8862	9·9
1890	5997	1921	7990	9·62
1899	5285	2162	7930	8·4

The following table gives the birth-rate, marriage-rate, and death-rate per thousand of the population for a series of years:—

	1880.	1881-90.	1890.	1891-98.	1899.
Birth-rate . .	33·27	30·89	28·61	28·61	27·67
Death-rate . .	21·42	19·30	21·47	19·27	18·44
Marriage-rate .	6·83	6·77	6·87	7·17	7·54

In 1891 the number of Gaelic-speaking persons in the county was 1438, and of foreigners 376. Valuation in 1889-90, £603,115; 1899-1900, £618,666.

Administration.—The county returns a member to Parliament. Dundee (160,871) returns two members, and Montrose, Arbroath, Brechin, and Forfar form, with Bervie in Kincardine, the Montrose group of parliamentary burghs. Dundee is a royal burgh, a city, and (since 1894) a county of a city, and other royal burghs are Montrose (12,401), Forfar, the county town (12,061), Brechin (8941), and Arbroath (22,372). There are 55 civil parishes, forming one combination. The number of paupers and dependents in September 1899 was 5923. Forfarshire is a sheriffdom, and there is a resident sheriff-substitute at Dundee and another at Forfar, and courts are held also at Arbroath.

Education.—Sixty school boards manage 148 schools, which had in 1898-99 an average attendance of 38,856, while 23 voluntary schools, of which 8 are Roman Catholic and 4 Episcopal, had 7211. There are 3 secondary schools at Dundee, and one each at Montrose, Arbroath, Brechin, and Forfar; academies with elementary departments at Broughty-Ferry and Kirriemuir, and one other school in Dundee and 12 in the county earned grants for giving higher education in 1898. There are technical schools at Dundee and Arbroath. The county council and Dundee and Arbroath town councils expend the "residue" grant in subsidizing science and art and technical schools and classes, including Dundee university college, textile school, technical institute, navigation school, and workshop schools, and Arbroath technical school, and cookery, dairy, dress-cutting, veterinary science, plumbing, and laundry classes at various centres.

Agriculture.—The percentage of land under cultivation in 1898 was 44·8. Oats are the principal but a declining crop, while the barley acreage continues to increase with fair steadiness. The wheat acreage, considerably reduced between 1875-1900, does not show a tendency to fall further; it was, for instance, 500 acres more in 1898 than in 1897. The following table gives the principal acreages at intervals of five years from 1880:—

Year.	Area under Crops.	Corn Crops.	Green Crops.	Clover.	Permanent Pasture.	Fallow.
1880	253,373	94,793	53,439	81,396	23,051	694
1885	254,012	93,231	50,128	82,965	27,360	328
1890	253,723	89,817	49,546	85,798	28,328	80
1895	252,200	87,837	48,524	84,823	30,771	51
1899	251,276	88,144	47,221	86,634	28,936	108

The following table gives particulars of the live stock during the same years:—

Year.	Total Horses.	Total Cattle.	Cows or Heifers in Milk or Calf	Sheep.	Pigs.
1880	10,443	46,304	11,685	122,856	5132
1885	9,612	50,406	12,310	132,167	6997
1890	9,947	55,401	12,397	152,203	7547
1895	10,653	49,163	11,634	146,329	7951
1899	10,028	51,668	12,536	167,219	6743

Of the 2637 holdings in 1895, the date of the last return, the average size was 96 acres. The percentage under 5 acres was 15·74, between 5 and 50 acres 35·76, and over 50 acres 48·50. The number of farms between 50 and 100 acres was 399; between 100 and 300, 687; between 300 and 500, 166; and over 500 acres, 27. The bothy system of housing farm servants still prevails in this county to a considerable extent, though the farm buildings are equal to any to be found elsewhere in Scotland. In 1898, 31,972 acres were under wood, 2685 having been planted since 1881. At the census of 1891, 9848 men and 579 women were returned as being engaged in agriculture.

Industries and Trade.—Shipbuilding (see DUNDEE) and manufactures of confectionery, jams, leather, machinery, soap, and chemicals, are all now important industries. In 1891, 52,345 men and 44,208 women were engaged in pursuits connected with industry, and of these 17,615 men and 34,398 women were associated with the manufacture of textiles. There is a number of sandstone quarries; the output was in 1895, 112,588 tons, valued at £56,446, and in 1899, 142,948 tons, valued at £64,990. The fisheries of the county are of considerable importance. All the ports of the county and one or two belonging to Kincardine are included in the

Montrose fishery district, statistics of which are given in the following table:—

Year.	Boats.			Value of Gear.	Resident Fishermen and Boys.	Total Value of all Fish.
	No.	Tons.	Value.			
1890	636	5084	£46,449	£29,709	1254	£85,593
1898	567	6700	£56,331	£32,608	1149	£75,633
1899	543	6377	£98,581	£30,252	1201	£95,877

In 1899 the number of persons connected with the various branches of the sea fisheries in the district was 3279. A considerable number of new branch railways has been opened since 1875, the total addition to the county mileage being over 60 miles.

AUTHORITIES.—Gammack's edition of JERVISE'S *Memorials of Angus and Mearns.* Edinburgh, 1895.—A. JERVISE. *Land of the Lindsays.* Edinburgh, 1882.—LORD LINDSAY. *Lives of the Lindsays.* London, 1858.—A. JERVISE. *Epitaphs and Inscriptions.* Edinburgh, 1879.—SIR W. FRASER. *History of the Carnegies.* Edinburgh, 1867.—C. ROGERS. *Abbey of Coupar-Angus Rental Book.* London, 1880.—A. H. MILLAR. *Historical Castles and Mansions.* Paisley, 1890.—A. REID. *The Birds of Angus and Mearns.* Paisley, 1897.—J. M. SCOTT. *The Martyrs of Angus and Mearns.* Paisley, 1885.—D. M. PETERS. *Baronage of Angus and Mearns.* Edinburgh, 1885.—G. HAY. *History of Arbroath.* Arbroath, 1876.—D. D. BLACK. *History of Brechin.* Edinburgh, 1867.—DR. CAMPBELL. *Balmerino and its Abbey.* Edinburgh, 1899.—D. MILLER. *Arbroath and its Abbey.* Edinburgh, 1860.

(W. WA.)

Forlì, a town and episcopal see of Italy (Emilia), capital of the province of Forlì, on the Via Emilia, and 40 miles south-east of Bologna by rail. Its principal industries are iron-works, foundries, and silk factories. Further, there are an industrial institute and a technical school. Population: of town (1881), 40,934; (1901), 43,457; of province (1881), 251,110; (1901), 279,072.

Form (in Music).—Every work of art possesses, of necessity, some design by means of which a sense of unity and connexion can be imparted to its different features; the various means by which this sense of unity is arrived at in music are known by the generic name of "form." Certain principles of form are common to all music, but the fully developed scheme on which Haydn, Mozart, and Beethoven wrote their symphonies, sonatas, and quartettes, and which is known as "sonata" or "first movement" form, did not make its appearance until the beginning of the 18th century. Before a form could be invented it was necessary that there should be material worth pouring into the mould. By 1729 the material was ready; Bach had brought melodic and harmonic invention to a pitch which has never been surpassed, and, further, it was Bach who largely helped to establish our present system of key-centres, which enabled musical movements on a large scale to revolve round a definite pivot. It is, therefore, not surprising to find, coincidentally with Bach's death, a sudden development of the "sonata" form.

The origin of this form may be found in the simple formula A, B, A, or statement, variety, and symmetry. But these principles of construction are common to all music; the particular species from which the Beethoven first-movement may be said to have descended is well represented by the tune *Barbara Allen.* This tune is divided into two halves, and these halves again into two sections. The first section consists of a phrase in the tonic, the second of one in the dominant, the third is a free passage leading back to the tonic, and the last is a repetition of the second in the tonic key. The Italian composers, Corelli (*b.* 1653) and Domenico Scarlatti (*b.* 1683), finding the fugue forms of their contemporaries unsuitable to their essentially melodic style, adopted the scheme above described. However, the form of *Barbara Allen* is obviously unsatisfactory when applied to a more extended movement, for the reason that there is no restatement of the first and principal phrase. This defect was remedied by making the third section a repetition, so far as possible, of the first, but modulating from dominant to tonic instead of from tonic to dominant. Meanwhile another development of the original form was growing up, chiefly among the German successors of Bach, such as Krebs (*b.* 1713). This scheme repeats the original subject where it will have its greatest effect, namely, at the return to the tonic key; the third section remains free as in the primitive design, but both first and second sections are repeated in the last quarter of the movement. This scheme was finally established by Emmanuel Bach and perfected by Mozart and Haydn. These two composers are responsible for the development of the third section; even Haydn often treated this part of the movement as a mere episode, having no thematic connexion with the rest of the movement. But already the idea of treating this section as an extension of themes already stated was prevalent. When this part of the movement consisted of the repetition of the first section it had been found necessary to alter and extend it so as to compass the altered modulation, so that the "free" section had already come to be considered a period of development rather than of restatement or digression. The following is an analysis of the "first-movement" form as perfected by Mozart.

1. *Tonic Section.*—A subject in the tonic key called the "first subject," either ending with a half close or followed by a passage leading to the dominant key (or relative major if the first key is minor). This passage is called the "first episode."

2. *Dominant* (or relative major) *Section.*—A subject in this key called the "second subject,"[1] followed by the "second episode," usually of a less melodious character, in which transient modulations sometimes occur. The first half of the movement is brought to a full close in the second key by a short phrase called the "cadence figure" or "codetta."

This half of the movement, consisting of sections 1 and 2, is repeated.

3. *Development Section*, or "Free Fantasia."—This consists of an extension and development of the themes already heard, passing through a definite succession of keys, until the tonic is once more reached.

4. *Recapitulation Section.*—The whole or a part of the first subject and first episode is restated, the latter being altered so as to remain in the tonic. The second subject, second episode, and codetta are also restated in the tonic key. These two sections (Free Fantasia and Recapitulation) are also occasionally repeated and a short coda added. This coda was originally introduced only when the second half of the movement was repeated, but it finally became universal.

In Beethoven's hands this scheme ceased to be an aggregation of items and became a united whole, in which the various sections are so welded together that it is impossible to see the join. He soon discarded the old system of tonic and dominant, and often introduces his second subject in remote keys such as the mediant; further, while he gives each section its relative importance, yet each passage has its own value, and the "padding" of earlier writers disappears. Moreover, though the principle of restatement is still part of his scheme, yet he never degrades it into a mere transcription of notes. But, perhaps, Beethoven's greatest innovation was his extension of the coda. Before his time the coda was little more than a few bars of tonic and dominant to emphasize the key and to avoid the bathos of ending up twice the same way; Beethoven's codas are long perorations, forming a climax to all that has gone before.

[1] Sometimes this is only a new version of the first subject.

The last three movements of a sonata are often written in the same form as the first; indeed, the scherzo (or minuet) and trio are always two short movements in this form, alternating with each other. But the slow movements and finales are often written in the aria, rondo, or variation forms. The Aria form reproduces the formula A, B, A in its simplest form, consisting of a section in one key, an episode in another, and a restatement of the original section with or without a coda. The Rondo is an extension of the aria. A musical paragraph is repeated several times, an episode intervening between each repetition. This form remained somewhat bald and obvious until Beethoven took it in hand. He made it approximate to the first-movement form by making the first episode into a regular second subject, the second episode into a development section, and the third episode into a recapitulation of the second subject. The Variation form requires no explanation from the structural point of view.

Beethoven seems to have brought "sonata form" to its furthest limits of development; even Brahms's innovations are those of style rather than of structure. The immediate successors of Beethoven gave their attention chiefly to poetic and dramatic expression, and invented new forms to suit their needs, but all these forms, whether exemplified by Schumann's *Kinderscenen* or Wagner's prelude to *Tristan und Isolde*, will be found to be ultimately built on the same ground-work as Beethoven's sonatas or *Barbara Allen.* (R. V. W.)

Formosa.—This island, called Taiwan by the Japanese, into whose possession it came after their war with China in 1895, is 225 miles long by from 60 to 80 miles broad, has a coast-line measuring 731 miles, an area of 13,429 miles—being thus nearly the same size as Kiushiu, the most southern of the four chief islands forming the Japanese empire proper—and a population of 2,729,503, and extends from 20° 56′ N. lat. to 25° 15′, and from 120° E. long. to 122°. Along the western coast is a low alluvial plain, not exceeding 20 miles in width at its widest part; on the east coast there is a rich plain called Gilan, and there are also some fertile valleys in the neighbourhood of Kwarenko and Pinan, but the rest of the island is mountainous and covered with virgin forest.

Mountains.—Since Formosa has been added, Fuji-yama ceases to be Japan's highest mountain, and sinks to the place of third on the list. Mount Morrison (14,270 feet) —which the Japanese have re-named *Niitake-yama* (New High Mountain)—stands first, and Mount Sylvia (12,480 feet)—to which they have given the name of *Setzu-zan* (Snowy Mountain) — comes second. Mount Morrison stands nearly under the Tropic of Cancer. It is not volcanic, but consists of argillaceous schist and quartzite. A recent ascent, made by Dr Honda of the Imperial University of Japan, showed that, up to a height of 6000 feet, the mountain is clothed with primeval forests of palms, banyans, cork trees, camphor trees, tree ferns, interlacing creepers and dense thickets of rattan or stretches of grass higher than a man's stature. The next interval of 1000 feet has gigantic cryptomerias and chamœcyparis; then follow pines; then, at a height of 9500 feet, a broad plateau, and then alternate stretches of grass and forest up to the top, which consists of several small peaks. There is no snow. Mount Morrison, being surrounded by high ranges, is not a conspicuous object. Mount Sylvia lies in 24° 30′ N. lat. It has not been ascended by persons competent to give any account of its condition. There are many other mountains of considerable elevation. In the north we have Getsurôbi-san (4101 feet); and on either side of Setzu-zan, with which they form a range running due east and west across the island, are Jusampun-zan (4698 feet) and Hari-zan (7027 feet). Twenty-two miles due south of Hari-zan stands Hakumôsha-zan (5282 feet), and just 20 miles due south of Hakumôsha-zan begins a chain of three peaks, Suisha-zan (6200 feet), Hôo-zan (4928), and Niitake-yama. These five mountains, Hari-zan, Hakumôsha-zan, Suisha-zan, Hôo-zan, and Niitake-yama, stand almost exactly under 121° E. long., and being in the very centre of the island, may be said to form its backbone. Yet farther south, and still lying in line down the centre of the island, are Sankyakunan-zan (3752 feet), Shurôgi-zan (5729 feet), Pôren-zan (4957 feet), and Kadô-zan (9055 feet), and, finally, in the south-east we have Arugan-zan (4985 feet). These, it will be observed, are all Japanese names, and the heights have been determined by Japanese observers. In addition to these remarkable inland mountains, Formosa's eastern shores show magnificent cliff scenery, the bases of the hills on the seaside taking the form of almost perpendicular walls as high as from 1500 to 2500 feet.

Rivers and Lakes.—Owing to the precipitous character of the east coast few rivers of any size find their way to the sea in that direction. The west coast, on the contrary, has many streams, but the only two of any considerable length are the Kotansui, which rises on Shurôgi-zan, and has its mouth at Tôkô after a course of some 60 miles, and the Scira, which rises on Hakumôsha-zan, and enters the sea at a point 57 miles farther north after a course of 90 miles. So far as is known, there are no lakes, but a great part of the interior of the island remains still unexplored.

Climate.—The climate is damp, hot, and malarious. In the north, the driest and best months are October, November, and December; in the south, December, January, February, and March. The sea immediately south of Formosa is the cradle of innumerable typhoons, but the high mountains of the island protect it partially against the extreme violence of the wind.

Towns.—The chief town is Taipeh (called by the Japanese Taihoku), which is on the Tamsui-yei river, and has a population of about 118,000, including 5850 Japanese. Taipeh may be said to have two ports; one, Tamsui, at the mouth of the river Tamsui-yei, 10 miles distant on the north-west coast, the other Kelung (called by the Japanese Kiirun), on the north-east shore, with which it is connected by rail, a run of some 18 miles. The foreign settlement at Taipeh lies outside the walls of the city, and is called Twatutia (Taitotei by the Japanese). Kelung is an excellent harbour, and the scenery is very beautiful. Tamsui (called Tansui by the Japanese) is usually termed Hobe by foreigners. It is the site of the first foreign settlement, has a population of about 7000, but cannot be made a good harbour without considerable expenditure. On the west coast there is no place of any importance until reaching Anping (23° N. lat.), a port where a few foreign merchants reside for the sake of the sugar trade. It is an unlovely place, surrounded by mud flats, and a hotbed of malaria. It has a population of 4000 Chinese and 200 Japanese. At a distance of some 2½ miles inland is the former capital of Formosa, the walled city of Tainan, which has a population of 100,000 Chinese, 2300 Japanese, and a few British merchants and missionaries. Connected with Anping by rail (26 miles) and lying south of it is Takao, a treaty port. It has a population of 6800, and is prettily situated on two sides of a large lagoon. Six miles inland from Takao is a prosperous Chinese town called Fêngshan (Japanese, Hôzan). The anchorages on the east coast are Suo, Kwarenkô, and Pinan, which do not call for special notice. Forty-seven miles east of the extreme south coast there is a little island called Botel-tobago (Japanese, Kôtô-sho), which rises to a height of 1914 feet, and is inhabited by a tribe whose customs differ essentially from those of the natives on the main island.

Administration.—The island is treated as an outlying territory; it has not been brought within the full purview of the Japanese constitution. Its affairs are administered by a governor-general, who is also commander-in-chief of the forces, by a bureau of civil government, and by four prefectural governors; its finances are not included in the general budget of the Japanese empire; it is garrisoned by a mixed brigade taken from the home divisions; its tribunals of justice are organized independently of the system followed in Japan proper; and its currency is on a silver basis. One of the first abuses with which the Japanese had to deal was the excessive use of opium by the Chinese settlers. To interdict the importation of the drug altogether, as is done in Japan, was the step advocated by Japanese public opinion. But, influenced by medical views and by the almost insuperable difficulty of enforcing any drastic import veto in the face of Formosa's large communications by junk with China, the Japanese finally adopted the middle course of licensing the preparation and sale of the drug, and limiting its use to persons in receipt of medical sanction. Steps have been taken also to convert the manufacture and export of camphor into an official monopoly, which is now farmed to a British firm, acting in conjunction with Japanese merchants; and China's example has been followed in the case of salt, transactions connected with that necessary being monopolized by the Government.

Finance.—In 1897, two years after Japan took possession, the revenue collected was $6\frac{1}{2}$ million yen, and the expenditure totalled $16\frac{1}{2}$ millions, independently of military and naval outlays. The deficiency of 10 millions on the side of revenue had to be defrayed by the imperial treasury. In 1900 the revenue collected was 13 million yen, approximately, and the expenditures aggregated 20 millions, but only $2\frac{1}{2}$ millions of the deficit were furnished by the imperial treasury, the remaining $4\frac{1}{2}$ millions being obtained by floating bonds. Over 7 millions of the expenditure was on account of public works, so that the floating of a loan was a legitimate operation. Government industries —that is to say, the monopolies of camphor, salt, and opium, and the working of railways—constituted one of the chief sources of revenue increase, the gross earnings under these headings being $9\frac{1}{4}$ million yen, and the expenditures, $5\frac{1}{2}$ millions. There were also considerable increments in the yield of customs duties and internal taxes, though it may be noted that the whole of the direct taxes levied do not aggregate more than $1\frac{3}{4}$ million yen. Up to the close of 1900, the island had cost Japan 100 millions of yen. The Japanese do not show much inclination to emigrate to Formosa. The number of Japanese residing there is only 9324, and the number that emigrated thither in 1899 was 3850.

Railways.—An extensive scheme of railway construction has been planned, the four main lines projected being (1) from Takow to Tainan; (2) from Tainan to Kagi; (3) from Kagi to Chianghoa; and (4) from Chianghoa to Kelung; these four forming, in effect, a main trunk road running from the south-west to the north-east, its course being along the foot of the mountains that border the western coast-plains. The Takow–Tainan section (26 miles) was opened to traffic on 3rd November 1900, and work on the other sections is progressing. Harbour improvements also are projected, but in Formosa, as in Japan proper, paucity of capital constitutes a fatal obstacle to rapid development.

Foreign Traffic.—The following figures show the state of foreign trade during the three years ended 1899 :—

	Exports.	Imports.	Total.
1897	£1,275,929	£1,265,929	£2,541,858
1898	1,282,718	1,687,919	2,970,637
1899	1,111,492	1,427,309	2,538,801

There are thirteen ports of export and import, but 75 per cent. of the total business is done at Tamsui. Tea and camphor are the staple exports. The greater part of the former goes to Amoy for re-shipment to the West, but it is believed that if harbour improvements were effected at Tamsui so as to render it accessible for ocean-going steamers, shipments would be made thence direct to New York. The camphor trade being now a Government monopoly, the quantity exported is under strict control.

History.—The original inhabitants appear to have come from Malay, and to have settled along the western coast. Towards the close of the 17th century a stream of Chinese immigration set in—Hakkas from Canton and Hoklas from Fohkien—who, dispossessing their semi-savage predecessors, drove them to the thickly wooded hills at the base of the high mountains, or into the still less accessible regions beyond. A more debased population than the peoples thus struggling for supremacy could scarcely be conceived. The aborigines, to whom the Chinese gave the name *Sheng-fan*, or "wild savages," deserved the appellation in some respects, for they lived by the chase and had little knowledge even of husbandry; while the Chinese themselves, uneducated labourers, acknowledged no right except that of might. A long era of conflict ensued between the Chinese and the aborigines. The latter were not implacably cruel or vindictive. They merely clung to their homesteads, and harboured a natural resentment against the raiders who had dispossessed them. Their disposition was to leave the Chinese in unmolested possession of the plain. But some of the most valuable products of the island, as camphor and rattan, are to be found in the upland forests, and the Chinese, whenever they ventured too far in search of these products, fell into ambushes of hill-men who neither gave nor sought quarter, and who regarded a Chinese skull as a specially attractive article of household furniture. Reconciliation never took place on any large scale, though it is true that, in the course of time, some fitful displays of administrative ability on the part of the Chinese, and the opening of partial means of communication, led to the pacification of a section of the *Sheng-fan*, who thenceforth became known as *Pepohoan*, or "civilized aborigines." In 1874 the island was invaded by the Japanese for the purpose of obtaining satisfaction for the murder of a shipwrecked crew who had been put to death by one of the semi-savage tribes on the southern coast, the Chinese Government being either unable or unwilling to punish the culprits. A war was averted through the good offices of the British minister, and the Japanese retired on payment of an indemnity. In 1884, in the course of belligerent proceedings arising out of the Tongking dispute, the forts at Keelung on the north were bombarded by the French fleet, and the place was captured and held for some months by French troops. An attack on the neighbouring town of Tamsui failed, but a semi-blockade of the island was maintained by the French fleet during the winter and spring of 1884–85. The troops were withdrawn on the conclusion of peace in June 1885. In 1895 the island was ceded to Japan by the treaty of Shimonoseki at the close of the Japanese war. The resident Chinese officials, however, refused to recognize the cession, declared a republic, and prepared to offer resistance. It is even said they offered to transfer the sovereignty to Great Britain if that Power would accept it. A formal transfer to Japan was made in June of the same year in pursuance of the treaty, the ceremony taking place on board ship outside Keelung, as the Chinese commissioners did not venture to land. The Japanese were thus left to take possession as best they could, and some four months elapsed before they effected a landing on the south of the island. Takow was bombarded and captured on the 15th October, and the resistance collapsed. Liu Yung-fu, the notorious Black Flag general, and the backbone of the resistance, sought refuge in flight. The general state of the island when the Japanese assumed possession, was that the plain of Gilan on the eastern coast and the hill-districts were inhabited by semi-barbarous folk, the western plains by Chinese of a degraded type, and that between the two there existed a traditional and continuous feud, leading to mutual displays of merciless and murderous violence. By many of these Chinese settlers the Japanese conquerors, when they came to occupy the island, were regarded in precisely the same light as the Chinese themselves had been regarded from time immemorial by the aborigines. Insurrections occurred frequently, the insurgents receiving secret aid from sympathizers in China, and the difficulties of the Japanese being increased not only by their ignorance of the country, which abounds in fastnesses where bandits can find almost inaccessible refuge, but also by the unwillingness of experienced officials to abandon their home posts for the purpose of taking service in the new territory. Gradually, however, the various obstacles are being overcome, and though some years must still elapse before the reign of peace and good order is thoroughly established, all the evidences point to ultimate success. (F. By.)

Formosa, a territory of the Argentine Republic bordering Bolivia and Paraguay. The official area at the census of 1895 was 41,402 square miles, and the population in 1895, 4829. The capital, Formosa, founded in 1879 on the Rio Paraguay, has a population of about 1000. The province is divided into five administrative divisions. In 1895 only 778 acres of land were planted in cereals, but the territory had 41,424 head of cattle.

Forres, a parliamentary burgh (Inverness group). with the privileges of a royal burgh, near the river Findhorn, in the county of Elgin, Scotland, 12 miles west by south of Elgin by rail. It is one of the healthiest spots in Scotland, and has the lowest rainfall in the country. The chief trade is in cattle. Industries are varied, but unimportant. There is a public hall, a museum containing a collection of the Old Red Sandstone fossils of the district, a mechanics' institute, an agricultural hall, market buildings and auction mart, a cottage hospital, and a Nelson Monument (1806). There is a well-endowed secondary school. Population (1881), 4030; (1901), 4313.

Forrest, Sir John (1847——), West Australian statesman and explorer, son of William Forrest, of Bunbury, West Australia, was born at Bunbury, 22nd August 1847, and educated at Perth, W.A. In 1865 he became connected with the Government Survey Department at Perth, and in 1869 led an exploring expedition into the interior in search of D. Leichardt, penetrating through bush and salt-marshes as far inland as 123° E. long. In 1870 he again made an expedition from Perth to Adelaide, along the southern shores. In 1874, with his brother ALEXANDER FORREST (born 1849), he explored eastwards from Champion Bay, following as far as possible the 26th parallel, and striking the telegraph line between Adelaide and Port Darwin; a distance of about 2000 miles was covered in about five months with horses and without carriers, a particularly fine achievement (see AUSTRALIA, *Exploration*). John Forrest also surveyed in 1878 the north-western district between the rivers Ashburton and Lady Grey, and in 1882 the Fitzroy district. In 1876 he was made deputy surveyor-general, receiving the thanks of the colony for his services and a grant of 5000 acres of land; for a few months at the end of 1878 he acted as commissioner of Crown lands and surveyor-general, being given the full appointment in 1883, and retaining it till 1890. When the colony obtained in 1890 its constitution of self-government, Mr Forrest (who was knighted in 1891) became its first premier, and for ten years held that position, his influence in West Australia being one of an almost autocratic character, owing to the robust vigour of his personality and his success in enforcing his views (see WEST AUSTRALIA, *History*). In 1877 he was made a member of the Privy Council. Sir John Forrest married in 1876 Margaret Hamersley. He has published *Explorations in Australia* (1876) and *Notes on Western Australia* (1884–87).

Forssell, Hans Ludvig (1843–1901), Swedish historian and political writer, the son of Adolf Forssell, a distinguished mathematician, was born at Gefle, where his father was professor, on 14th January 1843. At the age of sixteen he became a student in Upsala University, where he distinguished himself, and where, in 1866, having taken the degree of doctor, he was appointed reader in history. At the age of thirty, however, Forssell, who had already shown remarkable business capacity, was called to Stockholm, where he filled one important post after another in the Swedish civil service. In 1875 he was appointed head of the Treasury, and in 1880 was transferred to the department of Inland Revenue, of which he continued to be president until the time of his death. In addition to the responsibilities which these offices devolved upon him, Forssell was constantly called to serve on royal commissions, and his political influence was immense. In spite of all these public duties, which he carried through with the utmost diligence, Forssell also found leisure for an abundant literary activity. Of his historical writings the most important were: *The Administrative and Economical History of Sweden after Gustavus I.* (1869–75) and *Sweden in 1571* (1872). He was also for several years, in company with the poet Wirsén, editor of the *Swedish Literary Review.* He published two volumes of *Studies and Criticisms* (1875, 1888). In the year 1881, at the death of the historian Anders Fryxell, Forssell was elected to the vacant seat on the Swedish Academy. The energy of Forssell was so great, and he understood so little the economy of strength, that he unquestionably overtaxed his vital force. His death however, which occurred with great suddenness on the 2nd of August 1901, while he was staying at San Bernardino in Switzerland, was wholly unexpected. There was little of the typical Swedish urbanity in Forssell's exterior manner, which was somewhat dry and abrupt. Like many able men who have from early life administered responsible public posts, there appeared a certain want of sympathy in his demands upon others. His views were distinct, and held with great firmness; for example, he was a free-trader, and his consistent opposition to what he called "the new system" had a considerable effect on Swedish policy. He was not exactly an attractive man, but he was a capable, upright, and efficient public servant. In 1867 he married Miss Zalamith Emeroth, a daughter of the well-known pomologist of Upsala; she survived him, with two sons and two daughters. (E. G.)

Forst, a town of Prussia, on the Görlitzer Neisse, 13 miles east by south of Cottbus by rail, in the circle of Sorau, Government district of Frankfurt. It has 2 Evangelical, an Old-Lutheran, a Catholic, and an Apostolic churches, a progymnasium with *real* progymnasium, a higher-grade girls' and a burgher school, and over 100 woollen cloth and buckskin factories. Population (1890), 23,539; (1900), 32,075.

Forster, John Cooper (1823–1886), British surgeon, was born in 1823 in Lambeth, London, where his father and grandfather before him had been local medical practitioners. He entered Guy's Hospital in 1841 (M.R.C.S., 1844; F.R.C.S., 1849) was appointed demonstrator of anatomy in 1850, assistant-surgeon 1855, and surgeon 1870. In 1884 he became president of the College of Surgeons. He was a prompt and sometimes bold operator. In 1858 he performed practically the first gastrostomy in England for a case of cancer of the œsophagus. Among his best-known papers were discussions of acupressure, syphilis, hydrophobia, intestinal obstruction, modified obdurate hernia, torsion, and colloid curve of the large intestine; and he published a book on *Surgical Diseases of Children* in 1860, founded on his experience as surgeon to the Hospital for Children and Women in Waterloo Road. He died suddenly in the south of France in March 1886.

Forster, William Edward (1818–1886), British statesman, was born of Quaker parents at Bradpole in Dorsetshire, 11th July 1818. He was educated at the Friends' school at Tottenham, where his father's family had long been settled, and on leaving school he was put into business. He declined, however, on principle to enter a brewery. Becoming in due time a woollen manufacturer in a large way at Bradford, Yorkshire (from which after his marriage he moved to Burley-in-Wharfedale), he soon made himself known as a practical philanthropist. In 1846–47 he accompanied his father to Ireland, as distributor of the Friends' relief fund for the famine in Connemara, and the state of the country made a deep impression on him. In 1849 he wrote a preface to a new edition of Clarkson's *Life of William Penn*, defending the Quaker statesman against Macaulay's criticisms. In 1850 he married Jane Martha, eldest daughter of the famous Dr Arnold of Rugby. She was not a Quaker, and her husband was formally excommunicated for marrying her, but the Friends who were commissioned to announce the sentence "shook hands and stayed to luncheon." Forster thereafter ranked himself as a member of the Church of England, for which, indeed, he was in later life charged with having too great a partiality. There were no children of the marriage, but when Mrs Forster's brother, William Arnold, died in 1859, leaving four orphans, the Forsters adopted them as their own. One of these children was Mr H. O. Arnold-Forster, afterwards M.P. and secretary to the Admiralty.

Mr Forster gradually began to take an active part in public affairs by speaking and lecturing. In 1858 he gave a lecture before the Leeds Philosophical Institution on "How we Tax India." In 1859 he stood as Liberal candidate for Leeds, but was beaten. But he was highly esteemed in the West Riding, and in 1861 he was returned unopposed for Bradford. In 1865 (unopposed) and 1868 (at the head of the poll) he was again returned. He took a prominent part in Parliament in the debates on the American Civil War, and in 1868 was made under-secretary for the Colonies in Earl Russell's ministry. It was then that he first became a prominent advocate of Imperial federation. In 1866 his attitude on parliamentary reform attracted a good deal of attention. His speeches were full of knowledge of the real condition of the people, and contained something like an original programme of Radical legislation. "We have other things to do," he said, "besides extending the franchise. We want to make Ireland loyal and contented; we want to get rid of pauperism in this country; we want to fight against a class which is more to be dreaded than the holders of a £7 franchise—I mean the dangerous class in our large towns. We want to see whether we cannot make for the agricultural labourer some better hope than the workhouse in his old age. We want to have Old England as well taught as New England." In these words he heralded the Education campaign which occupied the country for so many years afterwards. Directly the Reform Bill had passed, the necessity of "inducing our masters to learn their letters" (in Robert Lowe's phrase) became pressing. Mr Forster and Mr Cardwell, as private members in opposition, brought in Education Bills in 1867 and 1868; and in 1868, when the Liberal party returned to office, Mr Forster was appointed vice-president of the Council, with the duty of preparing a Government measure for national education. The Elementary Education Bill (see Education) was introduced on 17th February 1870. The religious difficulty at once came to the front. The Manchester Education Union and the Birmingham Education League had already formulated in the provinces the two opposing theories, the former standing for the preservation of denominational interests, the latter advocating secular rate-aided education as the only means of protecting Nonconformity against the Church. The Dissenters were by no means satisfied with Forster's "conscience clause" as contained in the Bill, and they regarded him, the ex-Quaker, as a deserter from their own side; while they resented the "25th clause," permitting school boards to pay the fees of needy children at denominational schools out of the rates, as an insidious attack upon themselves. By the 14th of March, when the second reading came on, the controversy had assumed threatening proportions; and Mr Dixon, the Liberal member for Birmingham and chairman of the Education League, moved an amendment, the effect of which was to prohibit all religious education in board schools. The Government made its rejection a question of confidence, and the amendment was withdrawn; but the result was the insertion of the Cowper-Temple clause as a compromise before the Bill passed. Extremists on both sides abused Forster, but the Government had a difficult set of circumstances to deal with, and he acted like a prudent statesman in contenting himself with what he could get. An ideal Bill was impracticable; it is to Forster's enduring credit that the Bill of 1870, imperfect as it was, established at last some approach to a system of national education in England without running absolutely counter to the most cherished English ideas and without ignoring the principal agencies already in existence.

Forster's next important work was in passing the Ballot Act of 1872, but for several years afterwards his life was uneventful. In 1874 he was again returned for Bradford, in spite of Dissenting attacks, and he took his full share of the work of the Opposition Front Bench. In 1875, when Mr Gladstone "retired," he was strongly supported for the leadership of the Liberal party, but declined to be nominated against Lord Hartington. In the same year he was elected F.R.S., and made Lord Rector of Aberdeen University. In 1876, when the Eastern question was looming large, he visited Servia and Turkey, and his subsequent speeches on the subject were marked by studious moderation, distasteful to extremists on both sides. On Mr Gladstone's return to office in 1880 he was made

Chief Secretary for Ireland, with Lord Cowper as Lord-Lieutenant. He carried the Compensation for Disturbance Bill through the Commons, only to see it thrown out in the Lords, and his task was made more difficult by the agitation which arose in consequence. During the gloomy autumn and winter of 1880–81, Forster's energy and devotion in grappling with the situation in Ireland (see IRELAND) were indefatigable, his labour was enormous, and the personal risks he ran were many; but he enjoyed the Irish character in spite of all obstacles, and inspired genuine admiration in all his coadjutors. On 24th January 1881 he introduced a new Coercion Bill in the House of Commons, to deal with the growth of the Land League, and in the course of his speech declared it to be "the most painful duty" he had ever had to perform, and one which would have prevented his accepting his office if he had known that it would fall upon him. The Bill passed, among its provisions being one enabling the Irish Government to arrest without trial persons "reasonably suspected" of crime and conspiracy. The Irish party used every opportunity in and out of Parliament for resenting this Act, and Forster was kept constantly on the move between Dublin and London, conducting his campaign against crime and anarchy and defending it in the House of Commons. His scrupulous conscientiousness and anxiety to meet every reasonable claim availed him nothing with such antagonists, and the strain was intense and continuous. He was nicknamed "Buckshot" by the Nationalist press, on the supposition that he had ordered its use by the police when firing on a crowd. On 13th October Mr Parnell was arrested, and on the 20th the Land League was proclaimed. From that time Forster's life was in constant danger, and he had to be escorted by mounted police when he drove in Dublin. Early in March 1882 he visited some of the worst districts in Ireland, and addressed the crowd at Tullamore on the subject of outrages, denouncing the people for their want of courage in not assisting the Government, but adding, "whether you do or not, it is the duty of the Government to stop the outrages, and stop them we will." Forster's pluck in speaking out like this was fully appreciated in England, but it was not till after the revelations connected with the Phoenix Park murders that the dangers he had confronted were properly realized and it became known that several plans to murder him had only been frustrated by the merest accidents. On 2nd May, Mr Gladstone announced that the Government intended to release Mr Parnell and his fellow-prisoners in Kilmainham, and that both Lord Cowper and Mr Forster had in consequence resigned; and the following Saturday Forster's successor, Lord Frederick Cavendish, was, with Mr Burke, murdered in Phoenix Park. It was characteristic of the man that Forster at once offered to go back to Dublin temporarily as Chief Secretary, but the offer was declined. His position naturally attracted universal attention towards him, particularly during the debates which ensued in Parliament on the "Kilmainham Treaty." But Mr Gladstone's influence with the Liberal party was paramount, in spite of the damaging appearance of the compact made with Parnell, and Forster's pointed criticisms only caused thoroughgoing partisans to accuse him of a desire to avenge himself. It was not till the next session that he delivered his fiercest attack on Parnell in the debate on the Address, denouncing him for his connexion with the Land League, and quoting against him the violent speeches of his supporters and the articles of his newspaper organs. It was on this occasion that Parnell, on Forster's charging him, not with directly planning or perpetrating outrages or murder, but with conniving at them, ejaculated "It's a lie"; and, replying on the next day, the Irish leader, instead of disproving Forster's charges, bitterly denounced his methods of administration. Though, during the few remaining years of his life, Forster's political record covered various interesting subjects, his connexion with these stormy times in Ireland throws them all into shadow. He died on 6th April 1886, on the eve of the introduction of the Home Rule Bill, to which he was stoutly opposed. In the interval there had been other questions on which he found himself at variance with Gladstonian Liberalism, for instance, as regards the Sudan and the Transvaal, nor was he inclined to stomach the claims of the Caucus or the Birmingham programme. When the Redistribution Act divided Bradford into three constituencies, Forster was returned for the Central division, but he never took his seat in the new Parliament.

Forster, like John Bright, was an excellent representative of the English middle-class in public life. Patriotic, energetic, independent, incorruptible, shrewd, fair-minded, he was endowed not only with great sympathy with progress, but also with a full faculty for resistance to mere democraticism. He was tall (the Yorkshiremen called him "Long Forster") and strongly though stiffly built, and, with his simple tastes and straightforward manners and methods, was a typical North-country figure. His oratory was rough and unpolished, but full of freshness and force and genuine feeling. It was Forster who, when appealing to the Government at the time of Gordon's danger at Khartum, spoke of Mr Gladstone as able "to persuade most people of most things, and himself of almost anything," and though the phrase was much resented by Mr Gladstone's *entourage*, the truth that underlay it may be taken as representing the very converse of his own character. His personal difficulties with some of his colleagues, both in regard to the Education Act of 1870 and his Irish administration, must be properly understood if a complete comprehension of his political career is to be obtained. For an account of them we need only refer to the *Life of the Right Hon. W. E. Forster*, by Sir T. Wemyss Reid (Chapman & Hall), an admirable and sympathetic biography. (H. CH.)

Fort Dodge, capital of Webster County, Iowa, U.S.A., on Des Moines River, at an altitude of 1015 feet. It is at the intersection of four railways, the Chicago, Rock Island, and Pacific, the Illinois Central, the Minneapolis and St Louis, and the Mason City and Fort Dodge. It is the centre of a rich farming country, and enjoys a large trade as a supply and distributing point. Population (1880), 3586; (1890), 4871; (1900), 12,162, of whom 1832 were foreign-born, and 112 negroes.

Fort Donelson, Tennessee, U.S.A., a post erected by the Confederates during the Civil War, on the left bank of Cumberland River, 40 miles above its mouth, for the control of its navigation. It was taken by the Union forces under General Grant, on 16th February 1862, after a severe battle, in which each side lost about 2000 men. Some 14,000 Confederate troops were surrendered, besides large stores and munitions of war.

Fort Fisher, an earthwork constructed during the Civil War by the Confederates to defend the entrance to Cape Fear River below Wilmington, North Carolina, U.S.A. Being the chief defence of the city of Wilmington, which was then the principal port of blockade-runners, it was necessary to reduce it. This was finally accomplished by a combined land and naval attack on 15th January 1865, but at a loss to the Union forces of about 1000 men in killed, wounded, and missing. The Confederates lost about 2500 men, of whom 500 were killed or wounded.

Fort Madison, capital of Lee County, Iowa, U.S.A., on the western bank of the Mississippi river, at an altitude of 522 feet. It has three railways—the Atchison, Topeka, and Santa Fé; the Chicago, Burlington, and Quincy; and the Chicago, Fort Madison, and Des Moines. It contains the works of the first named of these lines, besides meat-packing houses and manufactories of agricultural implements. The city is on the site of a fort built in the early part of the century. Population (1880), 4679; (1890), 7901; (1900), 9278, of whom 1025 were foreign-born, and 230 negroes.

Fort Scott, capital of Bourbon County, Kansas, U.S.A., in 37° 50′ N. and 94° 42′ W., on the Marmaton river, which here is not navigable, at an altitude of 800 feet. Its site is a level plain, and the plan is regular. It is the point of intersection of the Kansas City, Fort Scott, and Memphis, the Missouri, Kansas, and Texas, and the Missouri Pacific railways, and has in consequence great traffic. Population (1880), 5372; (1890), 11,946; (1900), 10,322, of whom 474 were foreign-born, and 1205 negroes.

Fort Smith, capital of Sebastian County, Arkansas, U.S.A., in 35° 23′ N. and 94° 26′ W., on the south bank of the Arkansas river, at an altitude of 421 feet. It has a level site on the river bank, but the street plan is irregular. It is divided into five wards, and is on four railways, the St Louis, Iron Mountain, and Southern, the St Louis and San Francisco, the Port Arthur, and the Arkansas Central. It occupies a commanding position for trade, and for a time had a rapid growth. Population (1880), 3099; (1890), 11,311; (1900), 11,587, of whom 684 were foreign-born, and 2407 negroes.

Fort Sumter, an old military post in the harbour of Charleston, South Carolina, U.S.A. It is on a shoal at the entrance to the inner harbour, and is famous principally because of the Confederate attack on it, 12th April 1861, which opened the Civil War. It was surrendered to the Confederates on 14th April, the garrison, under the command of Major Robert Anderson, marching out with the honours of war. It was bombarded and assaulted by the Northern troops later, but was not captured until the fall of Charleston in February 1865.

Fort Wayne, capital of Allen County, Indiana, U.S.A., in 41° 05′ N. lat. and 85° 04′ W. long., where the junction of the St Mary and the St Joseph form the Maumee, at an altitude of 778 feet. The city is divided into ten wards. Its site is level, the street plan regular, and the streets are well paved, largely with brick and asphaltum, and there is a good water supply. It is a railway centre of importance, no fewer than seven railways passing through it or terminating here, and giving the city a trade in all directions. Its manufactures are in great portion connected with railway transportation, since several of its railways maintain car shops here. The capital invested in manufactures in 1890 was $7,000,000, employing 6000 hands, and with a product valued at $9,300,000. Of this, $1,726,117 consisted of car construction and repair. The value of foundry and machine shop products was $1,866,467. The assessed valuation of real and personal property, on a basis of about 70 per cent. of the full value, was, in 1900, $23,984,540, the net debt of the city was but $658,165, and the rate of taxation $21·20 per $1000. Population (1880), 26,880; (1890), 35,393; (1900), 45,115, of whom 6791 were foreign-born, and 276 negroes.

Fort William, the principal town of Thunder Bay district, Ontario, Canada, 426 miles (by rail) E.S.E. of Winnipeg, on the Kaministiquia river, about a mile from its *débouchement* into Lake Superior. It will be the eastern terminus of the Canadian Northern transcontinental railway, and is the western terminus of two steamship lines. It contains large grain elevators with a capacity of 5,250,000 bushels, railway repair shops, and docks, and has a large export trade in grain and other farm produce. The total shipping for the year 1899–1900 was 605 vessels, with a tonnage of 757,204 tons; exports, $3,671,154; imports, $1,164,482. Population (1901), 4800.

Fort Worth, capital of Tarrant County, Texas, U.S.A., in 32° 45′ N. and 97° 20′ W., on the south bank of the West Fork of Trinity River, at an altitude of 600 feet. The site of the city is level, the street plan is regular, and the streets are macadamized. The city is divided into six wards, and has a water supply owned and operated by it. Eight railways enter it from all sides, giving it great commercial importance far beyond its importance as a manufacturing city. In 1890 there was invested in manufactures a capital of $3,194,032, employing 2743 hands, with products valued at $6,826,083. These are of varied character, the principal being flour. Fort Worth is the seat of Fort Worth University and of the Polytechnic College, both Methodist-Episcopal institutions. The former, founded in 1881, had, in 1899, 31 instructors and 393 students, the majority of whom were in the preparatory department. The latter, founded in 1891, had, in 1899, 14 instructors and 308 students, also mainly in the preparatory department. The assessed valuation of property, real and personal was, in 1898, $15,099,720; the net debt of the city was $1,969,512; and the rate of taxation was $25·50 per $1000. Population (1880), 6663; (1890), 23,076; (1900), 26,688, of whom 1793 were foreign-born, and 4249 negroes.

Fortaleza, a town of Brazil, known to foreigners as Ceará, and capital of the State of Ceará. Population, 48,000. It is a well laid out and well built city. It is the principal port of export of the products of the State, these consisting principally of rubber, vegetable-wax (camauba), coffee, sugar, cotton, rum, rice, beans, fruits, hides, &c. It has a railway running to Quixeramobim-Quizada, 177 miles.

Forth, The, a river and firth of Scotland, measuring from the confluence of its two sources above Aberfoyle to the German Ocean 103⅗ miles. The steam ferries have been largely superseded by the opening of the Forth Bridge. The fall of the Tay Bridge in 1879 caused the suspension bridge commenced at Queensferry in 1878 to be abandoned; but in 1882 the work of spanning the river was again authorized by Parliament, and was undertaken at the same spot by the Forth Bridge Railway Company, formed by the Great Northern, North-Eastern, Midland, and North British companies. The bridge, which is constructed of Siemens-Martin steel, was built on the cantilever system. There are three main piers, each having a height of about 360 feet above high water, the small island of Inchgarvie forming the foundation for the central one. The clear distance between the piers is 1710 feet, and a headway at high water of 150 feet for a distance of 500 feet is given at the central portion of each span. The short arms of the cantilevers on the northern and southern shores are 680 feet long, and beyond this the bridge is continued on each side of the river by means of a viaduct. The engineers in chief were Sir John Fowler and Sir Benjamin Baker, and the principal contractor was Sir William Arrol. The work, including the approach railways, cost approximately £3,000,000, and the bridge was opened in March 1890. The river is also spanned by a railway bridge at Alloa.

FORTIFICATION.

1. Field.

Modern military history shows clearly the constant increase in the value of extemporized field defences; yet in spite of this, little real interest has been taken in the subject. The lesson of the American Civil War, that a line of trenches defended by two ranks of men with rifles could not be carried by direct attack, seemed to come as a fresh surprise with each succeeding war, until it was finally taught at Plevna. Even after this, although the European nations began to provide their troops with portable entrenching tools, little attempt was made to turn them to practical use. Such attempts would probably have shown that in the endeavour to avoid encumbering armies with transport for entrenching tools, an unsatisfactory compromise had been arrived at, since no portable tool, small enough to be constantly carried by the soldier, is of any practical use for entrenching, except in the very lightest soil. In the quiet years which followed 1877, and amid the babel of speculation as to the effect of the constant improvements in firearms, the old lesson began to be forgotten. Many voices were raised against the use of field defences, on the grounds that, as at Plevna, they led to strategical mistakes; that the use of stationary defences could not be reconciled with the rapidity of manœuvre which had now become the sole essential; and that troops could not remain in shelter trenches under the fire of modern artillery. Meanwhile, by constant improvements, the effectiveness of guns and rifles against troops in the open was steadily being increased. At the same time, on account of flatter trajectories, the increased tendency to ricochet, and in the British service the abandonment of common shell for field guns, their power against earthworks was if anything diminishing, and the introduction of smokeless powder gave the advantage of concealment to troops and guns behind cover, as against those advancing across the open. These considerations, added to previous experience, might have made it clear that in future wars field defences properly conceived and skilfully planned would be more effective than ever.

The South African War should set these questions at rest, and when its lessons have been fully learnt there can be no doubt that the use of entrenchments will rank as one of the first necessities of warfare. This use will be extended to the attack. The direct attack will seldom be attempted, and the endeavour of the assailant will be to outflank the defender. Since it is clear that a small force entrenched can resist the attack of a stronger one, it is open to the attack to leave a weak force entrenched in front of the enemy's main position, while endeavouring to get round his flank. The defence may reply in the same way, and the question will be which side shall be quickest in extending and pushing forward its flank works. In such a contest, mobility will be of the greatest importance. Such is the disparity of strength between the attack and the entrenched defence, that under certain conditions of ground it is even conceivable that the weaker force might surround and imprison the stronger. If a frontal attack is unavoidable, the assaulting troops, when checked within a certain distance of the position, should not retire, but hold on to what they have gained, extemporizing such cover as they can; and at nightfall entrench themselves there. By this means a secure position will be established close up to that of the enemy, and more troops can be collected there. If it is not close enough, a further advance may be made by night, or saps may be pushed forward until the distance will allow of a bayonet rush.

The methods of field fortification which prevailed till some years after the Franco-German War were practically those of the beginning of the 19th century. Since then they have been very much simplified. For instance, "lines of redans" or "lines *en crémaillère*," and redoubts of intricate design, are no longer contemplated in practice, though still found in many text-books. The refinements of these works belonged to the period of short-range weapons.

In order to understand present ideas, it is necessary first of all to know what are the powers of existing guns and rifles.

Artillery.—Field artillery projectiles may be roughly divided into two classes: shrapnel and common shell. The bullets of

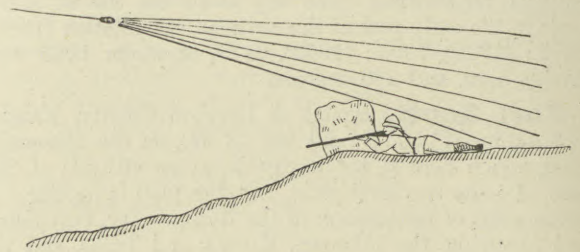


Fig. 1.

the former depend for their destructive power on the remaining velocity of the shell at the time when it is burst; the fragments of the latter are driven by the bursting charge of the shell. It follows that shrapnel bullets always fly forward, forming what is called a "cone of dispersion" about the line of flight of the shell. At a long range, when the shell falls at a steep angle, shrapnel bullets have not enough velocity to be effective. It is usually taken that the steepest slope of effective shrapnel is about one in three ($\frac{1}{3}$). Thus a man lying behind a boulder 3 feet high (see Fig. 1) would be protected against a shrapnel bullet; similarly a man in the trench shown in Fig. 2 would be safe.

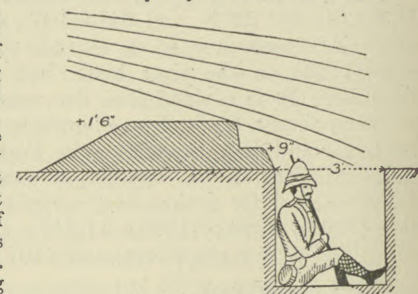


Fig. 2.

Common shell, if burst in the air, retain some forward velocity, but have more lateral spread than shrapnel. If burst on the ground the splinters may fly in any direction. They have more searching power than shrapnel, as will be seen from Fig. 3, but it is more difficult to time them properly.

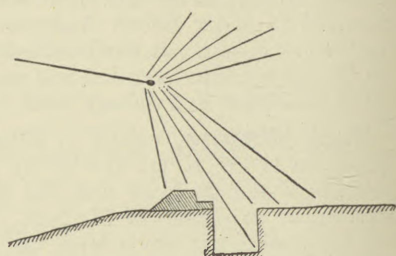


Fig. 3.

Howitzers usually fire common shell with percussion fuse. The effect of a high explosive bursting charge, as compared with gunpowder, is to give a more powerful shock of discharge, to break the shell into more splinters, and drive them harder. It also gives off poisonous fumes. A shell bursting in the trench, as in Fig. 4, would rake it from end to end; but

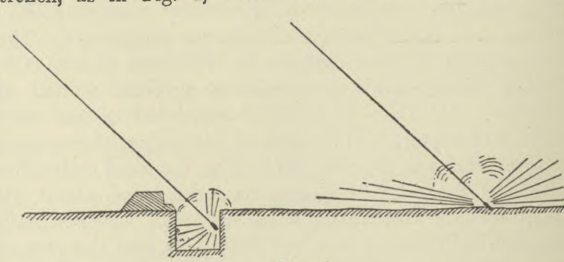


Fig. 4.

it will be observed that, in order to get its effect, it must fall *in* the trench.

The penetrative power of shrapnel bullets and of splinters is slight; from 6 inches to 1 foot of earth will suffice to keep out either.

Rifles.—Small-bore rifles depend for effect on their penetration, their trajectory being so flat that at ordinary ranges they have practically no searching power. A penetration table for the Lee-Enfield rifle is given below. It is much the same as that for other small-bore rifles.

Material.	Earth Un-rammed.	Sand.	Brick-work.	Soft Wood (Fir).	Hard Wood (Oak).	Hardened Steel Plate.	Fine Shingle in Boxes.
Maximum observed penetration (inches).	22	18	4½	42	24	$\frac{5}{16}$	4

It follows from the above, that in order to have protection against artillery fire, men must be close behind the covering parapet; and the parapet should not be less than 2 feet thick at the top (if of earth) to keep out rifle bullets. Overhead cover, when provided, against shrapnel and splinters, should consist of 6 inches to 1 foot of earth. No extemporized cover will keep out howitzer shell. If time admits, the trench should be deep and wide enough to admit of free passage, without the defenders being seen from the front.

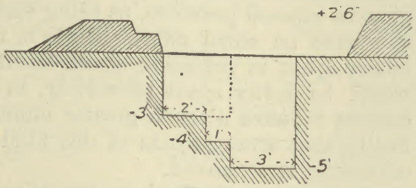


Fig. 5.

These considerations, together with the time, labour, and tools available, determine the section of shelter trenches. Fig. 2 shows the latest pattern of shelter trench adopted in the British service for execution when time presses. It can be made with the small entrenching tool in about three hours in moderately easy soil. This trench might be subsequently enlarged, as shown in Fig. 5.

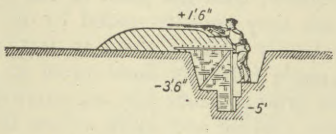


Fig. 6.

Fig. 6 shows how overhead cover might be provided. Such cover requires a large quantity of material, but if it can be made it is very useful, both for protection and shelter. Splinter-proof partitions, as shown in elevation in Fig. 6, are most useful for localizing the effects of shell explosions.

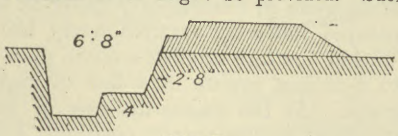


Fig. 7.

Fig. 7 is a German type of shelter trench.

Fig. 8 shows a protected look-out.

Fig. 9 is a section used by the Boers. It gives excellent cover from view, because the defenders' heads have an immediate background, but would not be suitable to most British sites, for want of command.

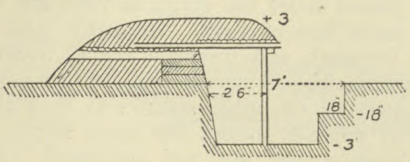


Fig. 8.

All these developments of the simple shelter trench require time, and much labour for the collection of materials; but it must be remembered, that though defences have sometimes to be extemporized in face of the enemy, yet all history shows that occasions have been more frequent when one or two days have been available for preparing a position on some line of advance to which the enemy is committed. (For instance, Deligrad, 1876, Shipka, Magersfontein, and Colenso.) Also as the enemy seldom abandons the assault of a position after the first trial, there is usually time for improvement of the works.

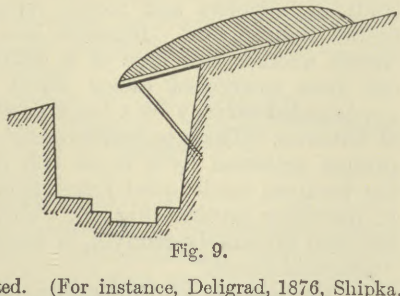


Fig. 9.

Trace or Siting of Trenches.—The system on which trenches are laid out is now much simplified by the fact that the decisive effect of the defenders' fire is obtained several hundred yards to the front. Thus, short faces flanking the front of the trench are not required; though if a cross fire over the front from neighbouring trenches can be arranged, the resistance will be greatly strengthened. The siting of the trenches will depend on the ground. The position generally should be on high ground, both for the sake of a clear view of the enemy's advance, and for concealment of the dispositions of the defence. When the high ground slopes steeply to a level plain, the front trenches may be on the level, and the artillery above them. In this way the trenches may be concealed from the enemy's artillery, and will gain the advantage of a grazing fire over the plain. With this arrangement, and for any position on the forward slope of the hill, the supports (which in any case must be entrenched) must either be very close to the front line, or must

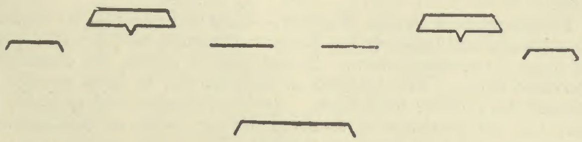


Fig. 10.

have access to it by a connecting trench, or at all events a screen. The reserves would probably have to occupy a second line of defensible trenches. On ground which has few marked features, to take the extreme case, a long straight ridge, narrow or flat at the top, the typical dispositions of the firing line may be divided into three classes, viz. (1) A long straight line of trenches on the forward edge, relying for support on the counter stroke of local reserves; (2) a line of trenches with redoubts among them, as *points d'appui;* (3) groups of trenches, with intervals between them to be defended by the flank trenches of the groups. In this case the nucleus of the group will often be a redoubt.

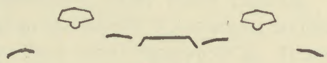


Fig. 11.

It is considered by the Germans that the *redoubt* is a form of work which will not often be used in future. The French (Fig. 10), and Austrians (Fig. 11), on the other hand, prescribe redoubts in connection with wing trenches.

Such simple positions, however, lending themselves to pure theory, will not often occur; especially as cases where the lie of the country more or less prescribes one line of advance for the enemy, will generally be found in rough ground. In broken and hilly ground there will be little choice of position for the trenches. Hills with convex slopes are not very suitable for defence, because the field of fire on the slope is always limited, sometimes dangerously so. Concave slopes, on the other hand, are generally accompanied by very rough ground, which is most suitable for concealment of trenches and reserve troops. They have the drawback that the top of the slope being very steep, troops in that position must expose themselves a good deal in firing upon the attack in its last stages. In defending such ground, the Boers have used trenches in all three of the positions shown at *a*, *b*, and *c* in Fig. 12.

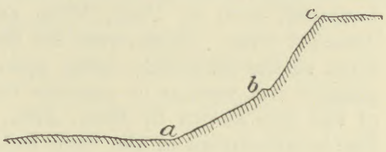


Fig. 12.

Redoubts, if used in connexion with trenches, will generally be of very simple trace adapted to the ground, and their parapets will be of shelter-trench section, so that they may be inconspicuous. In isolated positions, as when they are meant for posts on lines of communication, the parapets must be high enough to screen the interior from view, and a good obstacle must be provided. Guns should not be placed in redoubts. Epaulments may sometimes be provided for them, but concealment is their best protection.

Accidents of Ground.—The right use of these demands both judgment and training. *Hedges* when high and thick enough for concealment will be of great use, especially in connexion with smokeless powder. *Walls*, though penetrable by shells, afford concealment, and give protection against musketry. They may therefore be occupied. They can be made very strong by adding a bank of earth in front of them. *Houses* when in the line of battle are of little use for defence. They will attract artillery fire and become untenable. The ruins may be defended during the last stage of the attack, but it will not be worth while to prepare the house beforehand. The value of *woods* to the defence has altered little. They will still give a measure of defence against artillery fire, and they have the great advantage of concealing the dispositions of the defence. *Villages* are not likely to suffer more than formerly from artillery. High explosive common shell has more destructive but less incendiary power than the old powder shell.

Invisibility.—This is a point to be studied carefully in the arrangement of defence works. Not merely should trenches and other works be concealed by making them like the surrounding ground, with bushes, sods, &c., but marked accidents of the ground should be avoided, such as the meeting line between plough and pasture land, or the meeting of planes of surface of different inclination, where the lights will fall differently. Hedges may be a useful screen for guns, but the guns should be some distance behind them, so that it may be difficult to judge the range.

Obstacles.—Those made by digging should, as a rule, be avoided, on account of the labour involved. Abatis are useful where wood is plentiful, but the obstacle of the future is undoubtedly barbed wire.

Fortification in Savage Warfare.—This will as a rule be confined to obstacles and parapets for defence of camps, and forts for posts on lines of communication. In the case of camps the obstacle is the chief thing. The parapets of forts should be high enough to conceal the interior from view. As the defenders will probably be few, the old methods of flanking defence, such as bastions and caponiers, are sometimes employed. The water supply must be accessible and protected, and all other arrangements made for the comfort of the defenders, who may be shut in perhaps for a week at a time, in a tropical climate. (L. J.)

2. Permanent Land.

Recent years have witnessed extensive changes in the art of permanent fortification owing to the great development of detached forts and entrenched camps. In the early part of the 19th century, detached forts were used to occupy commanding points which were dangerous to the main fortress, but too far from the enceinte to be included in it. After the Crimean War Great Britain surrounded certain fortresses with a ring of detached forts, placed at a sufficient distance to prevent an enemy from bombarding the main position before he had penetrated the line of forts. The fortresses thus became entrenched camps, and the large area thus enclosed was of great value, in giving space to the garrison to manœuvre, and in increasing the length of the enemy's blockading line. At the time of the Franco-German War some of the principal Continental fortresses, such as Paris, Metz, and Antwerp, possessed detached forts. These were for the most part small editions of the fortresses, being open works with a single parapet and bastion or caponier defence for the ditches, of the type shown in *Ency. Brit.*, 9th ed., vol. ix. pl. 7. The bombardment of the Paris forts gave evidence of the increasing power of artillery, and the distance of the forts from the enceinte was increased. At the same time the attention of engineers was concentrated on improving the cover in the interior of the forts. It was sought to accomplish this by making the forts shallower from front to rear, and by making two parapets, one for infantry and one for artillery. In some cases the guns occupied the upper and in some the lower or front parapet. The result of this was to do away with the large open spaces in the interior of the forts, but not much additional cover against descending shells was gained, as the parapets were still open, that is, the guns fired from behind simple parapets without overhead cover.

In 1886, after the introduction of long shells filled with high explosive, some bombarding experiments carried out in France against the old fort of Malmaison made a great impression throughout the Continent. The effect of the powerful shells upon the old-fashioned slight escarps and the casemates covered with about three feet of masonry was immense. The general result was the formation of two opposite schools of thought, whose differences have not yet been reconciled. Most of the old school decided in favour of bomb-proof cover for the guns in the forts. A few, chiefly of the younger engineers, proposed to take the guns out of the forts and work them from concealed positions in the intervals. In any case the majority of the guns would have to be in the intervals for want of space in the forts. So far the bomb-proof school decidedly preponderates on the Continent of Europe, both among theorists and in the designs accepted by Governments.

The advocates of the removal of all the guns maintain that there is no necessary connexion between the artillery and the forts. They argue that the object of the forts is to form a series of secure positions supplying *points d'appui* for the entrenchments of the defence, and that their *rôle* is to maintain themselves, and defend the intervals by flanking fire. It is not necessarily their duty to take part in the distant artillery combat, thereby attracting to themselves the enemy's fire. It is also contended that unprotected guns in concealed positions are safer than protected guns in exposed positions, as being very difficult to locate, and have an equal effect. Thus it is alleged that the money spent in defensive arrangements, such as cupolas, would be better spent offensively, in guns; that cupola defence requires a much greater number of experts; and finally, that arrangements of this kind add greatly to the difficulties of command.

The bomb-proof school, on the other hand, declare that it is essential that there should be some guns in the forts to resist the enemy's guns as soon as they open fire, and before the provisional arrangements of the defence are complete; that the guns in the intervals will not be safe unless they are surrounded by defended ditches, which is practically putting them in forts; that cupolas can now be made perfectly bomb-proof at a moderate cost; and that arrangements for ammunition supply, &c., can be made simpler and more secure in the forts. The latest designs of the German school and of General Brialmont, which are very similar, consist, in their simplest expression, of triangular forts, with ditches flanked by quick-firing guns in counterscarp galleries, and an open infantry parapet following approximately the line of the ditch. Within the fort are half-a-dozen guns and howitzers of $4\frac{1}{2}$ to 6 inches' calibre in a line of cupolas in front of the gorge. At the angles are one or two more guns, and, dispersed in convenient positions, light quick-firing guns to defend the immediate front, all in cupolas. The cupolas are set in heavy masses of concrete. The magazines are under the guns. The infantry casemates are generally placed under the gorge, in rear, and on the flanks of the main line of guns. Germany, Austria, Italy, Belgium, Denmark, and Rumania are all working more or less on these lines. Russia and Japan so far appear to incline towards the other school: so does Holland, on the score of expense, except for coast forts. The latest French designs are not yet published. The most complete examples of recent designs are to be found among the smaller States, which only lately began to build detached forts. The entrenched camps at Bucarest, Liége and Namur, and Copenhagen are all worth study as complete and recent types. Fig. 1 shows a typical Belgian fort. Rumania has, on the line of the Sereth, another new type of a different nature. There are three entrenched camps which have no forts, but are defended entirely by a large number of small groups of batteries. These batteries consist of short lengths of parapet protected by a broad belt of obstacle. Behind the parapets small quick-firing guns are moved about in travelling cupolas (Fig. 2). This system, which has not been favourably received, is known as the system of "armoured fronts."

In the strategy of fortification, the latest theoretical development is the idea of "fortified regions." These would consist of a quadrilateral of entrenched camps occupying important points, some 15 to 20 miles apart, with a central fortress. There would be room for a large army to manœuvre in safety within this region, and as blockade would be impossible, the army could not be shut in, as it might be in an entrenched camp. The advantages of "fortified regions" can, however, only be realized by powerful field armies; and the real question is how far permanent fortification can aid such armies, and whether expenditure should not be devoted to mobile troops rather than to passive expedients. In details of execution, great attention has been paid to various devices for lessening the effect of shells on bombproofs. Masonry constructions are chiefly in concrete. The thickness of casemate arches is from 6 to 10 feet. Revetted escarps are not much used on front faces on account of their liability to be breached. Counterscarps are lower than formerly, and very massive. There is a tendency to do away with deep ditches and substitute broad belts of wire entanglement or thorn plantations. Electric searchlights and armoured observing stations are generally provided. The distance of the detached forts from the fortress varies from 8000 to as much as 18,000 yards. The distance between forts is laid down as about 3000 yards, but varies very much, according to the ground. (L. J.)

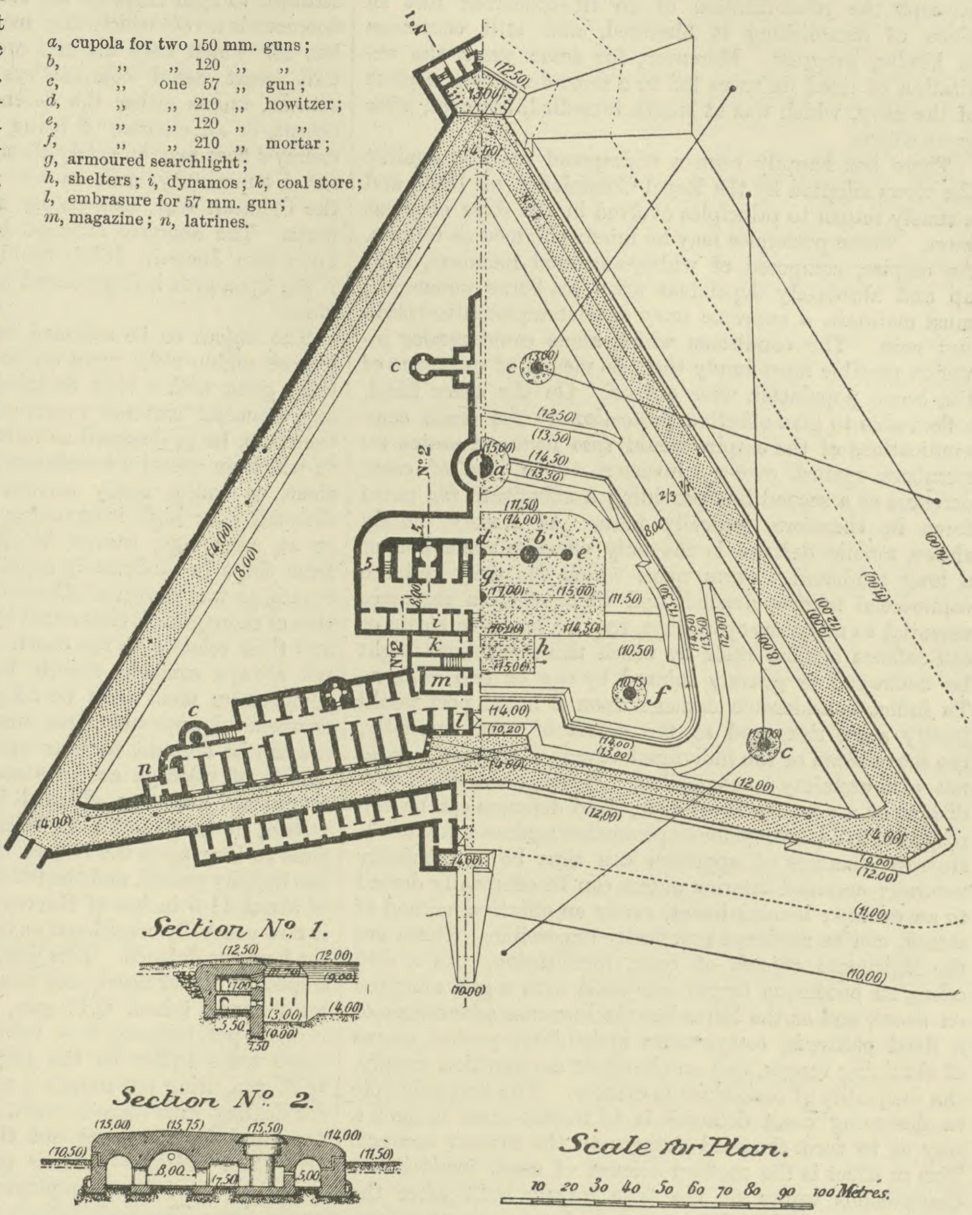


FIG. 1.—Plan and Sections of a Belgian Fort.

3. COAST.

Since about the year 1880 the whole question of coast defence has been the subject of much controversy, out of which certain definite principles are beginning to emerge. The mania for fortification, which gained hold upon Great Britain about the year 1859, produced most unfortunate results. A Royal Commission, appointed to consider and report upon an elaborate series of expensive projects, came to the conclusion that an island state was in some respects more exposed to invasion than one with long land frontiers, and that naval defence could not be trusted, because fleets were liable to be decoyed away when needed, and to be dispersed or rendered ineffective by storms. As a natural consequence, coast fortification usurped a position in the national defences which it had never filled in the past and could not fill in the future. Naval history, naval conditions, and the rich experience of war being alike ignored by the school which attained power, works were designed, and completed after long delay, which were totally unsuited to the purposes for which they were intended. The plain lessons of the Crimean War were unheeded, and monumentalism became the ideal of coast defences, although the performance of the little Telegraph Battery at Sebastopol, confirming much previous experience, should have amply sufficed to moderate the ambitions of military engineers. A false policy having been inaugurated, and the costly erections which it inspired having been begun, it was long before other views could obtain a hearing. Great Britain was thus saddled with

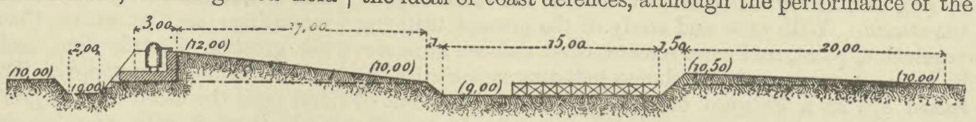


FIG. 2.—Section of Battery for Movable Cupola.

a large number of works which were obsolete before they were begun, and which have since been obstacles to effective coast defence. The natural tendency to attempt the rehabilitation of an ill-conceived fort in place of demolishing it hindered, and still continues to hinder, progress. Moreover, for some years the exaltation of fixed defences led to a most dangerous neglect of the navy, which was at length remedied, however, after great efforts.

There has happily been a widespread reaction against the views adopted by the Royal Commission of 1860, and a timely return to principles evolved in the days of great wars. Those principles may be briefly summed as follows. An empire, composed of widely-scattered members, built up and absolutely dependent upon sea-borne commerce, must maintain a supreme navy or contemplate disruption and ruin. The conditions which alone could render invasion possible must imply that the means of existence of the home population were cut off. On the other hand, a fleet able to give effective protection to the ocean communications of the empire would *ipso facto* guarantee its members against over-sea invasion. The idea of coast defences as a second line providing a substitute for naval force is, therefore, radically false. As history plainly shows, mobile defence is the only effective protection of a long sea-board. Ports upon which the navy and the commercial marine depend, and which contain resources essential to maritime operations, require, however, means of self-defence against raids by which those resources might be destroyed or gravely injured by one or two cruisers. To inflict considerable damage upon a naval port would justify some risk, and at the outset of war especially, the movements of the individual vessels of an enemy could not with certainty be controlled. If the geographical conditions of a port are favourable, fixed defences can be employed with advantage for its protection against naval raids. Narrow channels of approach can thus be economically secured; cramped interior waters can be effectually denied to an enemy; bombardment, rarely an effective method of attack, can be rendered practically impossible. These are the legitimate objects of coast fortification. As a ship offers an enormous target compared with a gun mounted on shore, and as the latter has the immense advantages of a fixed platform, comparative invisibility, perfect means of obtaining ranges, and an abundant ammunition supply, the inequality of conditions is evident. The first principle in designing coast defences is to mount guns in such a way as to turn these advantages to the utmost account. This in effect is the modern science of coast fortification. Conspicuous works of the type largely built after the Crimean War and in defiance of its lessons are, therefore, to be avoided. The object should be to give the guns such dispersion that they can be put out of action only by direct hits, to blend the works in which they are mounted as far as possible with the natural features of the coast line, and to utilize high sites, if such are available, even at some sacrifice of range, in order to increase the accuracy of fire, and at the same time to add to the difficulties of the attack. With care and study of the ground, utilizing vegetation, paint, and even screens, coast defence guns can be in most cases rendered almost indistinguishable by the naked eye at a distance of a mile. At the moment of firing, their positions of course become defined; but the difficulty of locating them sufficiently for accurate laying on board ship may nevertheless be considerable. In selecting sites for shore guns, it is necessary not merely to study the chart, but to take practical navigation into account, and to understand thoroughly what manœuvres a ship can accomplish and what she must perforce avoid. In discussions of questions of coast defence, it is sometimes assumed that attack upon fortified ports is the special and peculiar function of ships of war and the delight of naval commanders. Ships are, however, constructed to fight ships on the sea, and the attack of coast defences is a *rôle* which they may be called upon to play, but for which they are not well fitted. History shows that great naval commanders invariably eschew such attacks, unless either the defences are hopelessly incompetent, or all chances of being brought to action by the enemy's fleet may be safely dismissed. Only overpowering naval superiority, such as was asserted by the Allies in the Crimean War, can justify naval attacks on fortified ports. The abortive attempt by the American squadron upon San Juan in 1898 would have had serious results if the Spaniards had possessed a few well-handled modern guns.

The object to be attained by coast defences is thus to impose undue risks upon an enemy's ships seeking to use their guns with a view to injure a dockyard, shipping, or any essential national resources. The shore guns must, therefore, be so disposed as to bring their fire upon waters in which an enemy's vessels can take up positions enabling them to inflict really serious damage. Unaimed fire, directed over high intervening ground upon a dockyard or an anchorage, cannot be effective, and fire delivered from ships in moderately rapid motion is necessarily inaccurate, as was shown at Alexandria in 1882. The disposition of shore guns is thus noted by natural features of ground and their relation to the chart. The best natural sites do not always conform exactly to the requirements, and a compromise must then be adopted. For the defence of channels of approach sites would be chosen from which fire can be brought to bear upon a ship where the difficulties of pilotage are greatest. Where, as at Malta or Esquimalt, an easy channel leads into sheltered inner waters, it is desirable to bring the fire of two or three guns to bear upon the latter. The craze for monster guns has happily passed, and the 9·2-inch gun, with a penetration of about 11·5 inches of Harveyized armour at 2000 yards, is now generally considered as the largest ordnance required for harbour defence. This gun, as now mounted, will have a speed of fire of nearly one round per minute. The exceedingly handy 6-inch Q.F. gun, with a rate of about five rounds per minute, is a valuable addition, and will in some cases suffice as the staple armament. The 12-pr. Q.F. gun, firing ten rounds a minute, is admirably adapted for dealing with torpedo craft, for clearing the decks and tops, and for searching out the unarmoured portions of any ship. Muzzle-loading guns of old type, specially mounted, have been employed in many cases for high angle fire. The deck attach is naturally attractive, and such guns can be so concealed as to be absolutely secure from all injury. On the other hand, their fire must be directed by position-finders, and is slow and somewhat inaccurate. For convenience of working, it is undesirable to group guns of different types together. Rapid and accurate fire, combined with the highest degree of invisibility attainable, is the best protection of the shore guns. Modern mountings (see ORDNANCE, *Carriages*) are designed to give the greatest possible ease, and convenience of handling, and of ammunition supply. The 9·2-inch gun of 28¼ tons, and even the older 10-inch gun of 32 tons, can be trained and elevated with ease by one man, and in all recent mountings the laying number can work both gears, large movements being performed by alternative under-cover gear. The adoption of auto-sights with telescopes has greatly increased both the accuracy and the speed of coast defence guns. There has been a tendency to over-elaborate the tactical manipulation of coast artillery and to centralize the command of guns. The main requirement is to inflict the maximum number of hits in the shortest time, and auto-sights, together with smokeless powder, enable the gun to resume its individuality of action subject only to general control. Expert gun-layers and well-drilled detachments are thus of cardinal importance, and as a general rule the less interference they receive from any authority other than the battery commander on the spot the better.

Coast defence works are now simple in design, the objects being to merge them in the natural features of the shore line, to protect the vitals of the gun mountings, and to facilitate the supply of ammunition. Great forts, in which it was sought to combine the functions of the coast battery with those of a fortress, are no longer in favour. The self-defence of the coast battery against a landing party must, therefore, depend mainly upon a mobile infantry force, while the battery itself is usually protected by entanglements, sunken unclimbable fences, and machine guns. Mobile infantry garrisons of fortified ports are no new requirement, although this need has frequently been too little regarded. A fort is generally useless outside the *rayon* of its fire, and it may easily become a trap from which escape can be prevented. Even a small landing party, free to act for a short time, can effect much more destruction than any naval fire.

The only effective form of coast protection in the broad sense is that provided by a mobile navy. Naval raids on important harbours must, however, be guarded against by fixed defences, the scale of which can be extremely moderate, provided that guns and works are good, and that well-trained men are available. With such harbour defences, bodies of mobile infantry must be associated. Small fixed defences, armed with thoroughly effective guns, well manned and maintained in complete readiness for war, can fulfil all the requirements of the British empire. Large and costly schemes defeat their proposed objects, and being generally in an incomplete state and frequently undermanned, they are fertile sources of weakness. (G. S. C.)

4. United States.

The manner in which the fortifications of the United States are planned and constructed is controlled by Congress, and is subject to change at any time. At present the work is under the direction of the Secretary of War, certain definite duties being assigned to the different bureaux of the War Department. The selection of the sites to be fortified, the preparation of plans, including the determination of the number, calibre, and mounts of the guns, the construction and repair of the permanent parts of the works, the provision of torpedo material, and the planting and operation of the mine-fields, are part of the duties of the Corps of Engineers of the army; the armament, ammunition, and, in general, the instruments needed for the service of the guns, are procured and distributed by the Ordnance Department of the army; the barracks, quarters and other buildings needed for the garrison, are supplied by the Quartermaster's Department of the army. The works when finished are turned over to the artillery arm of the service. The selection of the types of guns and other implements to be adopted by the Government is entrusted to the Board of Ordnance and Fortification, acting under the control and supervision of the Secretary of War, and consisting now of the commanding general of the army, one officer each from the Corps of Engineers, the Ordnance Department, and the artillery, and one civilian.

The permanent fortifications of the United States have all been built to protect points on the sea-coast or lake frontier against naval attack. The great development on the coast-line renders it out of the question to protect every point at which a hostile landing is possible. The principles which have been kept in view in the defence of the coast were enunciated in 1826 by a Board of Engineers appointed in 1816 to examine the sea-coast, and propose plans for defensive works. The Board held that the means of defence consisted of, 1st, a navy; 2nd, fortifications; 3rd, interior communications by land and water; 4th, a regular army and militia. The duty of the navy was regarded as active and offensive, requiring the aid of fortifications to secure its bases on the coast. The interior communications were considered necessary as means of concentration and supply. The army and militia were held to be the vital principles of the system, and the objects of the fortifications were stated as follows:—

"Fortifications must close all important harbours against an enemy, and secure them to our military and commercial marine; second, must deprive an enemy of all strong positions where, protected by naval superiority, he might fix permanent quarters in our territory, maintain himself during the war, and keep the whole frontier in perpetual alarm; third, must cover the great cities from attack; fourth, must prevent, as far as practicable, the great avenues of interior navigation from being blockaded at their entrances into the ocean; fifth, must cover the coastwise and interior navigation by closing the harbours and the several inlets from the sea which intersect the lines of communication, and thereby further aid the navy in protecting the navigation of the country; and, sixth, must protect the great naval establishments."

These principles indicate the policy which has been followed by the United States in organizing its coast defences.

The early fortifications of the United States are usually considered by engineers as divided into three systems: the first embracing those built before and during the time of the French Revolution of 1789; the second, those built at the approach of the war of 1812; and the third, those built between 1816 and 1866. Works of the first two systems may be found at nearly all of the harbours which were of importance at the beginning of the 19th century. Castle Williams, Fort Lafayette, and others in New York harbour, are examples. Without costly alteration these works would now be useless for purposes of defence. The third system was inaugurated by the Board of Engineers, the report of which has already been quoted. The works belonging to it were of masonry, with exposed scarps on the sea-fronts, and contained usually two tiers of casemates surmounted by an open barbette battery. As examples may be mentioned Fort Warren at Boston, Fort Adams at Newport, and Forts Wadsworth and Schuyler at New York harbour. None of the works of this system as originally constructed could resist naval ordnance of the present day; but many have been retained as part of the modern defences, usually after extensive remodelling. When work ceased on the third system, about a year before the end of the Civil War, it was already out of date. The use of armour on ships of war was recognized at once in the United States, as well as elsewhere, as compelling some corresponding improvement in coast defences. Masonry could no longer be exposed, even on the sea-fronts, and must either be protected or discarded. After the Civil War the construction of a new system of works began, consisting of open barbette batteries, of strong profile, with earth or sand parapets, and thin breast-high walls. The armament was muzzle-loading, and consisted principally of smooth-bore, cast-iron Rodman guns, of 15, 10, and 8 inches' calibre, of 300-pounder, 200-pounder, and 100-pounder rifled Parrot guns, and of 8-inch converted rifles, made from the 10-inch Rodman gun by reboring and inserting a rifled lining tube; and of mortars of 13-inch and lower calibre. No attempt was made to plate or otherwise reinforce the existing masonry works with iron, this subject being left unsettled, pending further experiment and investigation in the United States and elsewhere. Between 1866 and 1875 Congress appropriated a total sum of nearly $11,000,000 for the construction of new works, this sum being in addition to the cost of the armament. At the same time, the development of a torpedo system, which was regarded as an indispensable adjunct to the shore batteries, was receiving constant attention. In 1875 the work of constructing new batteries was suspended. No further funds for this purpose were appropriated until 1890, although the small sums needed for the preservation and repair of the existing works, and for the experiments and work in the development of the torpedo system, were available for all except about two years of this interval. In 1885, after repeated warnings uttered by the military authorities who had the subject in charge, Congress and the people at large awoke to the fact that the power of ships of war had again increased to such an extent as to render the existing defences practically useless. Congress then directed the formation of a Board, to consist of the Secretary of War, two officers each from the Engineer Corps of the army, the Ordnance Corps of the army, and the line of the navy, and two civilians, to examine and report where fortifications were most needed, and what the character of the defences should be. This Board, known as the Endicott Board, submitted its report in January 1886. It named twenty-seven localities, some of which included two or more harbours, which demanded particular attention at the time, and indicated the strength of the high-power armament and the general character of the batteries for each. It proposed the use of armoured turrets, armoured casemates and barbette batteries, aided in some harbours by floating batteries, the last being carefully distinguished from the armoured sea-going ships of the navy. Submarine mines were regarded as "not accessories of the defence, but essential features," and were recommended for use, together with the necessary flanking batteries and search-lights. Movable torpedoes and torpedo-boats were also included in the plans. The guns proposed were 16, 14, 12, 10 and 8 inches in calibre, supplemented by 12- and 10-inch mortars and smaller rapid-fire guns. All were to be modern breech-loading rifles. These recommendations have been followed in a general way in the construction of coast defences since the report; but the details of the work done differ in many respects from those suggested by the Board.

The Endicott Board.

Four years after the report of the Endicott Board had been rendered, Congress began again to appropriate sums for the construction of new fortifications. Between the years 1890 and 1899, both included, a total sum of $20,150,923.93 was allotted for the engineering expenses of building new gun and mortar batteries, while additional sums, aggregating about $7,000,000, were allotted for purchase of sites, for preparation of the submarine mine system, and for certain other purposes connected with the coast defence. The cost of armament and carriages and the necessary ordnance expenses were not included in the amounts named. During the period in question about $26,000,000 was made available for these purposes. The projects in accordance with which the sums thus appropriated have been expended were prepared under the direction of the Chief of Engineers of the army, subject to the approval of the Secretary of War. As a general rule, the preparation of these projects is assigned by the Chief of Engineers to the Board of Engineers, a body composed of officers of the Corps of Engineers, and especially charged, among other duties, with that of planning and revising, as may be directed by the Chief of Engineers, from time to time, projects of permanent fortifications required for the national defence. The annual report for the year 30th June 1899, of the Chief of Engineers, stated that, "Under the general scheme of national defence outlined by the Endicott Board in its report of 16th January 1886, projects for permanent sea-coast batteries have been adopted for thirty localities in the United States, as follows:—

1. Penobscot River, Maine.
2. Kennebec River, Maine.
3. Portland, Maine.
4. Portsmouth, N.H.
5. Boston, Mass.
6. New Bedford, Mass.
7. Narragansett Bay, R.I.
8. Eastern Entrance to Long Island Sound.
9. New York, N.Y.
10. Philadelphia, Pa.
11. Baltimore, Md.
12. Washington, D.C.
13. Hampton Roads, Va.
14. Wilmington, N.C.
15. Charleston, S.C.
16. Port Royal, S.C.
17. Savannah, Ga.
18. St Johns River, Fla.
19. Key West, Fla.
20. Tampa Bay, Fla.
21. Pensacola, Fla.
22. Mobile, Ala.
23. New Orleans, La.
24. Sabine Pass, Texas.
25. Galveston, Texas.
26. San Diego, Cal.
27. San Francisco, Cal.
28. Mouth of Columbia River, Oregon and Washington.
29. Puget Sound, Wash.
30. Lake Champlain.

"The defence of several additional localities in the United States is now under consideration, for which no formal projects have yet been completed, or approved by the Secretary of War. In addition, considerable study has been given during the year to the subject of coast defences for our insular possessions, resulting in the completion of a project of defence for the harbour of San Juan, Puerto Rico, and of preliminary projects for the defence of Honolulu and Pearl Harbour, Hawaiian Islands. . . ."

"Existing approved projects for sea-coast defences contemplate the emplacement of about 500 heavy guns of 8, 10, 12 and 16 inches' calibre, of about 800 rapid-fire guns, and of about 1000 mortars, at an estimated approximate cost for the engineering work of $55,000,000. . . ."

The status of emplacements for which funds have thus far been provided by Congress was as follows at the close of that fiscal year:—

	12-in.	10-in.	8-in.	Rapid-fire.	12-in. mortars.
Guns mounted	27	83	59	46	176
Ready for armament	39	27	25	115	60
Under construction	19	8	10	122	108
Not yet begun	...	...	...	25	...
Totals	85	118	94	308	344

The emplacements enumerated in this table are situated at 77 places, in thirty different harbours. Practically all of those ports for which projects have been prepared have received a portion of the proposed defence, while at the greater part of them a sufficient number of heavy guns and mortars was installed on 30th June 1899, to make a strong resistance against naval attack. The regular appropriations made annually during the last few years, and the extraordinary appropriations made for the national defence at the outbreak of the war with Spain, have enabled the military authorities to make very gratifying progress with the entire scheme, and have encouraged the hope that in a few years it will be complete. The emplacements for which funds were provided on 30th June 1899, will mount guns of six inches' and heavier calibre as shown below:—

Present state.

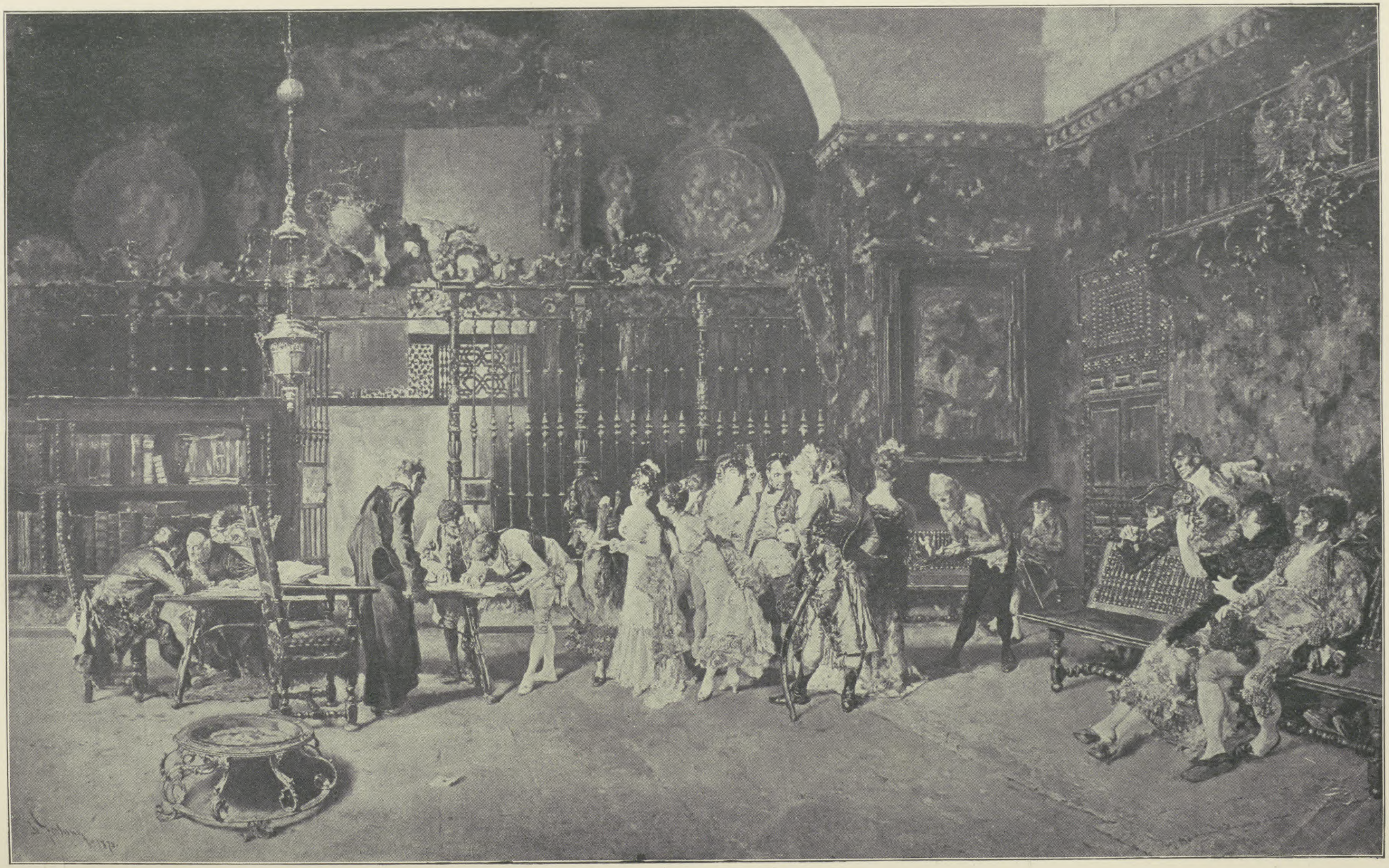
12-in. guns on lift mounts	2
12-in. guns on disappearing carriages	54
12-in. guns on non-disappearing carriages	29
10-in. guns on disappearing carriages	108
10-in. guns on non-disappearing carriages	10
8-in. guns on disappearing carriages	64
8-in. guns on non-disappearing carriages	30
6-in. R.F. guns on disappearing carriages	29
6-in. R.F. guns on non-disappearing carriages	33

The first 12-in. guns to be installed were the two in the lift battery, which was finished in 1895. In this each gun, with its carriage, is mounted on a platform which can be raised and lowered by a direct-acting hydraulic ram. The gun is lowered for loading behind the parapet, which is of sand and concrete, and is then raised by the ram to the firing position. It is fired in barbette, over the parapet. The operations of hoisting the ammunition to the breech of the piece and of ramming are performed by hydraulic power, the water for all of the cylinders being drawn from an accumulator into which it is pumped by steam. The time of ascent or descent of the gun is from 15 to 20 seconds, including the operation of locking the platform. The ammunition-lift is raised in 7 seconds. In a two-gun lift-battery the accumulators can be worked continuously at the rate of two minutes and thirty seconds' interval between shots, for each lift. The cost of the lift battery, as first built, for two guns, was about $455,000, exclusive of the guns. The remaining batteries, mounting guns in barbette on disappearing and non-disappearing carriages, are all of the same general type. The protection is given by a sand parapet in front of a retaining wall of concrete, behind which the guns are mounted. The thickness of the concrete wall in front of the gun is so great that its top forms a sufficient blast slope. Consecutive guns are separated by thick traverses, rising usually only to the level of the interior crest. Ample magazine space is provided, and suitable appliances for hoisting and conveying the ammunition either by hand or by electric power. The guns, as now mounted, are loaded and trained by hand. Experiments have been undertaken to test the advisability of manipulating the guns and carriages by electric power. The batteries are lighted by electricity and have the needful provisions for the installation of range-finding instruments, search-lights, and similar accessories.

The service disappearing carriage now adopted is of the well-known Buffington-Crozier type, the invention of two officers of the Ordnance Department, U. S. Army. By far the greater number of high-power guns in the United States are thus mounted at present, but there is a strong probability that this type of carriage will be less extensively used in the future. In trials for rapidity of fire these carriages have given results as follows:—

8-in. gun, 10 rounds in 12 m. 21 sec.
10-in. gun, 10 rounds in 14 m. 42 sec.
12-in. gun, 10 rounds in 16 m. 57 sec.

The guns were operated and loaded by hand. The trials began with the gun empty, the breech block closed, and the ammunition ready to hand. The mortar batteries mount either 16 or 8 mortars, in four or two pits, containing each four mortars. The pits are protected by a thick sand parapet, held up on the interior by a concrete wall, and are separated from each other by heavy traverses



"THE SPANISH MARRIAGE." BY FORTUNY.

(From a Photograph by J. Lacoste.)

containing bomb-proofs and magazines. In addition to the guns and mortars, batteries mounting one or more pneumatic dynamite guns have been established at San Francisco and Sandy Hook, and are to be placed at Fisher's Island and Port Royal. The heavy guns may be fired either by direct laying by the gunners, or by indirect laying, taking the azimuth and elevation from the position-finding station. The latter method possesses great advantages for the guns mounted on disappearing carriages, or on the gun lift, since the pointing may be done while the gun and detachment are completely covered by the parapet. The mortars are arranged for indirect laying only, the parapet being so high as to conceal the target from the gunner. The batteries have been built in some cases by hired labour, and in others by contract, the former method having given the more satisfactory results. The cost has varied very much, according to the situation. One of the principal items is the concrete, of which a single emplacement, as now built for the different high-power guns on disappearing carriages, contains approximately the following quantity, including magazine, platform, and all accessories :—

For the 12-in. gun . . .	5300 cubic yards.
For the 10-in. gun . . .	3600 cubic yards.
For the 8-in. gun . . .	3200 cubic yards.

The cost of such emplacements, complete, including ammunition lifts and all permanent parts, but not including gun or carriage, may be taken at between $30,000 and $45,000 for one 8-in. gun, between $35,000 and $50,000 for one 10-in. gun, and between $45,000 and $60,000 for one 12-in. gun. There is no marked difference in the cost of the emplacements as built for the disappearing and non-disappearing mounts. Armoured turrets, though contemplated, have not yet been constructed. The torpedo defence, which is regarded as an indispensable part of the general plan, is disposed in accordance with projects prepared in the same way as those for the artillery defence. Each harbour which is protected by land batteries has provision made for one or more mine-fields as well, situated in such manner as to be swept to advantage by the guns on shore. (H. F. H.)

Fortrose, a royal and parliamentary burgh (Inverness group), market town, and fishing port, Inverness-shire, Scotland, $10\frac{1}{2}$ miles N.N.E. of Inverness by rail. A water supply has been introduced, the harbour repaired, a new pier built, whilst a volunteer drill hall, a new academy, and a new United Free church have been erected. The schools include an academy. Population (1881), 874; (1901), 1179.

Fortune, Robert (1813–1880), British botanist and traveller, was born in Berwickshire on 16th September 1813. He was employed in the Botanical Garden at Edinburgh, and afterwards in the Royal Horticultural Society's Garden at Chiswick, and upon the termination of the Chinese War in 1842 was sent out by the Society to collect plants in China. His travels resulted in the introduction to Europe of many beautiful flowers; but another journey, undertaken on behalf of the East India Company, had much more important consequences, occasioning the successful introduction into India of the tea-plant, whose produce now competes so successfully with the tea of China. In subsequent journeys he visited Formosa and Japan, described the culture of the silkworm and the manufacture of rice paper, and introduced many trees, shrubs, and flowers now generally cultivated in Europe. The incidents of his travels were related in a succession of interesting books. He died in London, 13th April 1880.

Fortuny, Mariano Jose Maria Bernardo (1838–1874), Spanish painter, was born at Reus on 11th June 1838. His parents, who were in poor circumstances, sent him for education to the primary school of his native town, where he received some instruction in the rudiments of art. When he was twelve years old his parents died and he came under the care of his grandfather, who, though a joiner by trade, had made a collection of wax figures, with which he was travelling from town to town. In the working of this show the boy took an active part, modelling and painting many of the figures; and two years later, when he reached Barcelona, the cleverness of his handiwork made so much impression on some people in authority there that they induced the municipality to make him an allowance of forty-two francs monthly, so that he might be enabled to go through a systematic course of study. He entered the Academy of Barcelona and worked there for four years under Claudio Lorenzale, and in March 1857 he gained a scholarship that entitled him to complete his studies in Rome. Then followed a period of more than two years, during which he laboured steadily at copies of the old pictures to which he had access at Rome. To this period an end was put by the outbreak of the war between Spain and the emperor of Morocco, as Fortuny was sent by the authorities of Barcelona to paint the most striking incidents of the campaign. The expedition lasted for about six months only, but it made upon him an impression that was powerful enough to affect the whole course of his subsequent development, and to implant permanently in his mind a preference for the glitter and brilliancy of African colour. He returned to Spain in the summer of 1860, and was commissioned by the city of Barcelona to paint a large picture of the capture of the camps of Muley-el-Abbas and Muley-el-Hamed by the Spanish army. After making a large number of studies he went back to Rome, and began the composition on a canvas fifteen metres long; but though it occupied much of his time during the next few years, he never finished it. He busied himself instead with a wonderful series of pictures, mostly of no great size, in which he showed an astonishing command over vivacities of technique and modulations of colour. He visited Paris in 1868, and shortly afterwards married the daughter of Frederigo Madrazo, the Director of the Royal Museum at Madrid. Another visit to Paris in 1870 was followed by a two years' stay at Granada, but then he returned to Rome, where he died somewhat suddenly on 21st November 1874 from an attack of malarial fever, contracted while painting in the open air at Naples and Portici in the summer of 1874.

The work which Fortuny accomplished during his short life is distinguished by a superlative facility of execution and a marvellous cleverness in the arrangement of brilliant hues, but the qualities of his art are those that are attainable by a master of technical resource rather than by a deep thinker. His insight into subtleties of illumination was extraordinary, his dexterity was remarkable in the extreme, and as a colourist he was vivacious to the point of extravagance. At the same time, in such pictures as "La Vicaria" and "Choosing a Model," and in some of his Moorish subjects, like "The Snake Charmers" and "Moors playing with a Vulture," he showed himself to be endowed with a sensitive appreciation of shades of character, and a thorough understanding of the peculiarities of a national type. His love of detail was instinctive, and he chose motives that gave him the fullest opportunity of displaying his readiness as a craftsman.

See Davillier. *Fortuny, sa vie, son œuvre, sa correspondance, &c.* Paris, 1876.—C. Yriarte. *Fortuny* (*Artistes Célèbres* series). Paris, 1889. (A. L. B.)

Fostoria, a city of Seneca County, Ohio, U.S.A., nearly south of Toledo, at an altitude of 773 feet. It has large flour mills and glass-works, the latter being aided by its supply of natural gas. Fostoria is the point of intersection of five railway lines, making it an important railway centre. Population (1880), 3569; (1890), 7070; (1900), 7730, of whom 584 were foreign-born, and 168 negroes.

Fougères, chief town of arrondissement, department of Ille-et-Vilaine, France, 29 miles north-east of Rennes, on railway from Vitré to Mont St Michel. An equestrian statue of General de la Riboisière (died 1812) was erected in 1893, and there is a monument to the soldiers who fell in 1870–71. Population (1881), 13,125; (1891), 16,781; (1901), 20,952.

Fourier's Series are those series which proceed according to sines and cosines of multiples of a variable, the various multiples being in the ratio of the natural numbers; they are used for the representation of a function of the variable for values of the variable which lie between prescribed finite limits. Although the importance of such series, especially in the theory of vibrations, had been recognized by D. Bernoulli, Lagrange, and other mathematicians, and had led to some discussion of their properties, Fourier (see FOURIER, JEAN BAPTISTE JOSEPH, *Ency. Brit.*, ninth edition, vol. ix.) was the first clearly to recognize the arbitrary character of the functions which the series can represent, and to make any serious attempt to prove the validity of such representation; the series are consequently usually associated with the name of Fourier. More general cases of trigonometrical series, in which the multiples are given as the roots of certain transcendental equations, were also considered by Fourier.

Before proceeding to the consideration of the special class of series to be discussed, it is necessary to define with some precision what is to be understood by the representation of an arbitrary function by an infinite series. Suppose a function of a variable x to be arbitrarily given for values of x between two fixed values a and b; this means that corresponding to every value of x such that $a \leqq x \leqq b$, with the possible exception of a finite number of values of x, a definite arithmetical value of the function is assigned by means of some prescribed set of rules. A function so defined may be denoted by $f(x)$; the rules by which the values of the function are determined may be embodied in a single explicit analytical formula, or in several such formulæ applicable to different portions of the interval, but it would be an undue restriction of the nature of an arbitrarily given function to assume *à priori* that it is necessarily given in this manner, the possibility of the representation of such a function by means of a single analytical expression being the very point which we have to discuss. The variable x may be represented by a point at the extremity of an interval measured along a straight line from a fixed origin; thus we may speak of the point c as synonymous with the value $x=c$ of the variable, and of $f(c)$ as the value of the function assigned to the point c. For any finite number of points between a and b the function may be discontinuous, *i.e.*, it may at such points undergo abrupt changes of value. The only discontinuities here considered will be those known as ordinary discontinuities. Such a discontinuity exists at the point c if $f(c+\epsilon)$, $f(c-\epsilon)$ have distinct but definite limiting values as ϵ is indefinitely diminished; these limiting values are known as the limits on the right and on the left respectively of the function at c, and may be denoted by $f(c+0)$, $f(c-0)$. The discontinuity consists therefore of a sudden change of value of the function from $f(c-0)$ to $f(c+0)$, as x increases through the value c. If there is such a discontinuity at the point $x=0$, we may denote the limits on the right and on the left respectively by $f(+0)$, $f(-0)$.

Suppose we have an infinite series $u_1(x)+u_2(x)+\ldots+u_n(x)+\ldots$ in which each term is a function of x, of known analytical form; let any value $x=c(a \leqq c \leqq b)$ be substituted in the terms of the series, and suppose the sum of n terms of the arithmetical series so obtained approaches a definite limit as n is indefinitely increased; this limit is known as the sum of the series. If for every value of c such that $a \leqq c \leqq b$ the sum exists and agrees with the value of $f(c)$, the series $\sum_1^\infty u_n(x)$ is said to represent the function $f(x)$ between the values a, b of the variable. If this is the case for all points within the given interval with the exception of a finite number, at any one of which either the series has no sum, or has a sum which does not agree with the value of the function, the series is said to represent "in general" the function for the given interval. If the sum of n terms of the series be denoted by $S_n(c)$, the condition that $S_n(c)$ converges to the value $f(c)$ is that corresponding to any finite positive number δ as small as we please, a value n_1 of n can be found such that if $n \geqq n_1$, $|f(c)-S_n(c)| < \delta$.

Functions have also been considered which for an infinite number of points within the given interval have no definite value, and series have also been discussed which at an infinite number of points in the interval cease either to have a sum, or to have one which agrees with the value of the function; the narrower conception above will however be retained in the treatment of the subject in this article, reference to the wider class of cases being made only in connexion with the history of the theory of Fourier's Series.

Uniform Convergence of Series.—If the series $u_1(x)+u_2(x)+\ldots+u_n(x)+\ldots$ converge for every value of x in a given interval a to b, and its sum be denoted by $S(x)$, then if corresponding to a finite positive quantity δ as small as we please a finite number n_1 can be found such that the arithmetical value of $S(x)-S_n(x)$, where $n \geqq n_1$ is less than δ, for every value of x within the given interval, the series is said to converge uniformly within that interval. It may however happen that as x approaches a particular value the number of terms of the series which must be taken so that $|S(x)-S_n(x)|$ may be $<\delta$, increases indefinitely; the convergence of the series is then infinitely slow in the neighbourhood of such a point, and the series is not uniformly convergent throughout the given interval. If the number of such points in the neighbourhood of which the series ceases to converge uniformly be finite, they may be excluded by taking intervals of finite magnitude as small as we please containing such points, and considering the convergence of the series in the given interval with such sub-intervals excluded; the convergence of the series is now uniform throughout the remainder of the interval. The series is said to be *in general* uniformly convergent within the given interval a to b if it can be made uniformly convergent by the exclusion of a finite number of portions of the interval, each such portion being arbitrarily small. It is known that the sum of an infinite series of continuous terms can be discontinuous only at points in the neighbourhood of which the convergence of the series is not uniform, but non-uniformity of convergence of the series does not necessarily imply discontinuity in the sum.

Form of Fourier's Series.—If it be assumed that a function $f(x)$ arbitrarily given for values of x such that $0 \leqq x \leqq l$ is capable of being represented in general by an infinite series of the form

$$A_1 \sin\frac{\pi x}{l} + A_2 \sin\frac{2\pi x}{l} + \ldots + A_n \sin\frac{n\pi x}{l} + \ldots,$$

and if it be further assumed that the series is in general uniformly convergent throughout the interval 0 to l, the form of the coefficients A can be determined. Multiply each term of the series by $\sin\frac{n\pi x}{l}$, and integrate the product between the limits 0 and l, then in virtue of the property $\int_0^l \sin\frac{n\pi x}{l}\sin\frac{n^1\pi x}{l}dx=0$, or $\frac{1}{2}l$, according as n^1 is not, or is, equal to n, we have $\frac{1}{2}lA_n=\int_0^l f(x)\sin\frac{n\pi x}{l}dx$, and thus the series is of the form $\frac{2}{l}\sum_1^\infty \sin\frac{n\pi x}{l}\int_0^l f(x)\sin\frac{n\pi x}{l}dx$. (1)

This method of determining the coefficients in the series would not be valid without the assumption that the series is in general uniformly convergent, for in accordance with a known theorem the sum of the integrals of the separate terms of the series is otherwise not necessarily equal to the integral of the sum. This assumption being made, the other assumption of the possibility of the expansion insures that $f(x)$ is such that the integrals $\int_0^l f(x)\sin\frac{n\pi x}{l}dx$ have a definite meaning.

Before we proceed to examine the justification for the assumptions made, it is desirable to examine the result obtained, and to deduce other series from it. In order to obtain a series of the form

$$B_0 + B_1\cos\frac{\pi x}{l} + B_2\cos\frac{2\pi x}{l} + \ldots + B_n\cos\frac{n\pi x}{l} + \ldots$$

for the representation of $f(x)$ in the interval 0 to l, let us apply the series (1) to represent the function $f(x)\sin\frac{\pi x}{l}$; we thus find

$$\frac{2}{l}\sum_1^\infty \sin\frac{n\pi x}{l}\int_0^l f(x)\sin\frac{\pi x}{l}\sin\frac{n\pi x}{l}dx,$$

or

$$\frac{1}{l}\sum_1^\infty \sin\frac{n\pi x}{l}\int_0^l f(x)\left\{\cos\frac{(n-1)\pi x}{l}-\cos\frac{(n+1)\pi x}{l}\right\}dx.$$

On rearrangement of the terms this becomes

$$\frac{1}{l}\sin\frac{\pi x}{l}\int_0^l f(x)dx+\frac{2}{l}\sum\sin\frac{\pi x}{l}\cos\frac{n\pi x}{l}\int_0^l f(x)\cos\frac{n\pi x}{l}dx,$$

hence $f(x)$ is represented for the interval 0 to l by the series of cosines

$$\frac{1}{l}\int_0^l f(x)dx+\frac{2}{l}\sum_1^\infty\cos\frac{n\pi x}{l}\int_0^l f(x)\cos\frac{n\pi x}{l}dx \quad . \quad . \quad (2)$$

We have thus seen, that with the assumptions made, the arbitrary function $f(x)$ may be represented, for the given interval, either by a series of sines, as in (1), or by a series of cosines, as in (2). Some important differences between the two series must, however, be noticed; in the first place, the series of sines has a vanishing sum when $x=0$ or $x=l$, it therefore does not represent the function at the point $x=0$, unless $f(0)=0$, or at the point $x=l$, unless $f(l)=0$, whereas the series (2) of cosines may represent the function at both these points. Again, let us consider what is represented by (1) and (2) for values of x which do not lie between 0 and l; as $f(x)$ is given only for values of x between 0 and l, the series at points beyond these limits have no necessary connexion with $f(x)$ unless we suppose that $f(x)$ is also given for such general values of x in such a way that the series continue to represent that function. If in (1) we change x into $-x$, leaving the coefficients unaltered, the series changes sign, and if x be changed into $x+2l$, the series is unaltered; we infer that (1) is an odd function of x and is periodic of period $2l$; thus (1) will represent $f(x)$ in general for values of x between $\pm\infty$, if $f(x)$ is odd and has a period $2l$. If in (2) we change x into $-x$, the series is unaltered, and it is also unaltered by changing x into $x+2l$; from this we see that (2) represents $f(x)$ for values of x between $\pm\infty$, only if $f(x)$ is an even function, and is periodic of period $2l$. In general a function $f(x)$ arbitrarily given for all values of x between $\pm\infty$ is neither periodic nor odd, nor even, and is therefore not represented by either (1) or (2) except for the interval 0 to l.

From (1) and (2) we can deduce a series containing both sines and cosines, which will represent a function $f(x)$ arbitrarily given in the interval $-l$ to l, for that interval. We can express by (1) the function $\frac{1}{2}\{f(x)-f(-x)\}$ which is an odd function, and thus this function is represented for the interval $-l$ to $+l$ by

$$\frac{2}{l}\sum \sin\frac{n\pi x}{l}\int_0^l \tfrac{1}{2}\{f(x)-f(-x)\}\sin\frac{n\pi x}{l}dx;$$

we can also express $\frac{1}{2}\{f(x)+f(-x)\}$, which is an even function, by means of (2), thus for the interval $-l$ to $+l$ this function is represented by

$$\frac{1}{l}\int_0^l \tfrac{1}{2}\{f(x)+f(-x)\}dx+\frac{2}{l}\sum_1^\infty \cos\frac{n\pi x}{l}\int_0^l \tfrac{1}{2}\{f(x)+f(-x)\}\cos\frac{n\pi x}{l}dx.$$

It must be observed that $f(-x)$ is absolutely independent of $f(x)$, the former being not deducible from the latter by putting $-x$ for x in a formula; both $f(x)$ and $f(-x)$ are functions given arbitrarily and independently for the interval 0 to l. On adding the expressions together we obtain a series of sines and cosines which represents $f(x)$ for the interval $-l$ to l. The integrals

$$\int_0^l f(-x)\cos\frac{n\pi x}{l}dx,\quad \int_0^l f(-x)\sin\frac{n\pi x}{l}dx$$

are equivalent to

$$-\int_0^{-l} f(x)\cos\frac{n\pi x}{l}dx,\quad +\int_0^{-l} f(x)\sin\frac{n\pi x}{l}dx,$$

thus the series is

$$\frac{1}{2l}\int_{-l}^l f(x)dx+\frac{1}{l}\sum_1^\infty \cos\frac{n\pi x}{l}\int_{-l}^l f(x)\cos\frac{n\pi x}{l}dx$$
$$+\frac{1}{l}\sum_1^\infty \sin\frac{n\pi x}{l}\int_{-l}^l f(x)\sin\frac{n\pi x}{l}dx,$$

which may be written

$$\frac{1}{2l}\int_{-l}^l f(x^1)dx^1+\frac{1}{l}\sum_1^\infty\int_{-l}^l f(x^1)\cos\frac{n\pi(x-x^1)}{l}dx^1 \quad . \quad . \quad (3)$$

The series, (3) which represents a function $f(x)$ arbitrarily given for the interval $-l$ to l, is what is known as Fourier's Series, the expressions (1) and (2) being regarded as the particular forms which (3) takes in the two cases, in which $f(-x)=-f(x)$, or $f(-x)=f(x)$ respectively. The expression (3) does not represent $f(x)$ at points beyond the interval $-l$ to l, unless $f(x)$ has a period $2l$. For a value of x within the interval, at which $f(x)$ is discontinuous, the sum of the series may cease to represent $f(x)$, but as will be seen hereafter, has the value $\frac{1}{2}\{f(x+0)+f(x-0)\}$, the mean of the limits at the point on the right and the left. The series represents the function at $x=0$, unless the function is then discontinuous, in which case the series is $\frac{1}{2}\{f(+0)+f(-0)\}$; the series does not necessarily represent the function at the points l and $-l$, unless $f(l)=f(-l)$, its sum at either of these points, is $\frac{1}{2}\{f(l)+f(-l)\}$.

Examples of Fourier's Series.—(*a*) Let $f(x)$ be given from 0 to l, by $f(x)=c$, when $0\leq x<\frac{1}{2}l$, and by $f(x)=-c$ from $\frac{1}{2}l$ to l; it is required to find a sine series, and also a cosine series, which shall represent the function in the interval.

We have

$$\int_0^l f(x)\sin\frac{n\pi x}{l}dx=c\int_0^{\frac{1}{2}l}\sin\frac{n\pi x}{l}dx-c\int_{\frac{1}{2}l}^l \sin\frac{n\pi x}{l}dx$$
$$=\frac{cl}{n\pi}(\cos n\pi-2\cos\tfrac{1}{2}n\pi+1).$$

This vanishes if n is odd, and if $n=4m$, but if $n=4m+2$ is equal to $\frac{4cl}{n\pi}$, the series is therefore

$$\frac{4c}{\pi}\left(\frac{1}{2}\sin\frac{2\pi x}{l}+\frac{1}{3}\sin\frac{6\pi x}{l}+\frac{1}{5}\sin\frac{10\pi x}{l}+\ .\ .\ .\right).$$

For unrestricted values of x, this series represents the ordinates of the series of straight lines in Fig. 1, except that it vanishes at the points 0, $\frac{1}{2}l$, l, $\frac{3}{2}l$ . . .

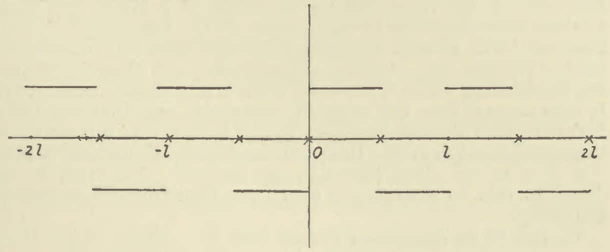


Fig. 1.

We find similarly that the same function is represented by the series

$$\frac{4c}{\pi}\left(\cos\frac{\pi x}{l}-\frac{1}{3}\cos\frac{3\pi x}{l}+\frac{1}{5}\cos\frac{5\pi x}{l}-+\ .\ .\ .\right)$$

during the interval 0 to l; for general values of x the series represents the ordinate of the broken line in Fig. 2, except that it vanishes at the points $\frac{1}{2}l$, $\frac{3}{2}l$ . . .

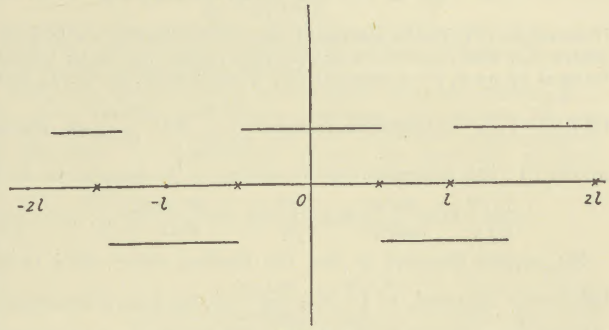


Fig. 2.

(*b*) Let $f(x)=x$ from 0 to $\frac{1}{2}l$, and $f(x)=l-x$, from $\frac{1}{2}l$ to l; then

$$\int_0^l f(x)\sin\frac{n\pi x}{l}dx=\int_0^{\frac{1}{2}l}x\sin\frac{n\pi x}{l}dx+\int_{\frac{1}{2}l}^l(l-x)\sin\frac{n\pi x}{l}dx$$
$$=-\frac{l^2}{2n\pi}\cos\frac{n\pi}{2}+\frac{l^2}{n^2\pi^2}\sin\frac{n\pi}{2}+\frac{l^2}{n\pi}\left(\cos\frac{n\pi}{2}-\cos n\pi\right)$$
$$+\frac{l^2}{n\pi}\cos n\pi-\frac{l^2}{2n\pi}\cos\frac{n\pi}{2}+\frac{l^2}{n^2\pi^2}\sin\frac{n\pi}{2}=\frac{2l^2}{n^2\pi^2}\sin\frac{n\pi}{2}$$

hence the sine series is

$$\frac{4l}{\pi^2}\left(\sin\frac{nx}{l}-\frac{1}{3^2}\sin\frac{3\pi x}{l}+\frac{1}{5^2}\sin\frac{5\pi x}{l}-\ .\ .\ .\right)$$

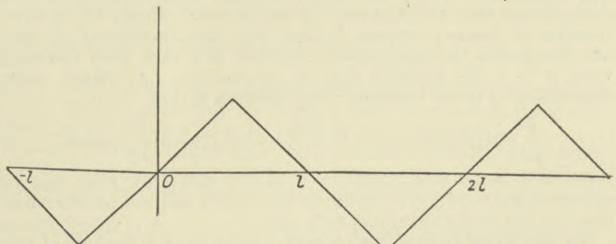


Fig. 3

For general values of x, the series represents the ordinate of the row of broken lines in Fig. 3.

The cosine series, which represents the same function for the interval 0 to l, may be found to be

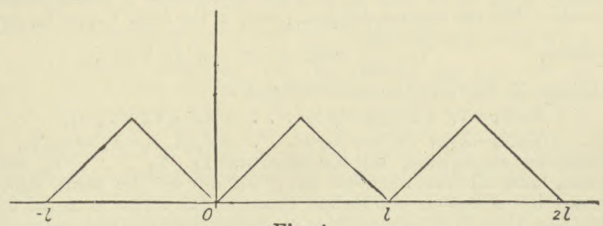


Fig. 4.

$$\frac{1}{4}l-\frac{2l}{\pi^2}\left(\cos\frac{2\pi x}{l}+\frac{1}{3^2}\cos\frac{6\pi x}{l}+\frac{1}{5^2}\cos\frac{10\pi x}{l}+\ .\ .\ .\right)$$

*

This series represents for general values of x the ordinate of the set of broken lines in Fig. 4.

Dirichlet's Integral.—The method indicated by Fourier, but first carried out rigorously by Dirichlet, of proving that with certain restrictions as to the nature of the function $f(x)$, that function is in general represented by the series (3), consists in finding the sum of $n+1$ terms of that series, and then investigating the limiting value of the sum, when n is increased indefinitely. It thus appears that the series is convergent, and that the value towards which its sum converges is $\frac{1}{2}\{f(x+0)+f(x-0)\}$, which is in general equal to $f(x)$. It will be convenient throughout to take $-\pi$ to π as the given interval; any interval $-l$ to l may be reduced to this by changing x into lx/π, thus there is no loss of generality.

We find by an elementary process that

$$\tfrac{1}{2}+\cos(x-x^1)+\cos 2(x-x^1)+\ .\ .\ .\ +\cos n(x-x^1)$$
$$=\frac{\sin\frac{2n+1}{2}(x^1-x)}{2\sin\frac{1}{2}(x^1-x)}$$

hence, with the new notation, the sum of the first $n+1$ terms of (3) is

$$\frac{1}{\pi}\int_{-\pi}^{\pi} f(x^1)\frac{\sin\frac{2n+1}{2}(x^1-x)}{2\sin\frac{1}{2}(x^1-x)}dx^1;$$

if we suppose $f(x)$ to be continued beyond the interval $-\pi$ to π, in such a way that $f(x)=f(x+2\pi)$, we may replace the limits in this integral by $x+\pi$, $x-\pi$ respectively; if we then put $x^1-x=2z$, and let $f(x^1)=\mathrm{F}(z)$, the expression becomes $\frac{1}{\pi}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}}\mathrm{F}(z)\frac{\sin mz}{\sin z}dz$, where $m=2n+1$; this expression may be written in the form

$$\frac{1}{\pi}\int_0^{\frac{\pi}{2}}\mathrm{F}(z)\frac{\sin mz}{\sin z}dz+\frac{1}{\pi}\int_0^{\frac{\pi}{2}}\mathrm{F}(-z)\frac{\sin mz}{\sin z}dz\ .\ .\ . \qquad (4)$$

We require therefore to find the limiting value, when m is indefinitely increased, of $\int_0^{\frac{\pi}{2}}\mathrm{F}(z)\frac{\sin mz}{\sin z}dz$, the form of the second integral being essentially the same. This integral, or rather the slightly more general one $\int_0^h\mathrm{F}(z)\frac{\sin mz}{\sin z}dz$, when $0<h\leqq\frac{1}{2}\pi$, is known as Dirichlet's integral. If we write $\mathrm{X}(z)=\mathrm{F}(z)\frac{z}{\sin z}$, the integral becomes $\int_0^h\mathrm{X}(z)\frac{\sin mz}{z}dz$, which is the form in which the integral is frequently considered.

The Second Mean-Value Theorem.—The limiting value of Dirichlet's integral may be conveniently investigated by means of a theorem in the integral calculus known as the second mean-value theorem. Let a, b be two fixed finite numbers such that $a<b$, and suppose $f(x)$, $\phi(x)$ are two functions which have finite and determinate values everywhere in the interval except for a finite number of points; suppose further that the functions $f(x)$, $\phi(x)$ are integrable throughout the interval, and that as x increases from a to b the function $f(x)$ is monotonous, *i.e.*, either never diminishes or never increases; the theorem is that

$$\int_a^b f(x)\phi(x)dx=f(a+0)\int_a^\xi\phi(x)dx+f(b-0)\int_\xi^b\phi(x)dx$$

when ξ is some point between a and b, and $f(a)$, $f(b)$ may be written for $f(a+0)$, $f(b-0)$ unless a or b is a point of indetermination for one of the functions $f(x)$, $\phi(x)$.

To prove this theorem, we observe that since the product of two integrable functions is an integrable function, $\int_a^b f(x)\phi(x)dx$ exists, and may be regarded as the limit of the sum of a series

$$f(x_0)\phi(x_0)(x_1-x_0)+f(x_1)\phi(x_1)(x_2-x_1)+\ldots+f(x_{n-1})\phi(x_{n-1})(x_n-x_{n-1})$$

where $x_0=a$, $x_n=b$, and $x_1, x_2\ .\ .\ .\ x_{n-1}$ are $n-1$ intermediate points. We can express $\phi(x_r)(x_{r+1}-x_r)$ in the form $\mathrm{Y}_{r+1}-\mathrm{Y}_r$, by putting

$$\mathrm{Y}_r=\sum_{\mathrm{K}=1}^{\mathrm{K}=r}\phi(x_{\mathrm{K}-1})(x_{\mathrm{K}}-x_{\mathrm{K}-1}),\ \mathrm{Y}_0=0.$$

Writing X_r for $f(x_r)$, the series becomes

$$\mathrm{X}_0(\mathrm{Y}_1-\mathrm{Y}_0)+\mathrm{X}_1(\mathrm{Y}_2-\mathrm{Y}_1)+\ .\ .\ .\ +\mathrm{X}_{n-1}(\mathrm{Y}_n-\mathrm{Y}_{n-1})$$

or $\mathrm{Y}_1(\mathrm{X}_0-\mathrm{X}_1)+\mathrm{Y}_2(\mathrm{X}_1-\mathrm{X}_2)+\ .\ .\ .\ +\mathrm{Y}_n(\mathrm{X}_{n-1}-\mathrm{X}_n)+\mathrm{Y}_n\mathrm{X}_n$.

Now, by supposition, all the numbers $\mathrm{Y}_1, \mathrm{Y}_2\ .\ .\ .\ \mathrm{Y}_n$ are finite, and all the numbers $\mathrm{X}_{r-1}-\mathrm{X}_r$ are of the same sign, hence by a known algebraical theorem the series is equal to $\mathrm{M}(\mathrm{X}_0-\mathrm{X}_n)+\mathrm{Y}_n\mathrm{X}_n$ where M is a number intermediate between the greatest and the least of the numbers $\mathrm{Y}_1, \mathrm{Y}_2, .\ .\ .\ \mathrm{Y}_n$. This remains true however many partial intervals are taken, and therefore when their number is increased indefinitely, and their breadths are diminished indefinitely according to any law, hence we have

$$\int_a^b f(x)\phi(x)dx=\{f(a)-f(b)\}\overline{\mathrm{M}}+f(b)\int_a^b\phi(x)dx$$

when $\overline{\mathrm{M}}$ is intermediate between the greatest and least values which $\int_a^x\phi(x)dx$ can have, when x is in the given interval. Now this integral is a continuous function of its upper limit x, and therefore there is a value of x in the interval, for which it takes any particular value between the greatest and least values that it has. There is therefore a value ξ between a and b, such that $\overline{\mathrm{M}}=\int_a^\xi\phi(x)dx$, hence

$$\int_a^b f(x)\phi(x)dx=\{f(a)-f(b)\}\int_a^\xi\phi(x)dx+f(b)\int_a^b\phi(x)dx)$$
$$=f(a)\int_a^\xi\phi(x)dx+f(b)\int_\xi^b\phi(x)dx.$$

If the interval contains any finite numbers of points of discontinuity of $f(x)$ or $\phi(x)$, the method of proof still holds good, provided these points are avoided in making the subdivisions; in particular if either of the ends be a point of discontinuity of $f(x)$, we write $f(a+0)$ or $f(b-0)$, for $f(a)$ or $f(b)$, it being assumed that these limits exist.

Functions, with Restricted Oscillation.—The condition that $f(x)$, in the mean-value theorem, either never increases or never diminishes as x increases from a to b, places a restriction upon the applications of the theorem. We can however show that a function $f(x)$ which is finite and continuous between a and b, except for a finite number of ordinary discontinuities, and which only changes from increasing to diminishing or *vice versâ*, a finite number of times, as x increases from a to b, may be expressed as the difference of two functions $f_1(x)$, $f_2(x)$, neither of which ever diminishes as x passes from a to b, and that these functions are finite and continuous, except that one or both of them are discontinuous at the points where the given function is discontinuous. Let α, β be two consecutive points at which $f(x)$ is discontinuous, consider any point x_1, such that $\alpha\leqq x_1\leqq\beta$, and suppose that at the points $\mathrm{M}_1, \mathrm{M}_2\ .\ .\ .\ \mathrm{M}_r$ between α and x_1, $f(x)$ is a maximum, and at $m_1, m_2\ .\ .\ .\ m_r$ it is a minimum; we will suppose, for example, that the ascending order of values is $\alpha, \mathrm{M}_1, m_1, \mathrm{M}_2, m_2\ .\ .\ .\ \mathrm{M}_r, m_r, x_1$; it will make no essential difference in the argument if m_1 comes before M_1, or if M_r immediately precedes x_1, m_r, being then the last minimum.

Let $\psi(x_1)=\{f(\mathrm{M}_1)-f(\alpha+0)\}+[f(\mathrm{M}_2)-f(m_1)]+\ .\ .\ .$
$+[f(\mathrm{M}_r)-f(m_{r-1})]+[f(x_1)-f(m_r)]$;

now let x_1 increase until it reaches the value M_{r+1} at which $f(x)$ is again a maximum, then let

$$\psi(x_1)=\{f(\mathrm{M}_1)-f(\alpha+0)\}+[f(\mathrm{M}_2)-f(m_1)]+\ .\ .\ .\ +[f(\mathrm{M}_r)-f(m_{r-1})]+[f(\mathrm{M}_{r+1})-f(m_r)];$$

and suppose as x increases beyond the value M_{r+1}, $\psi(x_1)$ remains constant until the next minimum m_{r+1} is reached, when it again becomes variable; we see that $\psi(x_1)$ is essentially positive and never diminishes as x increases.

Let

$$\chi(x_1)=[f(\mathrm{M}_1)-f(m_1)]+[f(\mathrm{M}_2)-f(m_1)]+\ .\ .\ .\ +[f(\mathrm{M}_r)-f(m_r)],$$

then let x_1 increase until it is beyond the next maximum M_{r+1}, and then let $\chi(x_1)=[f(\mathrm{M}_1)-f(m_1)]+[f(\mathrm{M}_2)-f(m_1)]+\ .\ .\ .$
$+[f(\mathrm{M}_r)-f(m_r)]+[f(\mathrm{M}_{r+1})-f(x_1)]$

thus $\chi(x_1)$ never diminishes, and is alternately constant and variable. We see that $\psi(x_1)-\chi(x_1)$ is continuous as x increases from α to β, and that $\psi(x_1)-\chi(x_1)=f(x_1)-f(\alpha+0)$ and when x_1 reaches β, we have $\psi(\beta)-\chi(x_1)=f(\beta-0)-f(\alpha+0)$. Hence it is seen that between α and β, $f(x)=[\psi(x)+f(\alpha+0)]-\chi(x)$, where $\psi(x)+f(\alpha+0)$, $\chi(x)$ are continuous and never diminish as x increases; the same reasoning applies to every continuous portion of $f(x)$, for which the functions $\psi(x)$, $\chi(x)$ are formed in the same manner; we now take $f_1(x)=\psi(x)+f(\alpha+0)+\mathrm{C}$, $f_2(x)=\chi(x)+\mathrm{C}$, where C is constant between consecutive discontinuities, but may have different values in the next interval between discontinuities; the C can be so chosen that neither $f_1(x)$ nor $f_2(x)$ diminishes as x increases through a value for which $f(x)$ is discontinuous. We thus see that $f(x)=f_1(x)-f_2(x)$, where $f_1(x)$, $f_2(x)$ never diminish as x increases from a to b, and are discontinuous only where $f(x)$ is so. The function $f(x)$ is a particular case of a class of functions defined and discussed by Jordan, under the name "functions with restricted oscillation" (*fonctions à variation bornée*); in general such functions have not necessarily only a finite number of maxima and minima.

Proof of the Convergence of Fourier's Series.—It will now be assumed that a function $f(x)$ arbitrarily given between the values $-\pi$ and $+\pi$, has the following properties:—

(*a*) The function is everywhere finite, and continuous except for a finite number of values of the variable, for which it may be ordinarily discontinuous.

(*b*) The function only changes from increasing to diminishing or *vice versâ*, a finite number of times within the interval; this is usually expressed by saying that the number of maxima and minima is finite.

These limitations on the nature of the function are known as Dirichlet's conditions; it follows from them that the function is integrable throughout the interval.

On these assumptions, we can investigate the limiting value of Dirichlet's integral; it will be necessary to consider only the case of a function $F(z)$ which does not diminish as z increases from 0 to $\frac{1}{2}\pi$, since it has been shown that in the general case the difference of two such functions may be taken. The following lemmas will be required:—

(1) Since

$$\int_0^{\frac{\pi}{2}}\frac{\sin mz}{\sin z}dz=\int_0^{\frac{\pi}{2}}\{1+2\cos 2z+2\cos 4z+\ .\ .\ .\ +2\cos 2nz\}dz=\frac{\pi}{2};$$

this result holds however large the odd integer m may be.

(2) If $0<\alpha<\beta\leqq\frac{\pi}{2}$,

$$\int_\alpha^\beta \frac{\sin mz}{\sin z}dz=\frac{1}{\sin\alpha}\int_\alpha^\gamma \sin mz\,dz+\frac{1}{\sin\beta}\int_\gamma^\beta\sin mz\,dz$$

where $\alpha<\gamma<\beta$, hence

$$\left|\int_\alpha^\beta\frac{\sin mz}{\sin z}dz\right|<\frac{2}{m}\left(\frac{1}{\sin\alpha}+\frac{1}{\sin\beta}\right)<\frac{4}{m\sin\alpha};$$

a precisely similar proof shows that $\left|\int_\alpha^\beta\frac{\sin mz}{z}dz\right|<\frac{4}{m\alpha}$,

hence the integrals $\int_\alpha^\beta\frac{\sin mz}{\sin z}dz$, $\int_\alpha^\beta\frac{\sin mz}{z}dz$, converge to the limit zero, as m is indefinitely increased.

(3) If $\alpha>0$, $\left|\int_\alpha^\infty\frac{\sin\theta}{\theta}d\theta\right|$ cannot exceed $\frac{1}{2}\pi$. For by the mean-value theorem $\left|\int_\alpha^h\frac{\sin\theta}{\theta}d\theta\right|<\frac{2}{\alpha}+\frac{2}{h}$,

hence $\left|L_{h=\infty}\int_\alpha^h\frac{\sin\theta}{\theta}d\theta\right|<\frac{2}{\alpha}$;

in particular if $\alpha\geqq\pi$ $\left|\int_\alpha^\infty\frac{\sin\theta}{\theta}d\theta\right|<\frac{2}{\pi}$.

Again $\frac{d}{d\alpha}\int_\alpha^\infty\frac{\sin\theta}{\theta}d\theta=-\frac{\sin\alpha}{\alpha}$, $\alpha>0$,

therefore $\int_\alpha^\infty\frac{\sin\theta}{\theta}d\theta$ increases as α diminishes, when $0<\alpha<\pi$;

but $L_{\alpha=0}\int_\alpha^\infty\frac{\sin\theta}{\theta}d\theta=\frac{\pi}{2}$, hence $\left|\int_\alpha^\infty\frac{\sin\theta}{\theta}d\theta\right|<\frac{\pi}{2}$,

where $\alpha<\pi$, and $<\frac{2}{\pi}$ where $\alpha\geqq\pi$.

To find the limit of $\int_0^{\frac{\pi}{2}}F(z)\frac{\sin mz}{\sin z}dz$, we observe that it may be written in the form

$$F(0)\int_0^{\frac{\pi}{2}}\frac{\sin mz}{\sin z}dz+\int_0^\mu\{F(z)-F(0)\}\frac{\sin mz}{\sin z}dz+\int_\mu^{\frac{\pi}{2}}\{F(z)-F(0)\}\frac{\sin mz}{\sin z}dz$$

where μ is a fixed number as small as we please, hence if we use lemma (1), and apply the second mean-value theorem,

$$\int_0^{\frac{\pi}{2}}F(z)\frac{\sin mz}{\sin z}dz-\frac{\pi}{2}F(0)$$

$$=\int_0^\mu\{F(z)-F(0)\}\frac{z}{\sin z}\frac{\sin mz}{z}dz$$

$$+\{F(\mu)-F(0)\}\int_\mu^{\xi^1}\frac{\sin mz}{\sin z}dz+\left\{F\left(\frac{\pi}{2}\right)-F(0)\right\}\int_{\xi^1}^{\frac{\pi}{2}}\frac{\sin mz}{\sin z}dz$$

when ξ^1 lies between μ and $\frac{1}{2}\pi$. When m is indefinitely increased, the two last integrals have a zero limit in virtue of lemma (2). To evaluate the first integral on the right-hand side, let $G(z)=\{F(z)-F(0)\}\frac{z}{\sin z}$, and observe that $G(z)$ increases as z increases from 0 to μ, hence if we apply the mean-value theorem

$$\int_0^\mu G(z)\frac{\sin mz}{z}dz=G(\mu)\int_\xi^\mu\frac{\sin mz}{z}dz$$

$$=G(\mu)\int_{m\xi}^{m\mu}\frac{\sin\theta}{\theta}d\theta$$

where $0<\xi<\mu$, since $G(z)$ has a zero limit when $z=0$. It has been shown by Kronecker that ξ cannot be zero.

As m increases ξ varies, being dependent on m and on the nature of $G(z)$, and it may happen that as m is increased indefinitely, ξ may be indefinitely diminished; if this is not the case the limit of $\int_\xi^\mu\frac{\sin mz}{z}dz$ is zero. If however $m\xi$ has a finite limit α, we see by virtue of lemma (3) that the limit of the integral does not exceed $\frac{\pi}{2}G(\mu)$. The fixed quantity μ may be chosen so small that $\left|\frac{\pi}{2}G(z)\right|<\delta$, if $0<z\leqq\mu$, where δ is any prescribed quantity as small as we please. It has now been shown that when m is indefinitely increased $\int_0^{\frac{\pi}{2}}F(z)\frac{\sin mz}{\sin z}dz-\frac{\pi}{2}F(0)$ has a zero limit.

Returning to the form (4), we now see that the limiting value of

$\frac{1}{\pi}\int_0^{\frac{\pi}{2}}F(z)\frac{\sin mz}{\sin z}dz+\frac{1}{\pi}\int_0^{\frac{\pi}{2}}F(-z)\frac{\sin mz}{\sin z}dz$ is $\frac{1}{2}\{F(+0)+F(-0)\}$,

hence the sum of $n+1$ terms of the series

$$\frac{1}{2l}\int_{-l}^{l}f(x)dx+\frac{1}{l}\sum\int_{-l}^{l}f(x^1)\cos\frac{n\pi(x-x^1)}{l}dx$$

converges to the value $\frac{1}{2}\{f(x+0)+f(x-0)\}$, or to $f(x)$ at a point where $f(x)$ is continuous, provided $f(x)$ satisfies Dirichlet's conditions for the interval from $-l$ to l.

Proof that Fourier's Series is in General Uniformly Convergent.—To prove that Fourier's Series converges uniformly to its sum for all values of x, provided that the immediate neighbourhoods of the points of discontinuity of $f(x)$ are excluded, we have from the above,

$$\left|\int_0^{\frac{\pi}{2}}F(z)\frac{\sin mz}{\sin z}dz-\frac{\pi}{2}F(0)\right|<\frac{\pi}{2}G(\mu)+\frac{4}{m\sin\mu}\{F(\mu)-F(0)\}$$

$$+\frac{4}{m\sin\xi^1}\left\{F\left(\frac{\pi}{2}\right)-F(0)\right\}$$

$$<\frac{\pi}{2}\frac{\mu}{\sin\mu}\{f(x+2\mu)-f(x)\}+\frac{4}{m\sin\mu}\{f(x+2\mu)-f(x)\}$$

$$+\frac{4}{m\sin\xi^1}\{f(x+\pi)-f(x)\}.$$

Now as x is excluded from certain portions of the interval in the neighbourhood of discontinuities of $f(x)$, μ may be chosen so small that for every value of x, $\frac{\mu}{\sin\mu}\{f(x+2\mu)-f(x)\}<\epsilon$ where ϵ is an arbitrarily small fixed number; also $f(x+\pi)-f(x)$ is never greater than some fixed finite number A, therefore a value of m can be found such that if m equals or exceeds this value,

$\left|\int_0^{\frac{\pi}{2}}F(z)\frac{\sin mz}{\sin z}dz-\frac{\pi}{2}F(0)\right|<\epsilon^1$, for all values of x considered,

when ϵ^1 is a fixed arbitrarily small number. If x had been allowed to approach very closely a point of discontinuity, a smaller value of μ would have had to be chosen, so that $\frac{\mu}{\sin\mu}\{f(x+2\mu)-f(x)\}<\epsilon$, thus μ would have to be continually diminished for this inequality to hold, and the argument would fail; thus the convergence is not uniform if x is allowed to move right up to a discontinuity.

Case of a Function with Infinities.—The limitation that $f(x)$ must be finite throughout the interval may, under a certain restriction, be removed. Suppose $F(z)$ is infinite at the point $z=e$, and is such that the limits of the two integrals $\int_c^{c\pm\epsilon}F(z)dz$ are both zero, as ϵ is indefinitely diminished, then

$\int_0^{\frac{\pi}{2}}F(z)\frac{\sin mz}{\sin z}dz$ denotes the limit when $\epsilon=0$, $\epsilon^1=0$ of

$\int_0^{c-\epsilon}F(z)\frac{\sin mz}{\sin z}dz+\int_{c+\epsilon^1}^{\frac{\pi}{2}}F(z)\frac{\sin mz}{\sin z}dz$, both these limits existing;

the first of these integrals has $\frac{\pi}{2}F(+0)$ for its limiting value when m is indefinitely increased, and the second has zero for its limit. The theorem therefore holds if $F(z)$ has an infinity up to which it is integrable; this will, for example, be the case if $F(z)$ near the point C is of the form $\chi(z)(z-e)^{-\mu}+\psi(z)$, where $\chi(e)$, $\psi(e)$ are finite, and $0<\mu<1$. It is thus seen that $f(x)$ may have a finite number of infinities within the given interval, provided the function is integrable through any one of these points; the function is in that case still representable by Fourier's Series.

The Ultimate Values of the Coefficients in Fourier's Series.—If $f(x)$ is everywhere finite within the given interval $-\pi$ to $+\pi$, it can be shown that a_n, b_n, the coefficients of $\cos nx$, $\sin nx$ in the series which represent the function, are such that na_n, nb_n, however great n is, are each less than a fixed finite quantity. For writing $f(x)=f_1(x)-f_2(x)$, we have

$$\int_{-\pi}^{\pi} f_1(x)\cos nxdx = f_1(-\pi+0)\int_{-\pi}^{\xi}\cos nxdx + f_1(\pi-0)\int_{\xi}^{\pi}\cos nxdx$$

hence

$$\int_{-\pi}^{\pi} f_1(x)\cos nxdx = f_1(-\pi+0)\frac{\sin n\xi}{n} + f_1(\pi-0)\frac{\sin n\xi}{n}$$

with a similar expression, with $f_2(x)$ for $f_1(x)$, ξ being between π and $-\pi$; the result then follows at once, and is obtained similarly for the other coefficient.

If $f(x)$ is infinite at $x=c$, and is of the form $\frac{\phi(x)}{(x-c)^K}$ near the point c, where $0<K<1$, the integral $\int_{-\pi}^{\pi} f(x)\cos nx\,dx$, contains portions of the form $\int_c^{c+\epsilon}\frac{\phi(x)}{(x-c)^K}\cos nxdx$ $\int_{c-\epsilon}^{c}\frac{\phi(x)}{(x-c)^K}\cos nxdx$; consider the first of these, and put $x=c+u$, it thus becomes $\int_0^{\epsilon}\frac{\phi(c+u)}{u^K}\cos n(c+u)du$, which is of the form $\phi(c+\theta\epsilon)\int_0^{\epsilon}\frac{\cos n(c+u)}{u^K}du$; now let $nu=v$, the integral becomes

$$\phi(c+\theta\epsilon)\left\{\frac{\cos nc}{n^{1-K}}\int_0^{n\epsilon}\frac{\cos v}{v^K}dv - \frac{\sin nc}{n^{1-K}}\int_0^{n\epsilon}\frac{\sin v}{v^K}dv\right\};$$

hence $n^{1-K}\int_{-\pi}^{\pi} f(x)\cos nxdx$ becomes, as n is indefinitely increased of the form $\phi(c)\left\{\cos nc\int_0^{\infty}\frac{\cos v}{v^K}dv - \sin nc\int_0^{\infty}\frac{\sin v}{v^K}dv\right\}$ which is finite, both the integrals being convergent and of known value. The other integral has a similar property, and we infer that $n^{1-K}a_n$, $n^{1-K}b_n$ are less than fixed finite quantities.

The Differentiation of Fourier's Series.—If we assume that the differential coefficient of a function $f(x)$ represented by a Fourier's Series exists, that function $f'(x)$ is not necessarily representable by the series obtained by differentiating the terms of the Fourier's Series, such derived series being in fact not necessarily convergent. Stokes has obtained general formulæ for finding the series which represent $f'(x)$, $f''(x)$—the successive differential coefficients of an everywhere finite function $f(x)$. As an example of such formulæ, consider the sine series (1); $f(x)$ is represented by

$$\frac{2}{l}\sum \sin\frac{n\pi x}{l}\int_0^l f(x)\sin\frac{n\pi x}{l}dx;$$

on integration by parts we have $\int_0^l f(x)\sin\frac{n\pi x}{l}dx$

$$=\frac{l}{n\pi}\left[f(+0)\pm f(l-0)+\sum\cos\frac{n\pi a}{l}\{f(a+0)-f(a-0)\}\right]$$
$$+\frac{l}{n\pi}\int_0^l f'(x)\cos\frac{n\pi x}{l}dx$$

where a represent the points where $f(x)$ is discontinuous, hence if $f(x)$ is represented by the series $\sum a_n\sin\frac{n\pi x}{l}$, and $f'(x)$ by the series $\sum b_n\cos\frac{n\pi x}{l}$, we have the relation

$$b_n=\frac{n\pi}{l}a_n-\frac{2}{l}\left[f(+0)\pm f(l-0)+\sum\cos\frac{n\pi a}{l}\{f(a+0)-f(a-0)\}\right]$$

hence only when the function is everywhere continuous, and $f(+0)$, $f(l-0)$ are both zero, is the series which represents $f'(x)$ obtained at once by differentiating that which represents $f(x)$. The form of the coefficient a_n discloses the discontinuities of the function and of its differential coefficients, for on continuing the integration by parts we find

$$a_n=\frac{2}{n\pi}\left[f(+0)\pm f(l-0)+\sum\cos\frac{n\pi a}{l}\{f(a+0)-f(a-0)\}\right]$$
$$+\frac{2l}{n^2\pi^2}\left[f'(+0)\pm f'(l-0)+\sum\sin\frac{n\pi\beta}{l}\{f'(\beta+0)-f'(\beta-0)\}\right]+\&c.$$

where β are the points at which $f'(x)$ is discontinuous.

History and Literature of the Theory.

The history of the theory of the representation of functions by series of sines and cosines is of great interest in connexion with the progressive development of the notion of an arbitrary function of a real variable, and of the peculiarities which such a function may possess; the modern views on the foundations of the infinitesimal calculus have been to a very considerable extent formed in this connexion. [See Functions of a Real Variable.] The representation of functions by these series was first considered in the 18th century, in connexion with the problem of a vibrating cord, and led to a controversy as to the possibility of such expansions. In a memoir published in 1747 (*Memoirs of the Academy of Berlin*, vol. iii.) D'Alembert showed that the ordinate y at any time t of a vibrating cord satisfies a differential equation of the form $\frac{\delta^2 y}{\delta t^2}=a^2\frac{\delta^2 y}{\delta x^2}$, where x is measured along the undisturbed length of the cord, and that with the ends of the cord of length l fixed, the appropriate solution is $y=f(at+x)-f(at-x)$, where f is a function such that $f(x)=f(x+2l)$; in another memoir in the same volume he seeks for functions which satisfy this condition. In the year 1748 (*Berlin Memoirs*, vol. iv.) Euler, in discussing the problem, gave $f(x)=a\sin\frac{\pi x}{l}+\beta\sin\frac{2\pi x}{l}+\ldots$ as a particular solution, and maintained that every curve, whether regular or irregular, must be representable in this form. This was objected to by D'Alembert (1750) and also by Lagrange on the ground that irregular curves are inadmissible. D. Bernoulli (*Berlin Memoirs*, vol. ix., 1753) based a similar result to that of Euler, on physical intuition; his method was criticized by Euler (1753). The question was then considered from a new point of view by Lagrange, in a memoir on the nature and propagation of sound (*Miscellanea Taurensia*, 1759; Œuvres, vol. i.), who, while criticizing Euler's method, considers a finite number of vibrating particles, and then makes the number of them infinite; he did not, however, quite fully carry out the determination of the coefficients in Bernoulli's Series. These mathematicians were hampered by the narrow conception of a function, in which it is regarded as necessarily continuous; a discontinuous function was considered only as a succession of several different functions. Thus the possibility of the expansion of a broken function was not generally admitted. The first cases in which rational functions are expressed in sines and cosines were given by Euler (*Subsidium Calculi Sinuum*, Novi Comm. Petrop., vol. v., 1754–55) who obtained the formulæ

$$\tfrac{1}{2}\phi=\sin\phi-\tfrac{1}{2}\sin 2\phi+\tfrac{1}{3}\sin 3\phi\ldots$$
$$\frac{\pi^2}{12}-\frac{\phi^2}{4}=\cos\phi-\tfrac{1}{4}\cos 2\phi+\tfrac{1}{9}\cos 3\phi\ldots$$

In a memoir presented to the Academy of St Petersburg in 1777, but not published until 1798, Euler gave the method afterwards used by Fourier, of determining the coefficients in the expansions; he remarked that if Φ is expansible in the form $A+B\cos\phi+C\cos 2\phi+\ldots$, then $A=\frac{1}{\pi}\int_0^{\pi}\Phi d\phi$, $B=\frac{2}{\pi}\int_0^{\pi}\Phi\cos\phi d\phi$, &c.

The second period in the development of the theory commenced in 1807, when Fourier communicated his first memoir on the Theory of Heat to the French Academy. His exposition of the present theory is contained in a memoir sent to the Academy in 1811, of which his great treatise the *Théorie Analytique de la Chaleur*, published in 1822, is, in the main, a reproduction. Fourier set himself to consider the representation of a function given graphically, and was the first fully to grasp the idea that a single function may consist of detached portions given arbitrarily by a graph. He had an accurate conception of the convergence of a series, and although he did not give a formally complete proof that a function with discontinuities is representable by the series, he indicated in particular cases the method of procedure afterwards carried out by Dirichlet. As an exposition of principles, Fourier's work is still worthy of careful perusal by all students of the subject. Poisson's treatment of the subject, which is still adopted in English works (see the *Journal de l'école Polytechnique*, vol. xi., 1820, and vol. xii., 1823, and also his treatise, *Théorie de la Chaleur*, 1835), depends upon the equality $\int_{-\pi}^{\pi} f(a)\frac{1-h^2}{1-2h\cos(x-a)+h^2}da$

$$=\frac{1}{2\pi}\int_{-\pi}^{\pi} f(a)da+\frac{1}{\pi}\sum h^n\int_{-\pi}^{\pi} f(a)\cos n(x-a)da$$

where $o<h<1$; the limit of the integral on the left-hand side is evaluated when $h=1$, and found to be $\frac{1}{2}\{f(x+0)+f(x-0)\}$, the series on the right-hand side becoming Fourier's Series. The equality of the two limits is then inferred. If the series is assumed to be convergent when $h=1$, by a theorem of Abel's its sum is continuous with the sum for values of h less than unity, but a proof of the convergency for $h=1$ is requisite for the validity of Poisson's proof; as Poisson gave no such proof of convergency, his proof of the general theorem cannot be accepted. The deficiency cannot be removed except by a process of the same nature as that afterwards applied by Dirichlet. The definite integral has been carefully studied by Schwarz (see two memoirs in his collected works on the Integration of the equation $\frac{\delta^2 u}{\delta x^2}+\frac{\delta^2 u}{\delta y^2}=0$), who showed that the limiting value of the integral depends upon the manner in which the limit is approached. Investigations of Fourier's Series were also given by Cauchy (see his "Mémoire sur les développements des fonctions en séries périodiques," *Mem. de l'Inst.*, vol. vi., also *Œuvres complètes*, vol. vii.); his method, which depends upon a use of complex variables, was accepted, with some modification, as valid by Riemann, but one at least of his proofs is no longer regarded as satisfactory. The first completely satisfactory investigation is due to Dirichlet; his first memoir appeared in *Crelle's Journal* for 1829, and the second, which is a model of clearness, in Dove's *Repertorium der Physik*. Dirichlet laid down certain definite sufficient conditions in regard to the nature of a function which is expansible, and found under these conditions the limiting value of the sum of n terms of the series. Dirichlet's determination of the sum of the series at a point of discontinuity has been criticized by Schläfli (see *Crelle's Journal*, vol. lxxii.) and by Du Bois-Reymond (*Mathm. Annalen*, vol. vii.), who maintained that the sum is really indeterminate. Their objection appears, however, to rest upon a misapprehension as to the meaning of the sum of the series; if x_1 be the point of discontinuity, it is possible to make x approach x_1, and n become indefinitely great, so that the sum of the series takes any assigned value between the two values $f(x_1+0)$, $f(x_1-0)$, whereas we ought to make $x=x_1$ first and afterwards $n=\infty$, and no other way of going to the double limit is really admissible. Other papers by Dircksen (*Crelle*, vol. iv.) and Bessel (*Astronomische Nachrichten*, vol. xvi.), on similar lines to those by Dirichlet, are of inferior importance. Many of the investigations subsequent to Dirichlet's have the object of freeing a function from some of the restrictions which were imposed upon it in Dirichlet's proof, but no complete set of necessary and sufficient conditions as to the nature of the function has been obtained. Lipschitz ("De explicatione per series trigonometricas," *Crelle's Journal*, vol. lxiii., 1864) showed that, under a certain condition, a function which has an infinite number of maxima and minima in the neighbourhood of a point is still expansible; his condition is that at the point of discontinuity β, $|f(\beta+\delta)-f(\beta)| < B\delta^{a}$ as δ converges to zero, B being a constant, and a a positive exponent; and his condition is not necessarily satisfied by a uniformly convergent function. A somewhat wider condition is

$$\underset{\delta=0}{L}\log\delta\{f(\beta+\delta)-f(\beta)\}=0,$$

for which Lipschitz's results would hold. This last condition is adopted by Dini in his treatise (*Sopra la Serie di Fourier*, &c. Pisa, 1880).

The modern period in the theory was inaugurated by the publication by Riemann in 1867 of his very important memoir, written in 1854, *Ueber die Darstellbarkeit einer Function durch eine trigonometrische Reihe*. The first part of his memoir contains a historical account of the work of previous investigators; in the second part, there is a discussion of the foundations of the Integral Calculus, and the third part is mainly devoted to a discussion of what can be inferred as to the nature of a function respecting the changes in its value for a continuous change in the variable, if the function is capable of representation by a trigonometrical series. Dirichlet and probably Riemann thought that all continuous functions were expansible; this view was refuted by Du Bois-Reymond (*Abh. der Bayer. Akad.*, vol. xii. 2). The first to call attention to the importance of the theory of uniform convergence of series in connexion with Fourier's Series was Stokes, in his memoir "On the critical values of the sums of periodic series" (*Camb. Phil. Trans.*, 1847; *Collected Papers*, vol. i.). As the method of determining the coefficients in a trigonometrical series is invalid unless the series converges in general uniformly, the question arose whether series with coefficients other than those of Fourier, exist which represent arbitrary functions. Heine showed (*Crelle's Journal*, vol. lxxi., 1870, and in his treatise *Kugelfunctionen*, vol. i.) that Fourier's Series is in general uniformly convergent, and that if there is a uniformly convergent series which represents a function, it is the only one of the kind. G. Cantor then showed (*Crelle's Journal*, vols. lxxii., lxxiii.) that even if uniform convergence be not demanded, there can be but one convergent expansion for a function, and that it is that of Fourier. In the *Math. Ann.*, vol. v., Cantor extended his investigation to functions having an infinite number of discontinuities. Important contributions to the theory of the series have been published by Du Bois-Reymond (*Abh. der Bayer. Akademie*, vol. xii., 1875, two memoirs, also in *Crelle's Journal*, vols. lxxiv., lxxvi., lxxix.), by Kronecker (*Berliner Berichte*, 1885), by O. Hölder (*Berliner Berichte*, 1885), by Jordan (*Comptes Rendus*, 1881, vol. xcii.), by Ascoli (*Math. Annal.*, 1873, and *Annali di Matematica*, vol. vi.), and by Genocchi (*Atti della R. Acc. di Torino*, vol. x., 1875). Hamilton's memoir on "Fluctuating Functions" (*Trans. R.I.A.*, vol. xix., 1842) may also be studied with profit in this connexion. A memoir by Brodén (*Math. Annalen*, vol. lii.) contains a good investigation of some of the most recent results on the subject.

The foregoing historical account has been mainly drawn from A. Sachse's work, "Versuch einer Geschichte der Darstellung willkürlicher Functionen einer Variabeln durch trigonometrische Reihen," published in *Schlömilch's Zeitschrift für Mathematik*. Supp., vol. xxv., 1880, and from a paper by G. A. Gibson "On the History of the Fourier Series" (*Proc. Ed. Math. Soc.*, vol. xi.). Reiff's *Geschichte der unendlichen Reihen* may also be consulted, and also the first part of Riemann's memoir referred to above. Besides Dini's treatise already referred to, there is a lucid treatment of the subject from an elementary point of view in C. Neumann's treatise, *Ueber die nach Kreis-, Kugel-, und Cylinder-Functionen fortschreitenden Entwickelungen*. Jordan's discussion of the subject in his *Cours l'Analyse* is worthy of attention; an account of functions with restricted oscillation is given in vol. i.; see also a paper by Study in the *Math. Annalen*, vol. xlvii. On the second mean-value theorem papers by Bonnet (*Brux. Mémoires*, vol. xxiii., 1849, *Liouville's Journal*, vol. xiv., 1849), by Du Bois-Reymond (*Crelle's Journal*, vol. lxxix., 1875), by Hankel (*Zeitschrift für Math. und Physik*, vol. xiv., 1869), by Meyer (*Math. Ann.*, vol. vi., 1872), and by Hölder (*Göttingen Anzeigen*, 1894) may be consulted. On the theory of uniform convergence of series, a memoir by Osgood (*American Journal*, vol. xix.) may be with advantage consulted. On the theory of series in general, a memoir by Baire (*Annali di Matematica*, Series III. vol. iii.) is of great importance. (E. W. H.)

Fourmies, a French town, in the arrondissement of Avesnes, department of Nord, 39 miles south-east of Valenciennes by rail, on an affluent of the Sambre. It is now one of the chief centres in France for wool combing and spinning. Three large establishments have, respectively, about 10,000, 12,000, and 19,000 spindles, while there are several others with upwards of 6000 spindles. A great variety of cloths is produced. The glass-works of Fourmies date from 1599, and were the first established in the north of France. Iron is worked in the vicinity, and there are important forges and foundries. Population (1881), 11,016; (1896), 12,957; (1901), 13,828.

Fowler, Sir John (1817–1898), English civil engineer, was born on 15th July 1817 at Wadsley Hall, near Sheffield, his father being a land-surveyor, who, though living in the neighbourhood of Sheffield, was chiefly employed in agricultural matters. At the age of nine John Fowler was sent to Mr Rider's private school near Ecclesfield, where he received a sound elementary education. At sixteen, having always been interested in engineering, he persuaded his father to allow him to go as pupil to John Towlerton Leather, the engineer of the Sheffield water-works. Mr Leather's uncle, Mr George Leather, was engineer of the Great Aire and Calder Navigation Company, of the Goole Docks, and other similar works, and Fowler passed occasionally into his employment, in which he acquired a thorough knowledge of hydraulic engineering. The era of railway construction soon swept both Fowler and his employers into its service, and one of his first employments under Mr G. Leather was to oppose the line of the Midland Railway, chosen by the Stephensons, which left Sheffield on a branch line, and was therefore strongly resented by the inhabitants. The prestige of the Stephensons carried all before it, but in later life Sir John Fowler had the satisfaction of seeing the opposition of his clients justified, and Sheffield placed on the main line. In 1838 he went into the office of Mr John Urpeth Rastrick, one of the leading railway engineers of the day, where he was employed in designing bridges for the line from London to Brighton, and also in surveying for railways in Lancashire. In 1839 he went as representative of Mr G. Leather to take charge of the construction of the Stockton and Hartlepool Railway. He remained as manager of this railway after he had superintended its construction, an experience which he afterwards valued highly as being extremely useful as well as probably unique. In 1844 he began his independent career as an engineer, and from the first was largely employed, more particularly in laying out the small railway systems which eventually were amalgamated under the title of the Manchester, Sheffield, and Lincolnshire. In the course of this work he designed a bridge known as Torksey Bridge, which was disallowed by the Board of Trade inspector, Captain (afterwards Field-Marshal Sir) Lintorn Simmons, R.E. The engineering profession espoused Fowler's side in the controversy which followed, and as a result the verdict of the Board of Trade was modified. The episode was the beginning of a warm friendship between these distinguished representatives of civil and military engineering. Fowler was also engaged in the making of railways in Ireland, and in 1867 he was selected by Mr Disraeli to serve on a commission to advise the Government in respect of a proposal for a state-purchase of the Irish railway system. He also carried out considerable works in relation to the Nene Valley drainage and the reclamation of land at the Norfolk estuary. In 1865 he was elected president of the Institution of Civil Engineers, the youngest president who had ever sat in the chair. He was strongly opposed to the project of a Channel tunnel to France, and in 1872 he endeavoured to obtain the consent of parliament to a Channel ferry scheme, whereby trains were to be transported across the strait in large ferry steamers. The proposal involved the making of enlarged harbours at Dover, and Andrecelles on the French coast. The Bill was thrown out by the casting vote of the chairman of a committee of the House of Lords. In 1875 he was enabled to render, in his private capacity, a signal service to the Italian Government, which was much embarrassed by impracticable proposals pressed on it by Garibaldi for a rectification of the course of the Tiber, and other engineering works. Mr Fowler had several interviews with the Italian patriot, and persuaded him of the impracticable nature of his plan, thereby obtaining for the Government leisure to devise a more reasonable scheme. These, however, were minor employments. Fowler will chiefly be remembered as the engineer of the London Metropolitan Railway and (along with his partner, Sir Benjamin Baker) of the Forth Bridge, and from his engagement for eight years from 1871 as general engineering adviser to the Government of Ismail, the Khedive of Egypt. The Metropolitan was a pioneer effort in underground railways. The noteworthy point about it is, that it was made not by tunnelling, but by excavating from the surface and then covering in the permanent way with buildings and roads. Sir John lived to be one of the engineers officially connected with the deep tunnelling system extensively adopted in London for deep electric railways. Though his engagement in Egypt resulted in the completion of no great work, it is of considerable historical and economic interest. He projected a railway to the Sudan, and also the reparation of the barrage. These and many other plans came to an end owing to financial reasons. But the maps and surveys for the railway were given to the War Office, and proved most useful to Lord Wolseley in his Nile expedition. For this service Fowler was made K.C.M.G. (1885). On the completion of the Forth Bridge he was made a baronet (1890). Sir John Fowler was a great practical rather than a great scientific engineer. He was reaching man's estate when railway construction began, and the hour belonged to the great organizer as well as to the great inventor. He was a man of very catholic powers of enjoyment, his profession, society, sport, and the making of his Highland home at Braemore, being all keen sources of pleasure. He died at Bournemouth on 20th November 1898. (T. M.*)

Fox Channel, an inlet separating the south-western portion of Baffin Land, known as Fox Land, from Southampton Island and Melville Peninsula, extends from about 64° to 69° N. lat. and from 75° to 81° W. long. It is connected with the Gulf of Boothia by Fury and Hecla Strait.

Fox, Sir William (1812–1893), New Zealand statesman, was the third son of George Townshend Fox, deputy-lieutenant for Durham County. He was born in England on 9th June 1812, and educated at Wadham College, Oxford, where he took his B.A. in 1832, proceeding to his M.A. seven years later. Called to the bar in 1842, he emigrated immediately thereafter to New Zealand, where, on the death of Captain Arthur Wakefield, killed in 1843 in the Wairau massacre, he became the New Zealand Company's agent for the South Island. While holding this position he made a memorable exploring march on foot from Nelson to Canterbury, through Cannibal Gorge, in the course of which he discovered the fertile pastoral country of Amuri. In 1848 Governor Grey made Fox attorney-general, but he gave up the post almost at once in order to join the agitation, then at its height, for a free constitution. As the political agent of the Wellington settlers he sailed to London in 1850 to urge their demands in Downing Street. The Colonial Office, however, refused to recognize him, and, after publishing a sketch of the New Zealand settlements, *The Six Colonies of New Zealand*, and travelling in the United States, he returned to New Zealand and again threw himself with energy into public affairs. When government by responsible ministers was at last initiated, in 1856, Fox ousted the first ministry and formed a cabinet, only to be himself beaten in turn after holding office but thirteen days. In 1861 he regained office, and was somewhat more fortunate, for he remained premier for nearly thirteen months. Again, in the latter part of 1863 he took office: this time with Sir Frederick Whitaker as premier, an arrangement which endured for another thirteen months. Fox's third premiership began in 1869 and lasted until 1872. His fourth, which was a matter of temporary convenience to his party, lasted only five weeks in March and April 1873. Soon afterwards he left politics, and, though he reappeared after some years and led the attack which overthrew Sir George Grey's ministry in 1879, he lost his seat in the dissolution which followed in that year, and did not again enter parliament. He was made K.C.M.G. in 1880. For the thirty years between 1850 and 1880 Sir William Fox was one of the half-dozen most notable public men in the colony. Impulsive and controversial, a fluent and rousing speaker, and a ready writer, his warm and sympathetic nature made him a good friend and a troublesome foe. He was considered for many years to be the most dangerous leader of the Opposition in the colony's parliament, though as premier he was at a disadvantage when measured against more patient and more astute party managers. His activities were first devoted to secure self-government for the New Zealand colonists. Afterwards his sympathies made him prominent among the champions of the Maori race, and he laboured indefatigably for their rights and to secure permanent peace with the tribes and a just settlement of their claims. It was during his third premiership that this peace, so long deferred, was at last gained, mainly through the influence and skill of Sir Donald M'Lean, native minister in the Fox cabinet. Finally, after Fox had left parliament he devoted himself, as joint-commissioner with Sir Francis Dillon Bell, to the adjustment of the native land-claims on the west coast of the North Island. The able reports of the commissioners were his last public service, and the carrying out of their recommendations gradually removed the last serious native trouble in New Zealand. When, however, in the course of the native wars from 1860 to 1870 the colonists of New Zealand were exposed to cruel and unjust imputations in England, Fox zealously defended them in a book, *The War in New Zealand* (1866), which was not only a spirited vindication of his fellow-settlers, but a scathing criticism of the generalship of the officers commanding the imperial troops in New Zealand. Throughout his life Fox was a consistent advocate of total abstinence. It was he who founded the New Zealand Alliance, and he undoubtedly aided the growth of the prohibition movement afterwards so strong in the colony. He died 23rd June 1893, exactly twelve months after his wife, Sarah, daughter of William Halcombe. (W. P. R.)

Fraga, a town of Spain, in the province of Huesca, on the river Cinca, on a high-road from Madrid to Barcelona. Population in 1897, 6792. There is trade in wheat, oil, hemp, fruit (for which it is famed), pigs, and cattle, and the local manufactures of linen, wool, soap, frieze, and bricks. Its streets are narrow and steep. The only important buildings are the town hall, the old parish church, formerly a mosque, and several convents.

Framingham, a town of Middlesex County, Massachusetts, U.S.A., has an area of 27 square miles of hilly surface, dotted with lakes and ponds. There are included within it three villages—Framingham Center, Saxonville, and South Framingham, the last being the most important. In this village intersect the Boston and Albany and a branch of the New York, New Haven, and Hartford railways. Population (1880), 6235; (1890), 9239; (1900), 11,302, of whom 2391 were foreign-born.

FRANCE.

1. Geography and Statistics.

On the western shore of Europe, between 51° 5′ and 42° 20′ N. lat., and 4° 42′ W. and 7° 39′ E. long., France is bounded on the N. by the English Channel and the Strait of Dover, on the N.E. by Belgium and Luxembourg, on the E. by Alsace-Lorraine (Germany), Switzerland, and Italy, on the S. by the Mediterranean and Spain, and on the W. by the Atlantic Ocean. Its greatest length, from the eastern extremity of the shore of France on the North Sea to the Serre de la Baque de Bordeillat in the Pyrénées-Orientales, is 605 miles; its greatest breadth, from the Pointe de Corsen on the west of Brittany to the easternmost point of the crest of the Vosges to the east of the village of Lubine, 552 miles. Total area 204,146 square miles (official survey), 207,081 (revised estimate of the ministry of War), or 207,170 (see table below).

Forests.—In relation to its total extent, France presents but a very limited area of forest land, amounting to only 34,220 square miles. Included under the denomination of "forest" are lands—*surfaces boisées*—which are *bush* rather than *forest.* The most wooded parts of France are the plateaux of the east and of the north-east, comprising the Forest de Haye, the Forest of Ardennes, and the Forest of Argonne. In the Parisian region there are the Forests of Compiègne (56 square miles), of Villers-Cotterêts, of Fontainebleau, &c. The Central Mountains and the Jura have still some considerable belts of wood, such as Mercoire, Aubrac, Chaux, no one forest, however, exceeding 45 square miles. The Forêt d'Orléans covers 152 square miles. The Alps and Pyrenees are in large part deforested, but efforts are being made in the way of reafforestation, &c., to minimize the effects of avalanches and sudden floods. Such are the remarkable labours in connexion with the Dévoluy and Cauterets. Between 1870 and 1900 more than 1200 square miles were replanted with various species of trees. The revenue of the forests, public and private, is estimated (1901) at £10,000,000. The value of the forest domain of the state exceeds £48,000,000. The production of the woods and forests, covering altogether about 17·88 per cent. of the entire surface of the country, is reckoned to amount annually to fully 32½ millions of cubic yards—an amount, however, still short by at least 8 millions of the consumption.

Climate.—Climatically, France is distinguished into two principal regions—that of the Atlantic, and that of the Mediterranean climate. It is further subdivided into local climates, generally grouped under the following seven designations:—(1) Parisian or Sequan climate, with a mean temperature of 50° F.; winters cold, summers mild; (2) Breton climate, with a mean temperature of 51·8° F.; winters mild, summers temperate, frequent rain; (3) Girondin climate (characterizing Bordeaux, Agen, Pau, &c.), having a mean of 53·6° F.; mild winters and hot summers; (4) Auvergne climate, comprising Cevennes, Plateau Central, Clermont, Limoges, and Rodez; mean temperature, 51·8° F.; with cold winters and hot summers; (5) Vosges climate (comprehending Épinal, Mézières, and Nancy), having a mean of 48·2° F.; long and severe winters, with hot summers; (6) Rhone climate (experienced by Lyons, Grenoble, and Bourg d'Oisans); mean temperature, 51·8° F.; cold and wet winters, hot summers; (7) Mediterranean climate, ruling at Valence, Nîmes, Nice, and Marseilles; mean temperature, 57·5° F.; mild winters and hot summers. This classification of the climate, which is the one of common acceptation, seems more precise and more practical than the old division according to the different zones of vegetation.

Geology.—Geologically, France may be distributed as follows:—(1) Volcanic regions, comprising the mountains of Auvergne, of Cantal, and of Velay; (2) the regions of Primitive rocks, comprehending the Cevennes, the Plateau Central, Pyrénées Centrales, the Alpine massifs Oisans, and of Mont Blanc, Vendée, and Brittany; (3) the regions of Primary rocks in Brittany, Cotentin, the Western Pyrenees, and Ardennes; (4) the regions of coal in the departments of Nord and Pas-de-Calais, in the Lyonese basin, and in patches in the plateaux of Cevennes; (5) the regions of Jurassic rocks in the Jura, Côte-d'Or, the plateaux adjacent to the Cevennes, Normandy, and the Alps of Vercors and Dévoluy; (6) the regions of Cretaceous rocks in Champagne, Picardy, and Corbières; (7) the regions of Tertiary strata in the Île de France, in the Landes, and in Périgord; (8) the regions of Quaternary layers in the basins of Paris, of Lyons, and of Toulouse.

Utilization of the Soil.—The entire surface of France measuring 204,092 square miles, the part laid out in agriculture, gardens, and prairies comprises 147,322 square miles, and in forests 34,220 square miles; the remainder, or 22,550 square miles, *i.e.*, about 11 per cent. of the whole surface, lying waste or uncultivated.

Flora and Fauna.—The indigenous flora comprises the ash, linden, oak, and chestnut in Northern and Central France; the yew, plane-tree, &c., in Southern France. The indigenous fauna includes the bear, now very rare, but still found in the Alps and the Pyrenees; the wolf, harbouring in the Cevennes and the Vosges mountains; the fox, the marten, the wild boar, the stag, the hare, and the rabbit. Among the birds are the eagle, the kite, the partridge, and the lark. Of the smaller reptiles may be mentioned the viper, the snake, and the lizard.

Geography and Human Culture.—The populations of the high plateaux, of the lands of granitic formation, and of raw climates, such as the people of Limousin or Auvergne in Central France, or of Lorraine in the east, are taller, robuster, ruder, and more weather-beaten, but also less vivacious, less versatile, less disposed to innovation, than are the inhabitants of the great plains of the Seine and the Loire, of maritime Languedoc, and the shores of the Mediterranean. This distinction of type and temperament, exemplified in the most striking manner in the contrast between the Vosgian and the Marseillese men, is carried also into the plane of politics, determining the one set of people as Conservatives, the other as Radicals. The great cities have all, or nearly all, arisen at the confluence of rivers, at easy altitudes, or along the sea coasts where at once the temperature is more moderate and communication with foreign countries of readier and larger attainment. The three great metallurgic areas of France—those of the Nord and Pas-de-Calais, the Saône-et-Loire, and the Lyonnais—are planted on regions of coal formation, and, on the other hand, the domains on which cattle are reared—in Brittany, Lorraine, and the Central Plateau—rest on crystalline or Jurassic strata. On the Cretaceous and Tertiary deposits—in the Île de France, Orléanais, Picardy, the riverine hills of the Garonne and the Gironde—is found the fertile land waving in wheat or mantled with vines.

Population.—The population of France, 36,905,788 in 1876, numbered 36,672,048 in 1881, 38,218,903 in 1886, 38,342,948 in 1891, 38,517,975 in 1896, and 38,595,500 in 1901. The following table gives the area in English square miles of each of the eighty-seven departments, with its population according to the census returns of 1881, 1896, and 1901 (provisional):—

Departments.	Area: English Square Miles.	Population.			Population per Square Mile, 1896.
		1881.	1896.	1901.	
Ain	2249	363,472	351,569	349,205	156·3
Aisne	2868	556,891	541,613	534,204	188·8
Allier	2899	416,759	424,378	421,074	148·9
Alpes, Basses-	2699	131,718	118,142	112,763	43·8
Alpes, Hautes-	2178	121,787	113,229	106,857	52·0
Alpes-Maritimes	1444	226,621	265,155	320,822	183·6
Ardèche	2145	376,867	363,501	349,961	169·5
Ardennes	2028	333,675	318,865	314,056	157·2
Ariège	1893	240,601	219,641	202,284	116·0
Aube	2327	255,326	251,436	245,596	108·1
Aude	2448	327,942	310,513	311,386	126·8
Aveyron	3386	415,075	389,464	377,559	115·0
Bouches-du-Rhône	2026	589,028	673,820	737,112	332·6
Calvados	2198	439,830	417,176	407,639	189·8
Cantal	2230	236,190	234,382	218,941	105·1
Charente	2306	370,822	356,236	344,376	154·5
Charente-Inférieure	2792	466,416	453,455	446,294	162·4
Cher	2819	351,405	347,725	342,889	123·4
Corrèze	2273	317,066	322,393	304,718	141·8
Corse (Corsica)	3368	272,639	290,168	276,829	86·2
Côte-d'Or	3392	382,819	368,168	358,708	108·5
Côtes-du-Nord	2787	627,585	616,074	597,032	221·1
Creuse	2164	278,782	279,366	259,138	129·1
Dordogne	3561	495,037	464,822	448,545	130·5
Doubs	2052	310,827	302,046	296,957	147·2
Drôme	2533	313,763	303,491	294,704	119·8
Eure	2331	364,291	340,652	331,184	146·1
Eure-et-Loir	2293	280,097	280,469	272,624	122·3
Finistère	2730	681,564	739,648	763,193	270·9
Gard	2270	415,629	416,036	418,470	183·3
Garonne, Haute-	2458	478,009	459,377	439,769	186·9
Gers	2429	281,532	250,472	236,204	103·1
Gironde	4141	748,703	809,902	820,781	195·6
Carry forward	83,717	12,468,768	12,393,384	12,251,874	...

Departments.	Area: English Square Miles.	Population.			Population per Square Mile, 1896.
		1881.	1896.	1901.	
Brought forward	83,717	12,468,768	12,393,384	12,251,874	...
Hérault	2403	441,527	469,684	488,285	195·5
Ille-et-Vilaine	2699	615,480	622,039	611,477	230·5
Indre	2666	287,705	289,206	286,961	108·5
Indre-et-Loire	2377	329,160	337,064	334,073	141·8
Isère	3180	580,271	568,933	563,813	178·9
Jura	1951	285,263	266,143	259,212	136·4
Landes	3615	301,143	292,884	291,657	81·0
Loir-et-Cher	2479	275,713	278,153	274,836	112·2
Loire	1853	599,836	625,336	644,532	337·5
Loire, Haute-	1931	316,461	516,699	306,671	267·6
Loire-Inférieure	2695	625,625	646,172	656,998	239·8
Loiret	2630	368,526	371,019	363,812	141·1
Lot	2018	280,269	240,403	223,736	119·1
Lot-et-Garonne	2079	312,081	286,377	276,607	137·7
Lozère	1996	143,565	132,151	124,049	66·2
Maine-et-Loire	2812	523,491	514,870	513,208	183·1
Manche	2475	526,377	500,052	488,361	202·0
Marne	3168	421,800	439,577	432,850	138·8
Marne, Haute-	2416	254,876	232,057	224,888	96·1
Mayenne	1987	344,881	321,187	311,207	161·6
Meurthe-et-Moselle	2037	419,317	466,417	484,002	229·0
Meuse	2409	289,861	290,384	283,136	120·5
Morbihan	2739	521,614	552,028	557,934	201·5
Nièvre	2659	347,576	333,899	319,506	125·6
Nord	2229	1,603,259	1,811,868	1,877,647	812·9
Oise	2272	404,555	404,511	405,642	178·0
Orne	2372	376,126	339,162	325,445	143·0
Pas-de-Calais	2606	819,022	906,249	949,968	347·8
Puy-de-Dôme	3090	566,064	555,078	529,181	179·6
Pyrénées, Basses-	2978	434,366	423,572	423,164	142·2
Pyrénées, Hautes-	1750	236,474	218,973	212,173	125·1
Pyrénées-Orientales	1599	208,855	208,387	209,447	130·3
Rhin, Haute- (Belfort)	235	74,244	88,047	91,765	387·4
Rhône	1104	741,470	839,329	835,157	760·3
Saône, Haute-	2075	295,905	272,891	265,179	131·5
Saône-et-Loire	3331	625,589	621,337	616,389	186·5
Sarthe	2412	438,917	425,077	422,944	176·2
Savoie	2389	266,438	259,790	249,460	108·7
Savoie, Haute-	1775	274,087	265,872	259,595	149·8
Seine	185	2,799,329	3,340,514	3,599,870	18056·8
Seine-Inférieure	2448	814,068	837,824	843,928	342·2
Seine-et-Marne	2273	348,991	359,044	355,638	158·0
Seine-et-Oise	2185	577,798	669,098	700,405	306·2
Sèvres, Deux-	2338	350,103	346,694	339,340	148·3
Somme	2423	550,837	543,279	534,101	224·2
Tarn	2232	359,223	339,827	326,396	152·3
Tarn-et-Garonne	1440	217,056	200,390	194,458	139·2
Var	2334	288,577	309,191	325,490	132·5
Vaucluse	1381	244,149	236,313	235,457	171·1
Vendée	2692	421,642	441,735	439637	164·1
Vienne	2712	340,295	338,114	333,896	124·7
Vienne, Haute-	2120	349,332	375,724	374,212	177·2
Vosges	2305	406,862	421,412	419,784	182·8
Yonne	2894	357,029	332,656	316,047	114·9
Total	207,170	37,672,048	38,517,975	38,595,500	186·0

The greater number of the French departments showed a decline in their population from 1881 to 1901. Those in which the decrease of population was most marked were: Basses-Alpes (18,955), Ariège (38,317), Aveyron (37,516), Dordogne (46,492), Eure (33,107), Gers (45,331), Lot (56,533), Orne (50,681), Yonne (40,982), departments all of them purely agricultural, lacking large cities as nuclei for population to rally round. The departments, on the other hand, showing an increase in their population were those in which the industries are developed, and in which, consequently, are centres of large population. While 38,517,975 represented the legal population (present and absent) of

France at the census of 1896, the population actually present at that date was only 38,269,011, or 248,964 less.

Of the population in 1896, 18,922,651 were males and 19,346,360 females, an excess of females over males of 423,709, *i.e.*, a little more than 11 per 1000, or about 506 females to every 494 males: a normal population pretty closely exemplified in all past censuses. The departments in which the female surplusage was most notable were Seine, with 151,073, or 9·5 per cent., more females than males out of a population of 3,308,007. Next, in less proportions, were Seine-Inférieure, with a surplus of 28,454 females out of a population of 829,364; Somme, with 12,835 females in excess among a population of 540,415; Manche, with a female surplus of 11,148; Haute-Garonne, 15,325; Morbihan, 13,893; Orne, 9868; Nord, 18,115. On the other hand, the male population predominated in Basses-Alpes to the number of 6981 out of a population of 117,619; in Hautes-Alpes, where the males outnumbered the females by 6113; Corsica, with a surplus of 6113 males; Drôme, with 6076 more males than females; Jura, 3139 males in excess; Haute-Rhin (Belfort), 6379; Meurthe-et-Moselle, 22,117.

In respect of nationality again, there were among the 38,269,011 inhabitants in 1896, 37,217,104 persons of French nationality; the remainder, 1,051,907, *i.e.*, 27 per 1000, being foreigners. All the departments included foreigners in their population: Calvados, in the north, numbering 1471; Cher, in the centre, 528; Alpes-Maritimes, in the south-east, 72,265; Bouches-du-Rhône, 94,728; Nord, 259,916; Seine, 191,687. The department having the largest infusion of foreigners is Alpes-Maritimes, in which 72,265, or 25 per cent., of the population is foreign.

The following table shows the distribution of the population according to their condition in respect of marriage:—

Males	Single	10,195,788,	*i.e.*, 266·6	per 1000 inhabitants.
	Married	7,689,997,	,, 201	,, ,,
	Widowers	1,011,313,	,, 26·35	,, ,,
	Divorced	25,553,	,, 0·65	,, ,,
Females	Single	9,465,874,	,, 247·4	,, ,,
	Married	7,728,854,	,, 202	,, ,,
	Widows	2,118,394,	,, 55·4	,, ,,
	Divorced	33,238,	,, 0·81	,, ,,

In respect of age, there were counted in 1896, 3,302,797 boys and 3,297,879 girls of less than ten years of age; 4,969,841 males and 5,065,994 females from ten to twenty-five years of age; and 10,644,637 men and 10,976,426 women from twenty-five years of age upwards. According to another division, there were, in 1896, 6,990,101 males and 7,009,533 females of less than twenty-one years of age; 1,623,805 males and 1,437,618 females from twenty up to twenty-four years of age; and 10,649,013 males and 10,982,487 females from twenty-five years of age and upwards; 40 men and 136 women were centenarians.

The following table shows the distribution of the active population of France according to their occupations in 1896:—

Occupations.	Males.	Females.	Total.
Forestry and agriculture	5,674,713	2,755,346	8,430,059
Manufacturing industries	3,488,077	1,890,292	5,378,369
Trade	1,030,977	572,840	1,603,817
Domestic service	217,197	751,867	969,064
Transport	551,731	160,880	712,611
Public service	584,134	104,959	689,093
Liberal professions	199,546	139,630	339,176
Mining, &c.	222,040	4,775	226,815
Fishing	66,388	5,238	71,626
Unclassed	26,318	20,390	46,708
Grand total	12,061,121	6,406,217	18,467,338

In 1901 there were in France fifteen towns having each more than 100,000 inhabitants. Their growth from 1876 to 1901 is shown in the following table:—

	1876.	1886.	1901.
Paris	1,988,806	2,344,550	2,660,559
Marseilles	318,868	376,143	494,769
Lyons	342,815	401,930	453,145
Bordeaux	215,140	240,582	257,471
Lille	162,775	188,272	215,431
Toulouse	131,642	147,317	147,696
St Étienne	126,019	127,482	146,671
Le Havre	92,068	112,074	129,044
Nantes	122,247	122,750	128,349
Nice	53,397	77,273	125,099
Roubaix	83,661	100,299	124,660
Rouen	104,893	107,163	115,914
Rheims	81,328	97,903	107,730
Nancy	66,303	79,038	102,463
Toulon	61,382	70,122	101,172

In the same years the following thirteen towns, now from 60,000 to 100,000 inhabitants, each had:—

	1876.	1886.	1901.
Amiens	66,896	80,288	90,038
Limoges	59,011	68,477	83,569
Angers	56,846	73,044	82,966
Brest	66,828	70,778	81,948
Nîmes	63,001	69,698	80,355
Tourcoing	33,895	58,209	79,468
Montpellier	55,258	56,765	76,364
Rennes	53,598	66,232	74,006
Dijon	45,607	...	70,428
Grenoble	43,054	52,484	68,052
Orléans	52,157	60,826	67,539
Tours	48,325	...	64,448
Le Mans	45,709	59,585	62,948

There were, besides, forty-one towns each having a population in 1901 of more than 30,000. The rural population in 1896 amounted to 23,492,123, or 60·9 per cent. of the entire population. The rural and urban population in 1872 were, the former 68·7, the latter 31·3 per cent. of the whole. There has accordingly been a very marked withdrawal of population from the country to the cities.

Movement of Population.

There were the following living births in France in the years specified:—

1874.	1881.	1891.	1899.
954,652	937,057	823,905	847,267

The yearly numerical mean of births for each of the following quinquennial periods was:—

1881–86.	1886–91.	1891–96.
932,000	884,000	877,000

These figures indicate a steady decrease.

The following were the numbers of legitimate and illegitimate births in the years specified:—

	1891.	1899.
Legitimate	758,969	772,657
Illegitimate	73,936	74,970

There were the following number of deaths in the years specified:—

1881.	1891.	1899.
828,828	876,882	816,233

The quinquennial mean of deaths fell from 841,000 for the period 1881–86 to 836,000 for the period of 1891–96. In 1881 the number of births exceeded the number of deaths by 108,229, and in 1896 by 93,700. The years 1891, 1892, and 1895 yielded an excess in the number of deaths over the number of births. In 1879 the number of still-born was 39,778; in 1882, 44,352; in 1886, 43,623; in 1891, 42,472; in 1896, 42,054; in 1899, 39,860. The birth-rate in 1899 was 22·1 per 1000; the death-rate 21·2 per 1000.

Marriage and Divorce.—The number of marriages registered in France amounted to 282,079 in 1881, 285,458 in 1891, and 295,752 in 1899, indicating a slight progress in the number of marriages. The number of divorces, 2950 in 1886, rose to 5752 in 1891, and 7179 in 1899.

Emigration.—The following figures of emigration are quoted from the statements of the ministry of the Interior. The statistics of emigration are, however, not drawn up in a strictly regular method, and the figures may therefore be taken with a certain reserve. In 1857–91 there were 285,873 French emigrants; in 1892, 5528; in 1893, 5300; in 1898, 4400.

Immigration.—There are no official annual statistics taken of the immigration into France any more than of the emigration from France. All that can be done is to cite the figures given in the census returns as to the number of foreigners on French territory. The foreigners in France numbered in the years named:—

1881.	1886.	1891.	1896.
1,001,090	1,126,531	1,130,211	1,051,907

In explanation of the last figures, it is to be remembered that the law of 1889 providing for automatic nationalization has contributed somewhat to the apparent diminution in the magnitude of the figures. In 1891 there were in France 39,687 English, 83,333 Germans, 465,860 Belgians, 286,042 Italians, and 83,117 Swiss. It is the Belgians and the Italians who have contributed the greatest number to the alien population in France since 1870.

Constitution.—The constitution of 1875, modified though it was in 1879 and 1884 in certain points, such as the suppression of senatorships which were irremovable and of the election of the Senate itself, has yet in its essential elements remained unchanged. From 1885 to 1889 the election of deputies was made on the plan of the *scrutin de liste départementale*, according to which each elector votes for as many deputies as the entire department returns to the Chamber; but in 1889 the *scrutin uninominal*, or one elector one vote, was re-established. In 1880 there were the following ministries, or heads of the great administrative departments—the Ministries of Justice, of the Interior, of Foreign Affairs, Finance, War, Marine and Colonies, Public Instruction, the Fine Arts and Worship, Agriculture and Commerce, and Public Works. Since then there have been constituted the separate ministries of Agriculture and of the Colonies, ministries which have become of extreme importance. France is divided into 87 departments, 360 arrondissements, 2865 cantons, and about 36,000 communes. The departmental organization has remained unchanged since 1875. Only one slight modification has been effected, the suppression of the arrondissements of St Denis and of Sceaux in the department of the Seine. The powers of the elected assemblies or general councils (*conseils généraux*) and their permanent delegations (*commissions départementales*) have remained to the present unaltered, though there is a large current of opinion in favour of administrative decentralization. On the other hand, the communal organization has been very markedly transformed by the law of 1884, which has increased the prerogatives of the municipal councils. This law, however, does not apply to Paris, which continues to be ruled by the former regulations. The municipal councils, representing the communes, comprise, according to the size of their population, from ten to thirty-six members. They formulate resolutions which either have the executive force of law, or need for their validity the sanction of the prefect. In all towns, whether large or small, the mayors are elected by the municipal council. The mayors are at once *officiers de l'état-civil*, executors of the decisions of the municipal council, judicial magistrates, and representatives of the central power. The number of deputy-mayors (*adjoints*) has been modified by the law of 1884: it is one in a commune of 2500 inhabitants, and two in a commune of from 2501 to 10,000. In communes of greater population there is in addition one deputy-mayor for every 25,000 inhabitants beyond that number, but in no case must the total exceed twelve, excepting at Lyons, where as many as seventeen are allowed.

Justice.—The judicial organization of France has undergone no alteration since the ninth edition of this work was published. According to the Statistics of Justice (1897), justices of the peace had, in 1897, 342,417 causes to hear; the civil tribunals 181,818, of which they settled 142,856; while the courts of appeal had to sit in trial on 21,848, of which 12,047 were determined. The number of judicial distraints (*ventes judiciaires*) was 23,988. The petitions for divorce and legal separation reached the number of 11,940. The commercial courts, again, had 209,066 disputed causes brought before them for decision, and settled 190,966 of them. The applications for bankruptcy and judicial liquidations numbered 17,342. In 1897 there were 3453 persons charged before the assize courts, and of them 980 were condemned for crimes against the person, and 1398 for crimes against property. Of these 2378 persons who were condemned, 2139 were males and 239 females. There were, further, 225,013 persons prosecuted for offences before the correctional courts (*tribunaux correctionnels*), and of these 207,926 were condemned to either fine or imprisonment. Theft alone furnished 43,677 charges; vagrancy and mendicity, 25,783. The common police cases numbered 385,276. The cases of felonious homicide in France throughout the quinquennial period (1892–97) have averaged 1·26 per 1000 inhabitants. The departments furnishing the smallest contingent of such cases were Jura (0·40 per cent. of the total number), Pyrénées-Orientales (0·31), and Mayenne (0·14). The departments, on the other hand, contributing the largest number of such cases were Bouches-du-Rhône (2 per cent. of the total number), Nord (2), Corsica (8), and Seine (9). Fourteen persons were in 1897 condemned to death, and of this number ten had their sentence commuted. The administration of the prisons is regulated by the law of the 9th June 1875, the first article of which enjoins that thenceforth the accused shall be kept separate from one another day and night. The condemned are subjected to individual imprisonment in cases in which the sentence pronounced upon them is for less than a year and a day. In case of the penalty exceeding the term of a year and a day, the condemned may claim the application of the same *régime*, and then by law his sentence is reduced by a quarter. The same law of 1875 has ordained the reconstruction of the metropolitan prisons, but the execution of this ordinance is not yet accomplished. Since the passing of the law of 1885, the *récidivistes*, those, namely, who, having been already condemned become guilty of new crimes or offences, are transported to the French colonies. The penitentiary population of the metropolis in both the central and departmental prisons (*maisons*) amounted on the 1st of January 1899 to the number of 33,695. The produce of prison labour in 1898 exceeded the value of 4,046,000 francs.

Religion.—The total expenditure set down in the state budget towards the support of the four recognized religious confessions (Roman Catholic, Calvinist, Lutheran, and Hebrew), together with the Mussulman confession in Algeria, an expenditure attached sometimes to the ministry of Public Instruction, sometimes to that of the Interior, and sometimes to that of Justice, amounted in 1901 to a little over 43 million francs. In recent years several amendments have been laid before the Chamber, aiming at the suppression of this item of the budget, but all have been rejected.

Roman Catholic.—The *curés*, though appointed by the bishops (whose nomination by the President of the Republic has to be confirmed by the canonical institution of the Pope), have also to be accepted by the Government. There are in France 17 archbishops, receiving a salary each of 15,000 francs ; under them are 67 bishops, with a salary each of 10,000 francs. The archbishops and bishops are assisted by 685 vicars, whose stipends range severally from 2500 to 4500 francs. Attached to each cathedral church, moreover, whether episcopal or archiepiscopal, are chapters of canons—orders doomed to ultimate extinction. In 1901 they numbered 695. The inferior orders comprise the *curés* (drawing salaries of from 1200 to 2400 francs each) to the number of 3451, *desservants* and curates (*vicaires*) to the number of 38,002. The total strength of the Roman Catholic clergy in France accordingly exceeds 42,000 persons. They are recruited from the seminaries, which are distinguished from one another as great and little, according to the grade of instruction they impart. The total grant made by the State to the Roman Catholic clergy amounts to about 41 million francs. The regular clergy are subdivided into congregations, recognized and non-recognized, the latter existing only by the tolerance of the Government. According to statistics published in 1900 by the ministry of the Interior, there were 127 congregations of men, 97 of which are not recognized, and 1276 congregations of women, of which 784 are not recognized. No table of the number of members associated with these has been drawn up, but it is estimated that the number of both sexes is about 150,000. The value of the known real estate belonging to convents is 1071 million francs, and that of the personal estate is at least 8000 million francs. Lastly, notwithstanding legal proscriptions, the Jesuits, reorganized, have established themselves in forty-eight departments.

Protestants.—The two Protestant forms of worship figure in the budget together at about 1,500,000 francs. The Reformed or Calvinist confession includes 628 pastors, who are paid salaries of from 1800 to 3000 francs a year. The Augsburg or Lutheran Church counts 62 pastors, paid at the same rate as the Calvinist pastors.

Jews.—The Hebrew Church costs the State yearly about 150,000 francs. Its service is conducted by 10 chief rabbis, receiving from 4000 to 12,000 francs each ; 24 ordinary rabbis, paid from 1750 to 2500 francs each ; and 23 officiating ministers, with salaries of from 600 to 2000 francs each.

Precise statistics are wanting of the number of followers of each confession. The Roman Catholics of France may be counted at 36 millions, the Protestants at 2 millions. As to the Hebrew Church, its followers are variously estimated at 50,000 and 100,000 ; more probably their number will be about 80,000. The Protestants have their chief seat in the departments of the centre and of the south along the range of the Cevennes. In this region Nîmes is the most important centre. Considerable sprinklings of them are also to be found in the two Charentes, in Dauphiné, in the Seine, and in Franche-Comté. The localities in which the Jews are most common are Paris, Lyons, and Bordeaux. There are also small groups of them in Provence, Lorraine, and Champagne.

Education.—Since the 16th May 1877—a critical date in the history of the Third Republic—profound changes have been introduced into the organization of public instruction. Along with the colonial expansion of France and the remodelling of its army, this transformation in education is the most considerable enterprise undertaken by the Government. To characterize the new departure in few words, public instruction has been developed in all directions and withdrawn as much as possible from the influence of the Church. Education of a primary kind has been made free and obligatory. Paul Bert and Jules Ferry are names associated with a thorough organic reconstruction which provoked many controversies and commotions.

General Organization.—At the head of public instruction is the minister of State, entitled the Grand-Master of the University. He is assisted by the Superior Council of Instruction. This body has been reorganized in a lay sense by the law of the 27th February 1880, and comprehends, in addition to the minister-president, five members of the Institute of France, nine persons designated by writ of the President of the Republic, forty professors of the three degrees of public instruction elected by their colleagues, and four delegates of free education. The whole territory of France is divided into sixteen academical districts, having their centres respectively at the seats of the academies, which by the law of 1896 have been transformed into universities. The capitals of these academic districts are Paris, Aix, Besançon, Bordeaux, Caen, Chambéry, Clermont-Ferrand, Dijon, Grenoble, Lille (formerly Douai), Lyons, Montpellier, Nancy, Poitiers, Rennes, Toulouse. Within the jurisdiction of each rector of a district are the three orders of instruction. He is assisted by an Academic Council which, like the Superior Council, was reorganized in 1880, and comprises, besides the rector-president, the district inspectors and a variable number of members nominated or elected. The district inspectors are each placed at the educational head of the departments constituting his academic district. Like the Superior Council, the Academic Councils exercise functions consultative and disciplinary. The budget of public instruction amounted in 1901 (in round numbers) to 206½ million francs. In 1847 it stood at 18 millions, in 1877 at 57 millions, in 1886 at 150 millions.

Superior Education.—This is given in the first place by the universities, which themselves comprise a variable number of faculties, namely, Law, Medicine, Theology, Letters, and Sciences. The degrees they confer are those of bachelor, licentiate, and doctor. A fellowship (*agrégation*) is a title rather than a degree, giving the right to teach in a secondary State institution. The right of conferring these degrees is reserved to the faculties of the State, the higher education being free, as will appear from certain figures below. In 1900 there were 29,377 students in the faculties of the State, of whom over 12,192 were at Paris University, and 1629 in the Roman Catholic institutes. It is mostly in the faculty of Law that these latter draw students, counting 1109 against 9700 of the State institutions. Other free or public establishments imparting higher education are, in the first category, the *École des Chartes, École des hautes Études*, &c. ; in the second category, the *École des Sciences politiques* and the *Collège des Sciences sociales.*

Secondary Education.—This is imparted by the lycées and colleges of the State and in free institutions. It is subdivided into a classical course, the right of giving instruction in which is earned by the acquisition of the diploma of bachelor in classics (Latin and Greek) ; and a modern course, the right of giving instruction in which belongs to any one having the modern bachelor's diploma (competence in living languages). The professors of public secondary education require to be fellows. They are trained—male professors in the *École normale supérieure* (for the classical branch) or in the *École normale de Cluny* (for the modern branch) ; female professors in the *École normale de Sèvres*. In 1900 there were 109 lycées for boys, 13 of them at Paris ; and 229 *Collèges Communaux*—a total of 338, against 324 in 1877. The total number of pupils amounted to 85,599. The secondary establishments for girls comprised, in 1900, 11,994 pupils. The first lycée dates only from 1881. With respect to the free secondary establishments, the lay ones comprised 10,182 pupils, and the clerical 91,825. The total number of young persons receiving secondary instruction amounted in 1900 to 203,838.

Primary Instruction is, by the law of the 16th June 1881, gratuitous, and by the law of the 28th March 1882, obligatory. Since the passing of the law of the 30th October 1886 primary public instruction may, in principle, be committed to the care only of lay masters and mistresses. The secularization of the schools has not yet, however, been universally accomplished, and there still remain 7000 to 8000 teachers belonging to the religious Congregations. From the age of six to that of thirteen a child is bound to attend a school, public or private, primary instruction being free, unless the parents prefer to have the education imparted at home. Permission to adopt this mode of instruction is given in the *Certificat d'Études.*

Public Schools.—Among them are to be distinguished infant schools (*Écoles maternelles*) ; primary elementary schools receiving children of from six to thirteen years of age—the schools which the laws of 1881 and 1882 had more particularly in view ; and the primary upper schools (*Écoles primaires supérieures*), designed to supplement the general instruction and prepare pupils for professional instruction.

In 1899 the number of pupils in attendance at the public infant schools amounted to 463,202 ; at the primary elementary public schools, 4,169,578 ; at the primary upper schools, 31,602. Altogether, then, these public infant and juvenile educational establishments comprised a population of more than 4,650,000—a register for 1899 which compares favourably with that of 1880, 4,200,000, and that of 1875, which hardly reached four millions. The masters and mistresses of the primary schools, elementary and higher, are trained in the normal departmental schools (*Écoles normales départementales*), which in 1899 counted 8036 male and female student-teachers, pretty equally divided. The professors of the training schools are themselves taken, the men from the higher training primary schools of St Cloud, the women from the schools of Fontenay-aux-Roses.

The budget of primary education, for which, between 1880 and 1901, very remarkable amounts were voted, has risen from 16 million francs in 1875 to 28 millions in 1880, to 86 millions in 1885, to 121 millions in 1890, to 143 millions in 1895, and to 155 millions in 1901.

Free Schools.—Before any one can exercise the functions of a male or female teacher in a free school (*École libre*), it is necessary for him or her to have a certificate of competency (*brevet de capacité*). Such certificate is obtained after passing an examination before a departmental commission, the presidency of which belongs to the academic (district) inspector. The certificate may be either for an elementary or a higher school. The free schools in 1899 comprised 1624 pupils in the higher primary class, 1,369,721 in the elementary primary class, and 284,042 in the infant class of schools, giving a total of more than 1,655,000 pupils. Adding this to the figures of pupils in the public schools, we get, as the sum-total of the infant and juvenile school population of France in 1899–1900, about 6,300,000. In 1875 the corresponding figures were 4,800,000, and in 1880, 5,600,000.

Illiterate.—Owing to the new school laws, the proportion of illiterate persons in France has sensibly declined since 1875, and more especially since 1880. The 20 per cent. of conscripts entered as illiterate in 1875, dropped to 16 per cent. in 1880, 11·4 per cent. in 1885, thence to 7·7 per cent. in 1890, and to 4·8 per cent. in 1898. The illiterate statistics of the wedded tell pretty much the same tale. In the case of the men there were, in 1870, 27 per cent. of those entering the married state unable to either read or write; in 1880 the percentage had fallen to 19, in 1885 to 13, in 1890 to 8, and in 1898 to 5. In the case of women entering the married state, the corresponding percentages for 1870, 1880, 1885, 1890, and 1898 were 39, 24, 21, 13, and 8.

Adult or Evening Schools.—For some years, more particularly since 1892, a great extension has been given to after-school education by the establishment of evening classes for adults. This new departure aims at completing the school education, and, while confirming the learning which pupils have already acquired, it is intended further to benefit the youth of from thirteen to eighteen years of age by enabling them to attend classes in a variety of advanced subjects.

Under this category there were in 1899–1900, 38,191 courses of instruction given—27,842 for men and 10,349 for women. To this number have to be added at least 5000 courses provided by societies of popular instruction, syndicates, and labour bursaries (*bourses de travail*). The attendance at these classes exceeded the number of 950,000.

The Academies.—This summary review of education would scarcely be complete unless something were said about the Institute of France. It consists of five academies—the Académie Française, the Académie des Sciences, the Académie des Inscriptions et Belles Lettres, the Académie des Beaux-Arts, and the Académie des Sciences, Morales et Politiques. Each of these academies comprises forty titular members, elected by their colleagues, with the exception of the Académie des Sciences, which has sixty-three members, and the Académie des Beaux-Arts, forty-one. Each academy, moreover, with the exception of the Académie Française, nominates free members (*membres libres*) and foreign correspondents. The Académie de Médecine is a separate scientific institution (with 100 members), as is also the Société Nationale d'Agriculture.

Charitable Institutions.—The general organization of public charity has undergone no essential alteration. Several new laws, however, have been passed tending to complete the system. As is well known, the giving of relief to the needy is in France regarded as a moral but not a legal obligation. A special department of the ministry of the Interior, designated *Assistance Publique*, is charged with the general superintendence of this duty. The costs of relief to the poor devolve on the State or on the departments, but, above all, on the communes. Under the present constitution it is the commune in fact, and indeed of necessity, in which centres all organization of charity: the commune being in immediate touch with the needy, is enabled promptly to appreciate their wants and to render them relief.

Since the enforcement of the law of 1879 the *bureaux de bienfaisance* are administered by a commission composed of the mayor of the commune, acting as president, and six members. Their number in France amounts to about 18,060, and their yearly expenses reach the figure of 50 million francs. The income is drawn from the revenues of the real estate belonging to the *bureaux*, a poor-tax on playhouses, and donations and legacies of private persons, the last item amounting in 1897 to 43,550,000 francs. The *bureaux de bienfaisance* afford outdoor relief. Hospitals and asylums (*hospices*) receive the sick, and nurse them throughout their period of sickness; infirm and old people and infants are kept as pensioners. These, too, are under the administration of the commission. In 1898 there were 1736 hospital establishments, against 1654 in 1884. The staffs consisted of 34,254 persons, of whom 3373 were physicians and surgeons, and they contained 52,468 inmates. Paris alone has forty-eight such establishments, with 24,278 beds. The revenue of the hospitals and asylums amounted in 1898 to 145,300,000 francs, of which amount 51 millions were derived from their own resources, 32 from communal subventions, and the rest from pure charity. The expenses amounted to 139,233,000 francs.

Charity Children (*Enfants Assistés*).—This class is divided into three categories: First, foundlings really abandoned; second, children receiving help at their homes; third, children morally abandoned, *i.e.*, children of morally abandoned parents—a category dating from the law of 1889. The keeping of these children devolves at once on the State, the departments, and the communes. The total number of children of these three categories amounted in 1897 to 120,177, against 98,000 in 1885; and the total outlay on them was nearly 25 million francs, to which amount the contribution of the State was 4½ millions.

Lunatics.—Although since 1866 no longer legally bound to maintain lunatic asylums, most of the departments have yet kept them. Lunatics are supported either in such departmental asylums, or in the national asylum at Charenton, or in separate quarters of the infirmaries (*hospices*) set apart for them; but they may also be kept privately by their own people. The census of lunatics in 1897 figured at 64,639, of whom 30,355 were males and 34,284 females: 608 of them were entered in the national asylum, and 45,914 in the departmental and communal asylums.

Gratuitous Medical Aid.—This service has been organized and charged to the account of the departments by a law of 1893. By 1895 it had been brought into operation in 83 departments, and is now at work in all of them, more than 20 millions of people profiting by the service. The yearly contribution of the State treasury is 1,450,000 francs.

Old-Age Pensions.—By the law of 1897 the State has to contribute to the old-age pensions, fixed by the departments at not less than 90 and not more than 200 francs per person in favour of people aged seventy and upwards. This contribution must not, however, exceed 50 francs per head, nor be given in more cases than 2 per 1000 of the population. The law remains, then, only an affirmation of principle, which is valued in the budget, to express it in this way, at an inscription of 590,000 francs.

It may be remarked here that the whole contribution of the national treasury to institutions for relief of the poor amounts to only 12,684,000 francs.

Finance.—The minister of Finance exercises jurisdiction over all matters of public finance. He co-ordinates in one general budget the separate budgets prepared by his colleagues of the council of State, and provides ways and means. In principle, the budget of any one financial year has to be laid on the table of the Chamber of Deputies in the course of the ordinary session of the previous year, so that the discussion thereon, opening in October, may close before the 31st December. The financial year in France always begins on the 1st January, although various attempts have been made to postpone the initial date to the 1st of July. The *projet de loi*, laid before the Chamber of Deputies, is submitted to a special commission of thirty-three members elected for one year. This commission appoints a general reporter, and one or more special reporters for each of the ministries. The budget having been voted by the Chamber of Deputies and sent to the Senate, this assembly proceeds after the same fashion, but its financial commission numbers only twenty-seven members. When the budget is not voted within a practicable time, namely, before the 31st December, Parliament grants provisional twelfths, that is to say, the authorization to incur expenses up to the amount of those of the preceding year for one, two, or three months. This practice has of late years become generalized, and has sometimes been carried to as far as sixth-twelfths. The taxes authorized by the financial law are gathered by different bodies of agents; all the sums collected ultimately, however, find their way into the respective treasuries of the arrondissements, and thence into the general treasury. The *trésorier payeur général*, almost always resident at the capital of the department, has to give account at the central office for all the sums collected in his department, and to pay the charges due by the treasury. To this end he is in correspondence with the general direction of the movement of the funds, which has its seat at the ministry in Paris, and organizes the circulation of the public funds throughout the whole territory of the State. The *trésoriers payeurs généraux*, whose reponsibilities are weighty, receive, in the shape of fixed emoluments and allowances, considerable salaries, up to 120 and 130 thousand francs. These salaries have, however, in recent years been sensibly reduced. The taxes collected and the charges of the services paid, the budget is subjected to a double control, that of the *cour des comptes*, whose function it is to overhaul the accounts of the State, the departments, and the communes, and that of Parliament, which passes a vote of definitive settlement.

Expenditure.—Since 1875 the State budget of expenditure has passed through the most drastic fluctuations. This expenditure reached its maximum in 1883, from which date it descended in 1888 and 1889, to mount once more in an almost continuous ascent, yet by gradations of growth not too severe. The credits voted for the discharge of the public services are—at least have been, and may still be—classed under the two distinct heads of *ordinary* and of *extraordinary* budget. The ordinary budget of expenditure is that which has to be met exclusively by the produce of the taxes; the extraordinary budget of expenditure is that which has to be incurred in the way either of an immediate loan or in aid of the funds of the floating debt. Under various names it has existed since 1871.

The progress in the growth of the expenditure of France is shown in the following summary figures, the figures of expenditure for the specified years denoting respectively so many millions of francs:—

1875.	1880.	1885.	1890.	1895.	1901.
2980	3412	3472	3400	3510	3554

To these totals of expenditure the ordinary budget contributed:—

1875.	1880.	1885.	1890.	1895.	1901.
2670	2912	3293	3130	3430	3532

The figures contributed by the extraordinary budget of expenditure were:—

1875.	1880.	1885.	1890.	1895.	1901.
310	500	179	270	80	22

Although the term *budget extraordinaire* is no longer the usual one, there still remains in the State expenditure a good 76 millions of francs in excess of what is included in the ordinary budget.

From 1892, the successive ministers have, after the example of M. Rouvier, followed the practice of what has been named a policy of incorporation (*la politique des incorporations*); that is to say, they have entered in the ordinary budget, each under its own head, the expenditure on war, marine, and public works, items formerly figuring under the head of extraordinary expenditure. By this proceeding, country and Parliament have been enabled to obtain a more precise appreciation of the annual expenditure, a large part being no longer, as before, wrapped up under any disguise.

The following table gives an exact view of the progress of the costs of the principal public services since 1871, the figures representing so many millions of francs:—

	1876.	1884.	1894.	1901.
Public debt	928	1048	1127	1133
Guaranteed interests to railway companies	47	17·5	109·7	17
Sinking fund	164·7	156·5	63·8	37
Algeria	32	45·6	70·1	...[1]
Colonies	28	116	73·8	112
Public relief	15	17·6	17·2	19
Bourses	3·3	4·8	6	7·5
Subventions	47·5	80·7	54·3	54
Maintenance of works and new works	105·7	238·5	92·4	92
Régie	81·4	101·7	112·7	121
Repayments and restitutions	36·8	55	43	32·3
Administration	300	229	231	254
Salaries of the public officers (President, senators, and deputies)	11·6	12·9	13·1	13·3
War	841	690	627·5	691
Marine	164·6	193·8	265·9	327·7
Military pensions	74·4	115·2	134	141
Instruction	51·5	175	181	206
Monopolies	141·6	211	215	230

Distributed among the different ministerial departments, the budget of 1901 showed the following figures in millions of francs:—

Public debt, salaries, and finance	1520	Marine	327
Justice	35	Instruction and Fine Arts	223
Worship	43	Commerce and posts	242
Foreign affairs	16	Colonies	112
Interior	78	Agriculture	44
War	691	Public works	221

Altogether, the great increase since 1875 in the State expenditure has been incurred chiefly under the heads of debt, which in itself absorbs nearly a third of the budget; of the colonies, which have more than tripled their burden on the State; of public works, which are, however, more and more moderating their claims; of public instruction, which has been entirely reorganized; and of war.

Debt.—The public debt is subdivided into funded debt, terminable debt (*dette à terme*), and annuities. The capital of the public debt may be estimated, at the least, at 30 milliards, or £1200,000,000. The loans contracted by the Third Republic alone amount to 13 milliards, or £520,000,000. The costs of the war of 1870–71, which devolved in part on the present *régime*, are estimated at from 9 to 9½ milliards (£360 to £380 millions); and the charges of the colonial wars at nearly a milliard (£40,000,000). The interest on the consolidated debt amounted in 1876 to 743 million francs, in 1884 to 700 millions, in 1894 to 761 millions, and in 1901 to 675 millions. The difference in the amounts for 1894 and 1901 is due to the last conversion, in 1894, of 4½ per cents. to 3½ per cents. The terminable debt, consisting of 3 per cents. redeemable, was set down in 1876 at 116 million francs, in 1884 at 277 millions, in 1894 at 280 millions, and in 1901 at 324 millions. The annuities (*dette viagère*), again, figured in 1869 at 152 million francs, in 1876 at 158 millions, in 1884 at 176 millions, in 1894 at 187 millions, and in 1901 at 226 millions.

Besides this debt, which may be characterized as fixed, there is a floating debt contracted to meet the daily wants of the Treasury, a debt undergoing continuous extinction and reconstitution. In 1891 this floating debt reached the sum of 1077 million francs; in 1893, 953 millions; in 1895, 1282 millions; in 1900, about 1054 millions. It comprises 200,025 different bills, in particular *bons du trésor*, amounting to 100 to 250 millions.

Revenue.—The following table shows the rapid growth of the State revenue of France during the period 1875–1901, the figures for the specified years representing so many millions of francs:—

1875.	1880.	1885.	1890.	1895.	1901.
2705	2956	3056	3229	3428	3554

The revenue of 1901 was derived from the following sources (in millions of francs):—

Direct contributions	482	Customs	438
Taxes assimilated to direct contributions	40	Indirect contributions	649
Registration (*enregistrement*)	554	Sugar	200
Stamps	173	Monopolies	456
Tax on transferable securities (*valeurs mobilières*)	75	Posts telegraphs, and telephones	255
		Domains	55

[1] Since 1st January 1901 Algeria has had a budget of its own.

The following table shows the different parts played by the respective items of taxation in the growth of the State revenue from 1876 to 1901 (in millions of francs):—

	1876.	1884.	1894.	1901.
Direct contributions and taxes assimilated thereto .	412	416	501	522
Registration (of transfers of property, &c.) . .	470	519	548	556
Stamps	154	155	161	173
Tax on investments in public funds or bonds of private companies . . .	35	46	69	75
Customs	225	304	465	438
Indirect contributions . .	603	604	601	649
Sugar	189	171	203	200
Monopolies	352	406	411	456
Posts, &c.	133	163	207	255
Domains	57	43	47	55

Legislation.—During the period between 1875 and 1900 a number of modifications were introduced into the department of taxes. New taxes have been established. By the law of 1889, amended in 1898, a military tax is imposed on young men exempted or partially exempted from military service. This tax has given the revenue an average of 3 million francs yearly. A tax is also levied on velocipedes, yielding, in 1893, 1,350,000 francs. By a law of 1880 a tax, again, is laid on the revenues of religious Congregations, a tax subject to increase. It yields yearly about 3,800,000 francs. Another new tax is that levied, by law of 1893, on bourse operations, bringing to the State revenue some 7 million francs yearly. Then, again, various taxes have been amended in respect of the quotas attached. The assessment on patents was amended in 1889 and 1893, and the big shops have been more heavily taxed than before. The imposts on the revenue from money vested in public funds or private company bonds have been raised from the 3 per cent. fixed by the law of 1872 to 4 per cent. by law of 1890. Succession laws since 1892 have added at least 100 million francs to the yearly proceeds of the customs dues.

Lastly, special mention must be made of the tax laid on house property. From being a distributive impost (*impôt de répartition, i.e.,* fixed as a lump sum by Parliament and then distributed among the arrondissements, communes, and the persons affected) this tax was, by law of 1890, converted into a rating impost (*impôt de quotité—i.e.,* proportional to the revenue estimated to be derived from the buildings).

Projected Reforms.—Of late years the financial system of France has been much criticized. More particularly, repeated attempts have been made to substitute an income tax for the present direct contributions. A Bill in this sense was even brought forward by the Government in 1895. On the other hand, the laws about succession and the liquor law have been modified by the votes of the Chamber of Deputies; but these laws were definitely adopted in 1900 and 1901.

Direct Taxes.—The direct taxes, properly so called, are four in number:—First, the tax on building-property (*impôt foncier sur la propriéte bâtie*), amounting in 1889 to 84 million francs; and the tax on property not built on, amounting in 1900 to 100 millions. Second, the tax on house rent (*contribution personelle mobilière*), consisting, in fact, of two different contributions, one imposing a fixed charge on all citizens alike of each department, the charge, however, varying, according to the department, from 1 franc 50 centimes (=1s. 3d.) to 4 francs 50 centimes (=3s. 9d.); the other, levied on every proprietor or tenant in proportion to the rent of the house he lives in. The total number of properties in France charged in 1900 with the *contribution personelle mobilière* was 9,294,525, 9,193,025 being houses and 101,500 factories, and their lump letting value was 2982 million francs, of which sum 2778 millions was to the account of houses. Third, the contributions on doors and windows, levied in each case on the number of openings, a tax which in 1900 yielded 63 millions. Fourth, the license tax affecting industrial and commercial occupations. It consists of a fixed duty on the total value of one occupation, but varying according to the kind of occupation; and of an assessment in proportion to the letting value of the premises occupied. This tax gave a return in 1900 of 134 million francs, affecting as it did 1,728,200 persons. The department of the Seine by itself yielded 29 million francs, contributed by 174,100 persons. Lozère, on the other hand, at the bottom of the list, shows only 3967 licenses, contributing no more than 60,000 francs. The administration of the direct contributions includes, for the duty of determining the individual quotas, a director to each department assisted by *contrôleurs.* The direct taxes are collected by a *percepteur* residing at the chief town of the canton.

Indirect Contributions.—Under this head are comprised the taxes on "hygienic drinks" (wines and cider), producing 173 million francs; on beer, yielding 27 million francs; and on alcohol, returning to the revenue 300 million francs. There is a whole army of officials employed in the discharge of this service, which is one of the most costly.

Registration.—This tax comprises duties charged on the transfers of property in the way of business (*à titre onéreux*) or sales, bringing in to the Government 205 million francs; on changes in ownership of property effected *à titre gratuit,* in the way of donation or succession, the succession dues alone yield the Treasury 223 million francs yearly. The functionaries engaged in this service are called *conservateurs des hypothèques* and *receveurs.* Some of them are in receipt of high salaries, reaching in the Seine department to as high as 180 and 244 thousand francs.

Departmental Finances.—The French departments, as *personnes morales,* have their own separate budgets. It devolves on them to keep in repair the departmental highways and cross-roads, to support public instruction, and take charge of *enfants assistés.* The departmental expenditure amounts to about 320 million francs, and is met in large part by taxation additional to the four direct contributions.

Communal Finance.—The communes, in the matter of finance, enjoy a still larger autonomy than the departments. Their expenses in 1900, leaving Paris out of the account, amounted altogether to 760 million francs, against 695 millions in 1877. Their indebtedness, moreover, amounts to nearly two milliards. The communal revenue is derived from taxes levied for the superintendence of streets, roads, and buildings (yielding in 1900, 207 million francs), various local taxes, and tolls. Nearly 1500 communes were until 1899–1900 in receipt of revenue from this last source (*octroi*), but since 1st January 1901 the *octroi* has been either finally suppressed or else materially reduced. The gross revenues of the communes, Paris not included, was, in 1900, 181 million francs; with the inclusion of Paris, 333 millions. Next to the capital, the towns drawing the most revenue from the excise imposed on the importation of articles of consumption were Lyons (realizing 11 million francs), Marseilles (11 millions), Bordeaux (6 millions), and Lille (5 millions).

Army.—The recruitment of the army of France is regulated by the law of the 15th July 1889, which, superseding that of 1872, has on the one hand done away with volunteering, and on the other has reduced the period of active service from five to three years. According to the enactment in force, every Frenchman owes his country his personal service for the term of twenty-five years (Titre i.). Every year, in each commune, there is drawn up a list of the young men in it who the year before reached the age of twenty. These men have next to appear before a cantonal revising body (*conseil de révision cantonal*), composed of the prefect or his substitute, a councillor of the prefecture, a councillor-general, a councillor of the arrondissement, a superior officer, a *sous-intendant* (having direction in affairs of pay, provisions, clothing, &c.), the recruiting commandant, and a military doctor. The revising body decide on cases of exemption, of adjournment, and of dispensation. The exempt are young men who by reason of infirmity are unfit either for active or for auxiliary service, to which latter are assigned those in weakly condition included in the yearly contingent. The adjourned are those who, being neither infirm nor weakly, are yet not up to the required standard of vigour. The dispensed, that is, those required to serve only one year, are young men who engage to serve for ten years in a public educational institution; seminarists preparing themselves for the ministry of the Church in one of the recognized confessions; young men who have obtained or are prosecuting their studies with a view to obtaining the licentiate degree in letters or in science, a doctor's degree in law or in medicine, a "prix de Rome" or a prize at the conservatorium of music, or one of various other diplomas specified by the law; young men the practice of whose avocations is necessary to the support of their families, the dispensed in this last case, however, not to amount to more than 5 per cent. of the contingent enlisted for three years.

The soldier must be at least 1 mètre 54 centimètres (60·631 inches) in height (Titre iii.). The law provides for voluntary engagements, *i.e.,* it authorizes young men to anticipate the call to military service, and solicit their incorporation into the army at the age of eighteen years. In such cases, however, they are enrolled for three, four, or five years. The law further provides for the re-enlistment of medalled soldiers, corporals, and non-commissioned officers. Such re-engagements, covering two, three, or five years' effective service, and capable of extension to fifteen years, date from the time of the legal expiry of active service. Soldiers so re-enlisting are entitled to a bounty, to a high daily pay, and at the conclusion of the service to a pension (Titre iv.). The number of the re-enlisted is 16,000.

Effective Strength. — Every French citizen owes his country twenty-five years' service. He passes successively into the active army; into the reserve of the active army, in which he completes two periods of service of twenty-eight days each; into the territorial army and its reserve, in which he completes two periods of thirteen days each. The total peace strength of the active army provided for in the budget was, in 1898 557,000 men, as against 508,000 in 1893, and 488,000 in 1888. The number of conscripts who appeared before the *conseils de révision* was, in 1888, 295,000; in 1893, 330,000; in 1898, 331,000. Of these 331,000, 232,000 passed muster as up to the required standard; 74,000 of them being enrolled for one year, and 158,000 for periods of two and three years. The number of officers, on the other hand, slightly exceeded 28,000. The full war strength of the army of France comprises, according to careful estimates, about 4,250,000 men. Under the law of 1872 the utmost effective strength at disposal in case of mobilization was 3,800,000 men.

Military Organization.—The President of the Republic makes the appointments to all military offices, and may therefore be considered the supreme head of the army, though he does not command it. The command belongs to the Minister of War, who is assisted by the generalíssimo, the actual commander on the field; by the brigade-major (*chef d'état major*), whose business it is to plan the campaign; and by the superior council of war, composed of nine members. The ministry of War is itself divided into branches corresponding to the different services—infantry, cavalry, engineering, commissariat, ammunition, health.

France is divided into two military governments, Paris and Lyons, and into twenty *corps d'armée;* Nancy having been created a new district since the ninth edition was published. Each army corps consists of two divisions of infantry, one brigade of cavalry, one brigade of artillery, one battalion of engineers, and one squadron of the military train, an organization maintained alike in peace and in war.

The active army comprises 163 infantry regiments of the line; 30 battalions of chasseurs-à-pied, stationed preferably in the Alps and the Vosges; 4 regiments of Zouaves; 4 regiments of tirailleurs algériens; 2 régiments étrangères, constituting the légion étrangère, recruited by way of enlistment; 5 battalions of African light infantry; 13 regiments of cuirassiers, 31 of dragoons, 21 of chasseurs, 14 of hussars, 6 of chasseurs d'Afrique, 4 of Spahis; 16 battalions of foot artillery; 40 regiments of horse artillery; 7 regiments of engineers; and 19 squadrons of train. There is further at Paris the légion de la Garde Républicaine, the régiment des sapeurs pompiers, also for the whole of the territory, and 19 legions of Gendarmerie.

In 1898 the infantry of the line were numbered at 273,000 men; the Zouaves at 13,000; the tirailleurs algériens at 15,000; the légion étrangère at 10,000; the chasseurs-à-pied at 29,000; the light infantry at 8000—or some 348,000 men as the total strength. The dragoons, cuirassiers, chasseurs, and hussars made up 66,000 men; the chasseurs d'Afrique and Spahis, 9000—or a total of 75,000. The foot artillery mustered 14,000 soldiers, and the horse artillery 64,000, to which had to be added 4000 artillery artificers—a total of 82,000. The engineers were set down (1898) at 15,000, and the train at 13,000. There are various other corps forming the complement.

According to the budget for 1900, the total effective of the French army was 539,515 men, exclusive of 25,693 for the gendarmerie and Garde Républicaine. The total number of officers was in addition 29,740.

The mean strength of a regiment of the line stands at about 1800 men; that of a regiment of cavalry at 850; that of a regiment of mounted artillery at 1600.

Military Schools.—The higher military school is intended for the training of staff officers, who are said to be "brevetés." It receives students who have passed a competitive examination at which officers of all arms are represented. It enrols yearly 70 to 90 new officers, whom it keeps in training for two years. The function of the polytechnic school (*École polytechnique*) is to prepare artillery and engineer officers. It admits yearly 225 students, the period of whose training is two years. At the end of this course, those who have gained inclusion in the first class are free to enter the corps des ingénieurs de l'état (roads and bridges, mines, &c.). The military school of St Cyr, receiving annually 450 young men, has the task of training infantry and cavalry officers. Its course of study is also for two years. Other military schools are the military prytaneum of La Flèche, the artillery and engineer school at Fontainebleau, the cavalry school at Saumur, an ammunition school, a military medical and pharmaceutical school, at the Val de Grâce in Paris, l'école du service de santé militaire at Lyons, the school of commissariat at Vincennes, an école normale de gymnastique, shooting artillery and pyrotechnic schools, a military infantry school at St Maixent, a school of artillery at Versailles, and various preparatory schools for soldiers' children.

Fortified Places.—The region of the north of France, along a frontier of 341 miles, is defended by Dunkirk, Calais, Lille, Valenciennes, and Maubeuge, fortresses of the first class; the entrenched camp of Laon, first class; La Fère, second class; Paris, third class. The Lorraine frontier on the north-east is defended by the entrenched camps of Toul and Verdun, first class; Reims, second class. The Vosges frontier, 93 miles in length, is protected by the first-class fortresses of Épinal and Toul, and the second-class fortification of Langres, on the Plateau de Langres. The Jura frontier, 180 miles long, is guarded by the stronghold of Pontarlier and the entrenched camp of Besançon, as also by the second-class forts of Dijon, planted on the escarpments of the Côte-d'Or. The frontier at the Alps is 427 miles long. Its fortifications are Albertville, Grenoble, Briançon, and Nice. And an enemy, if he succeeded in forcing the valleys of the Isère and the Durance, would still find himself confronted by the great entrenched camp of Lyons, resting against the mountains of Lyonnais. On the south, the Pyrenean frontier, extending 354 miles, is fortified only at its two extremities — Perpignan and Montlouis in the east, Bayonne in the west.

Navy.—The personal establishment of the French navy is recruited in part by voluntary enlistment, in part by appropriation to the naval service of a proportion of the yearly army contingent, in part by "maritime inscription," in which are enrolled the names of all lads and men from eighteen to fifty years of age engaged in fishing or in navigation. The number thus enrolled was, in 1899, 219,000, of whom the quarter of Marseilles alone furnished 11,800.

Personnel.—The officers of the French navy in 1899 included 15 vice-admirals, 30 rear-admirals, 125 *capitaines de vaisseau*, 215 *capitaines de frégate*, 754 lieutenants, 531 ensigns, and 219 cadets —in all 1889 officers. The rank and file was made up in 1899 of 1352 boatswains (*premiers maîtres*), 4910 boatswains' mates (*seconds maîtres*), 8921 *quartiers maîtres*, and 29,161 sailors; giving a total of 44,344 men. Lastly, the infantry in the service of the navy consists of thirteen regiments, with 1642 officers and 25,110 men; the artillery of two regiments, with 690 officers and 7411 men.

The French fleet on the 1st January 1899 consisted of—

- 34 armoured battleships of 341,747 tons, 274,119 horse-power, and 1425 guns;
- 5 armoured cruisers of 29,130 tons, 18,935 horse-power, and 126 guns;
- 7 coast-defence vessels of 33,084 tons, 21,513 horse-power, and 68 guns;

8 armed cruisers (of a different class from the above, 5) 2 fast cruisers 6 cruisers, 1st class 16 cruisers, 2nd class 18 cruisers, 3rd class	having a total tonnage of 228,000, a total horse-power of 286,000, and 1334 guns.

The navy further included 10 torpedo-boat destroyers, 19 gunboats, 22 advice boats, 24 transports, 14 sloops, 10 torpedo despatch boats, 263 torpedoes, and 3 submarine boats.

Altogether, the entire French fleet amounted to 461 vessels of 701,782 tons, 1,025,793 horse-power, with 3766 guns; and, in process of construction, 1 battleship, 8 cruisers, 5 torpedo-destroyers, &c. The programme of new construction to be continued or undertaken in 1899 comprised the following ships building in dockyards:—7 battleships, 14 first-class armoured cruisers, 4 fast cruisers, 1 second-class protected cruiser, 2 third-class protected cruisers, 1 first-class sloop, 2 torpedo-gunboats, 2 gunboats, 1 aviso (advice)-transport, 8 submarine boats, 6 first-class torpedo boats, 10 torpedo cruisers, 11 sea-going torpedo boats of 150 tons, 22 first-class torpedo boats of 86 to 90 tons, 11 torpedo boats of 85 tons, and 6 small torpedo boats—at an estimated cost, altogether, of £8,724,247. The expense of naval construction amounted from 1871 to 1880 to 245 million francs; from 1881 to 1890, to 387 millions; from 1891 to 1899, to 685 millions.

Naval Schools.—The *École supérieure de Marine*, corresponding to the *École supérieure de Guerre*, was after a short existence suppressed. The *École Navale* is intended for the training of officers.

Lads from fourteen to seventeen years of age are admitted to this institution, which has its seat at Brest. After completing their course in this school, the young officers go to pass a year on the *frégate École*. In addition there are schools of naval medicine at Toulon, Brest, and Rochefort, a school of naval warfare at Paris, and a torpedo school (*École des Torpilles*) at Toulon, &c.

Fortifications on the Coast.—Fortified places on the coast are those on the North Sea, namely, Dunkirk and Calais (extending along 43½ miles); those on the English Channel, protecting a stretch of 716 miles—at Boulogne, le Havre, Cherbourg, Granville, and St Malo; those extending 535 miles along the Atlantic—at Brest, Lorient, St Martin de Ré, Île d'Aix, Oléron, Rochelle, Rochefort, Estuary of the Gironde, Socoa; those stretching 388 miles along the Mediterranean coast—at Port Vendres, Cette, Toulon, Marseilles, St Tropez, Antibes, Villefranche.

Colonial Bases of Operation.—*Points d'appui* in the French colonies, serving as bases of operation for the Atlantic, Pacific, and Indian Ocean divisions of the fleet, have, by decree of 1898, been established at Fort de France (Martinique), Dakar (Senegal), Cape St Jacques (Cochin-China), Port Courbet (Tongking), Nouméa (New Caledonia), Diégo Suarez (Madagascar), Saintes (Guadeloupe), Port Phaeton (Tahiti), Libreville (Congo), and Obock.

2. Production and Industry.

Agriculture.—Agriculture figures in the budget at more than 44 million francs, and has been (by decree of 1881 and 1882) distributed into the four divisions of forests, breeding-stud, agriculture, and agricultural hydraulics. Encouragements of every kind, in the shape of premiums, subventions, and indemnities, are given to the rearing of cattle, viticulture, sericulture, the culture of flax and hemp, &c.

The most important movement, however, made in the interest of the agriculture of France since 1875 has been the marked growth of agricultural education. Whereas in 1870 there were but sixty institutes of agricultural tuition and fourteen professorial chairs, the number of such institutes in 1900 was 107, and of professorial chairs, 268. Among the schools imparting superior instruction, there have further to be enumerated an agronomic institute, three veterinary schools, and one school of forestry. The secondary agricultural schools include three national schools of agriculture, one dairy school, one school of industrial cultures, and one of horticulture. Third-class schools include forty-eight practical schools (*Écoles pratiques*), fourteen *fermes Écoles*, and twenty other establishments. Account has further to be made of five *chaires de facultés*, ninety departmental and 131 special professoriates, sixty-six agronomic stations, &c.

Agricultural Area.—According to the decennial official returns of 1892, there were 170,817 square miles laid out in agriculture (crops, grass, forests, and fallow), of which 153,506 square miles denoted private property. The arable land alone amounted to 99,503 square miles.

Cereals.—The area laid out in 1899 in cereals amounted to 28 per cent. of the entire territory. The following table shows the different acreages in France laid out in the cereal crops specified in 1888 and 1899:—

	1888.	1899.
	Acres.	Acres.
Wheat	17,235,991	17,141,806
Mixed Corn	756,779	553,280
Rye	4,023,240	3,577,683
Barley	2,207,439	1,990,827
Oats	9,223,666	9,734,334
Buckwheat	1,501,484	1,447,225
Maize	1,411,494	1,388,481

The mean yearly production of the different cereals for the periods specified was, in millions of bushels:—

	1876–85.	1886–95.	1896–97.
Wheat	279·647	284·563	283·937
Rye	68·684	64·625	56·925
Barley	50·586	47·179	42·281
Mixed Corn	17·107	12·188	7·370
Oats	221·974	239·992	236·780
Maize	26·815	27·310	29·466
Buckwheat	27·769	26·340	24·640

The production of wheat in 1899 was 354,433,000 bushels; mixed corn, 11,604,700 bushels; rye, 65,072,500 bushels; barley, 43,060,400 bushels; oats, 263,030,700 bushels; buckwheat, 22,372,500 bushels; maize, 24,845,500 bushels.

The following table shows in bushels the mean annual production of the different crops per hectare (2·471 acres) for the periods specified, as also the production for 1898:—

	1876–85.	1886–95.	1899.
Wheat	49·44	45·10	53·06
Rye	45·04	40·96	42·68
Barley	54·25	50·87	54·64
Mixed Corn	49·14	44·55	48·57
Oats	69·16	62·70	66·79
Maize	49·96	47·85	38·16
Buckwheat	47·54	45·37	37·19

The entire cereal production in 1899 was valued at 3396 million francs, a total much below that of 1882, which was valued at 5362 millions.

Potatoes and Beetroot.—The potato crop covered in 1899, 3,863,082 acres, against 3,651,036 acres in 1892. The weight of potatoes raised in 1899 amounted to 241,938,802 cwts., valued at £24,638,193. Mangold-wurzel covered in 1899, 11,045,213 acres, and its production amounted to 207,252,460 cwts., valued at £8,504,390. Beetroot (sugar) occupying in 1898 about three-fifths of the ground covered by, and producing about five-sevenths of the amount produced by, mangold-wurzel, yielded the value of £7,424,593.

Clover, &c.—The following table shows the acreages, the amounts produced, and the values of the *prairies artificielles* in 1899:—

Prairies Artificielles.	Acreage.	Amount of Produce in Cwts.	Value in £.
Trefoil	3,041,520	81,099,126	7,714,134
Lucerne	2,221,800	70,234,720	7,737,683
Sainfoin	2,504,400	45,678,640	4,638,160
Meadows and permanent pasture	15,842,400	384,200,097	39,480,000

Industrial Cultures.—The subjoined table shows the respective averages, amounts produced, and values of the various industrial crops in 1899:—

	Acreage.	Bushels of Produce.	Value in £.
Colza	142,236	2,298,272	778,661
Rape	14,248	208,927	62,355
		Cwts.	
Hemp	80,061	427,838[1]	630,005
Flax	46,537	432,515[1]	407,875
Tobacco	42,092	449,128	839,813
Hops	7,728	76,120	166,183

Vineyards.—In 1899 there were 4,504,320 acres covered with vineyards, against 4,446,000 acres in 1892, and 5,424,120 acres in 1882. The great invasion of the phylloxera lasted from 1881 to 1892. If the area now planted in vineyards is less by nearly 2 million acres than it was in 1857, viticulture has nevertheless fought a stubborn battle against the scourge. Certain departments, such as Hérault, Gironde, Aude, and Gard, have been under the necessity of completely renewing their plants. The production of wine in France, 738,782,000 gallons in 1882, 638,814,000 gallons in 1892, 592,174,000 in 1895, 702,746,000 in 1897, amounted to 936,200,000 gallons in 1899. The departments yielding the largest contribution of wine in 1899 were Aude, with 117 million gallons; Gard, with 79 million gallons; Hérault, with 264 million gallons; Pyrénées-Orientales, with 64 million gallons. Gironde and Côte-d'Or, whose Bordeaux and Burgundy wines are in special request, figure in the list of wine-producing places, the former with only 62 million gallons, the latter with 12 million gallons. The average production of wine per hectare (2·471 acres) reached its maximum in 1899 in the Seine (890 gallons), Hérault (1461 gallons), and Bouches-du-Rhône (1740 gallons). The minimum wine production per hectare, on the other hand, was furnished by Corrèze, whose wine contribution was 102 gallons a hectare (or nearly 48 gallons an acre), and Alpes-Maritimes, which yielded 129 gallons per hectare. The average production per hectare throughout France was 578·3 gallons (134·9 gallons an acre).

[1] Seed and fibre.

The total value of the wine production, which amounted to 905 million francs in 1892, 755 millions in 1897, was 1,193,056,820 francs in 1899.

Fruits.—The value of the total crop of chestnuts in the country in 1899 was £1,450,223; walnuts, £533,202; olives, £699,998; cider-apples, £5,190,513; plums, £306,758; mulberry leaves, £416,014.

Silk Culture.—The sericultural production in 1898 amounted to 15,385,376 lb of cocoons; 156,202 lb of cocoons were exported, valued at £33,184, and 7,812,867 lb of raw silk, valued at £5,388,866.

Live Stock.—On the 31st December 1899 the number of farm animals was 2,917,160 horses, 204,750 mules, 357,820 asses, 13,550,880 cattle (including bulls, oxen, cows, and calves), 21,357,660 sheep, 6,305,200 pigs, 1,504,390 goats. According to the census of 1892, there were 47,471,178 farm animals of the value of 5200 million francs; viz., 2,794,529 horses, 217,083 mules, 366,895 asses, 13,708,997 cattle, 21,115,713 sheep, 7,421,073 pigs, and 1,845,088 goats. The census of 1892 valued the horses at 1166 million francs, the asses at 34 millions, the mules at 80 millions, the cattle at 3 milliards, the sheep at 466 millions, the pigs at 500 millions, the goats at 28 millions. Poultry in 1897 figured at the number of 85 millions (54 millions cocks and hens), valued at 166 million francs. Of the products of farm animals in 1899, the milk was estimated at £50,610,409, the wool at £2,230,939, the honey at £451,201, and the wax at £198,030.

Total Agricultural Return.—The gross revenue of the entire agriculture of France, without deduction of expenses, rent, interest, &c., oscillated in 1899 between 11 and 12 milliards of francs. According to the statistics of 1892, the gross production was valued at 314 francs per hectare for cereals, 627 francs per hectare for industrial cultures, 301 for forage plants, and 222 for grass.

Agricultural Allotments.—The decennial statistics of 1892 gave the number of agricultural allotments of all sorts and sizes at 4,792,814, of which 3,387,245 were in the immediate hands of the proprietors, who accordingly engrossed 71 per cent. of the agricultural holdings of France. The remainder, 1,405,569, or 29 per cent. of the total, were cultivated by farmers and *métayers*, *i.e.*, farmers giving part of the produce as rent. The number of proprietary agriculturists in 1892 had decreased by 138,097 from the figure of 1882, which was 3,525,342. The number of farmers and *métayers*, on the other hand, had increased by 95,665. Of the agricultural properties, again, the very small ones of less than 1 hectare (2·47 acres) covered, in 1892, 2·67 per cent. of the entire agricultural land. Small properties of 1 to 10 hectares (2·47 to 247 acres) covered 22·80 per cent. Medium properties of from 247 to 988 acres occupied 28·98 per cent. Large properties (above 988 acres) engrossed 45·55 per cent. of the whole. The figures of 1892, compared with those of 1882, show a slight increase in the number of very small properties (of less than 1 hectare). The small and medium properties, on the other hand, show a decline while the large properties have added to their number.

Agricultural Machines.—In 1892 the number of agricultural machines and motors of every kind was 4,321,000.

Value of French Soil.—From 1882 to 1892 the market value of land markedly declined. The average price of arable land per hectare fell from 2000 to 1600 francs; of viticultural land per hectare, from 2300 to 2100 francs; of meadow land, from 2·900 francs to 2·450 francs.

Sea Fisheries.—The products of the fishing industry were set down for 1896 at the value of 102 million francs, of which 93 millions was to the account of boat-fishing and 9 millions to the account of fishing from land. The Iceland fishing yielded in 1896, 28,600,000 lb, of the value of 6½ million francs; the Newfoundland fishing yielded 40,865,000 lb, valued at 7 million francs. The herring fishery for 1896 was set down at 100,100,000 lb, valued at 9,300,000 francs; the mackerel fishing at 55 millions lb, of 5 million francs' value; sardines at 39,600,000 lb, of 9 million francs' value; tunny at 112,200,000 lb, and 2½ million francs' value; salmon at 550,000 lb, and 1 million francs' value. The oyster culture yielded 2,378,200 lb of oysters, valued at 13,700,000 francs. The equipment of fishing craft has been encouraged, always with considerable success, by means of bounties, and in the year named 1222 undecked vessels and boats gained bounties for being fitted out as fishing craft.

Mineral Production.—The total mineral production, including the yield of its quarries, amounted in 1898 to 81,467,444 tons, of the value, at the place of production, of 640,659,439 francs.

Coal.—The output of combustible material (coal, anthracite, and lignite) in 1898 amounted to 32,356,000 tons, of the (pit-mouth) value of 363,153,417 francs. To this total (including anthracite) coal contributed 31,826,000 tons, lignite figuring with only 530,000 tons. In 1899 the output of coal amounted to 32,500,000 tons. The increase in the production of coal from 1870 to 1899 is shown by the following figures of output, which denote the number of tons:—

1870.	1880.	1890.	1897.	1899.
13,300,000	19,300,000	26,100,000	30,350,000	32,500,000

The output of coal in France, accordingly, more than doubled within the period 1870–99. The supply still, however, comes far short of the demands of industry, which in 1898 consumed nearly 43 million tons, valued at 842½ million francs. The import of coal continues therefore to be very considerable, amounting in 1898 to 11,917,000 tons.

The following table shows the respective contributions of the different basins of France to the total output of coal in 1898:—

Basins.	Mines in Work.	Output in Tons.
Nord and Pas-de-Calais (Valenciennes, Le Boulonnais)	35	19,287,000
Loire (St Étienne and Rave-de-Gier)	46	3,912,000
Bourgogne and Nivernais (Le Creusot, Blanzy, Épinac, &c.)	19	2,341,000
Gard (Alais, Aubenas, le Vigan)	21	1,974,000
Tarn, Aveyron (Aubin, Carmaux, &c.)	19	1,781,000
Bourbonnais (Commentry et Doyet, St Eloy)	14	1,123,000
Auvergne (Brassac, Champagnac, &c.)	13	464,000
Alps (le Drac, Maurienne, &c.)	50	217,000
Vosges (Ronchamp)	2	217,000
Hérault (Graissessac)	6	201,000
Creuse and Corrèze (Ahun, Aublac, &c.)	5	196,000
West (Le Maine, Vouvant, and Chantonnay)	9	119,000

The different coal-mining concessions granted by the Government numbered on the 1st January 1899, 634, extending over 1,364,724 acres, comprised in sixty-four departments. The total number of persons (men, women, and young persons from thirteen to sixteen years of age) engaged in the working of the coal mines in 1898 amounted to 148,600. The average daily wage of the miner in 1898 was 4 francs 23 centimes (about 3s. 6d.). The mean price of the (metric) ton of coal at the pit's mouth was, in 1898, 11 francs 22 centimes (9s. 4d.), as against 13 francs 45 centimes (11s. 2½d.) in 1877. At the centres of consumption 19 francs 86 centimes (16s. 6½d.) in 1898, as against 22 francs 50 centimes (18s. 9d) in 1877.

Peat was extracted in 1898 to the amount altogether of 104,000 tons, of the value of 1,507,000 francs, the department of the Somme alone contributing 33,000 tons.

The iron ore yielded by the mines amounted in 1898 to 4,731,000 tons, of the value, at the place of production, of 16 million francs, against 3,300,000 tons in 1883, and 3,000,000 tons in 1873. The following table shows the departments contributing the greatest quantities to this production, and the respective amounts of their contribution in 1897:—

	Tons.		Tons.
Meurthe-et-Moselle	3,804,000	Lot-et-Garonne	33,000
Saône-et-Loire	146,000	Ariège	26,000
Haute-Marne	146,000	Cher	19,000
Calvados	101,000	Isère	15,000
Pyrénées-Orientales	75,000	Tarn	10,000
Gard	61,000	Aude	10,000
Ardèche	46,000	Var	8,000
Aveyron	39,000		

There were employed 8200 persons in 1898 in iron-mining, at an average daily wage each of 4 francs 34 centimes (3s. 7½d.). The ore sold on an average at 3 francs 39 centimes (3s. 8d.) a ton. Other metallic seams yielded in 1898 altogether 458,200 tons, valued at nearly 16 million francs—argentiferous lead, 320,000 francs; zinc, 7 millions; pyrites, 4 million francs; manganese, 831,000 francs; antimony, 325,000 francs; arsenic, 109,000 francs. The mines of rock-salt, found chiefly in Lorraine and Franche-Comté, supplied, in 1898, 304,000 tons, valued at 4,371,000 francs.

The French quarries yielded in 1898, 42½ million tons of stone and other material, valued at 231,800,000 francs. Of this total value, 152 millions was to the account of building materials — building stone being valued at 49; gravel at 7; limestone at 30; cement, 26; plaster, 12; slate, 20. The industrial materials supplied by the quarries counted for 9 million francs; agricultural for 24 (phosphates alone, 15); paving materials, 36; and ornamental, 10 (marble, 5). The persons engaged in the open-air quarries numbered 108,152, and those in the subterranean quarries, 22,568.

Out of 294,362 persons employed in the coal and other mines and in quarries in 1898, 1722 met with accidents, 342 of them fatal.

Manufactures.—The steam apparatus in use in the various industries in 1898 comprised, exclusive of those employed in railways and boats, 70,755 engines, of 1,441,336 horse-power; 85,839 steam-boilers, and 30,175 receivers.

The increase in the amount of industrial horse-power at work between 1880 and 1898 was as follows:—

1880.	1885.	1890.	1895.	1897.	1898.
544,000	683,000	852,000	1,163,000	1,330,000	1,441,336

The number of industrial establishments, with the respective amounts of horse-power employed by them, in 1898 was as follows:—

Branches of Industry.	No. of Estabs.	No. of Steam-Engines.	Horse-Power.
Textile and Clothing	6,661	7,456	315,190
Metallurgic	5,114	8,454	260,811
Building	7,440	8,649	217,374
Mining and Quarrying	3,167	5,852	197,262
Alimentary	9,605	11,183	150,867
Agricultural	15,976	19,997	120,458
Chemical and Tanning	3,153	3,866	66,447
Paper, Printing, Furniture, &c.	3,464	3,862	62,649
State Services	483	1,436	50,278
Total	55,063	70,755	1,441,336

Metallurgy.—The total production of the industry in metals amounted in 1898 to 4,524,329 tons, valued at 610,680,500 francs (£24,427,220). Of this amount 4,465,000 tons, of the value of 560,615,000 francs (£22,424,620), was on account of iron and steel; and 59,329 tons, of the value of nearly 50 million francs (£2,000,000), on account of other metals. The production in pig-iron alone amounted to 2,525,000 tons, valued at £6,371,680; finished iron, 766,000 tons, of the value of £5,044,360; wrought steel, 1,174,000 tons, valued at £11,008,560. The products of the zinc industry amounted in 1898 to 37,155 tons, valued at nearly 18 million francs; lead, 10,920 tons, valued at nearly 3,700,000 francs; copper, 7834 tons, valued at 11 million francs; nickel, 1540 tons, valued at 4,600,000 francs; aluminium, 565 tons; antimony, 1226 tons. Fine gold was also produced to the amount of 587 lb, and silver to the amount of 199,282 lb.

The following figures show the production in tons of pig-iron for the years specified:—

1880.	1885.	1890.	1895.	1898.
1,725,000	1,631,000	1,734,000	2,004,000	2,525,000

To the total production of pig-iron in 1898 the department of Meurthe-et-Moselle contributed 1,551,000 tons, more than six-tenths of the whole. The department producing the next greatest amount of pig-iron, though at a long interval, was Nord, with 277,000 tons; next, with amounts varying from 106,000 to 75,000 tons, come Saône-et-Loire, Pas-de-Calais, Landes, Gard, and Loire-Inférieure. Twenty-two departments had blast-furnaces at work. To the total production of finished iron, amounting in 1898 to 766,000 tons, Nord alone contributed 297,000 tons; Ardennes, 90,000; Haute-Marne, 68,000; Meurthe-et-Moselle, 45,000; Saône-et-Loire, 47,000. In the total steel production of 1898, Bessemer and Martin steel ingots figured to the amount of 1,433,717 tons, of which Meurthe-et-Moselle contributed 545,333 tons; Nord, 218,000 tons; Saône-et-Loire, 142,919 tons; Pas-de-Calais, 79,964; Loire-Inférieure, 71,902. The most important departments for the production of wrought steel were Nord, producing in 1898 263,000 tons, Meurthe-et-Moselle (233,000), Saône-et-Loire (112,000), Loire (75,000), Pas-de-Calais (64,000). The lead manufactures have been carried on principally in the department of Loire-Inférieure; zinc manufactures in Nord, Aveyron, and Pas-de-Calais; copper in Ardennes, Pas-de-Calais, and Vaucluse. The number of workmen engaged in the manufacture of pig-iron in 1898 was 11,400; finished iron, 24,900; wrought steel, 35,000; in the manufacture of metals other than iron and steel, 3400, leaving out of account the much more numerous *personnel* occupied in secondary elaborations. The iron manufacture has declined since 1878, when it yielded 843,000 tons. In 1882 the iron production reached 1,073,000 tons. From 1888 to 1893 its average yield was 825,000 tons a year. The steel production of 1898 (1,174,000 tons) compares favourably with that of 1895 (715,000 tons), that of 1890 (582,000), that of 1885 (554,000), and that of 1880 (389,000).

Textiles.—The textile industry engrossed, in 1898, 22 per cent. of the total power of the steam-engines at work. Cotton spinning counts 5,300,000 spindles and more than 100,000 operatives. The consumption, figuring at 500,000 quintals (each 220½ lb) in 1877, 675,000 quintals in 1887, amounted to 1,400,000 in 1897. The cotton industry is distributed in three principal groups. The one longest established is that of Normandy, having its centres at Rouen, Havre, Evreux, Falaise, and Flers, comprising 250 factories, 2,200,000 spindles, and 20,000 looms. The group in the north of France sprang up about the middle of the 19th century, and has its centres at Lille, Tourcoing, Roubaix, St Quentin, which last manufactures cambric muslin, and Amiens, in which the manufacture of fustian is developed. More than 1,500,000 spindles are at work in the departments of Nord, Pas-de-Calais, Somme, and Aisne. Lastly, there is the Vosges group, which has experienced a large extension since the loss of Alsace-Lorraine, and now counts 900,000 spindles around Belfort, Épinal, St Dié, and Remiremont. Secondary groups are those of Nantes, Cholet, and Laval in the west, Troyes in Champagne (with 80,000 spindles), and Tarare in Lyonnais.

The *linen and hemp* industry employs 65,000 operatives, working 45,000 looms. It has its seat in the departments of Nord, Somme, Sarthe, and Mayenne.

The *woollen* industry comprises more than 2000 establishments and 120,000 employees. The number of its spindles exceeds three millions. In consequence of the introduction of steam power the number of persons employed has since 1865 been reduced by 120,000. The woollen manufacture is most extensively carried on in the north, where its centres are Roubaix, Tourcoing, Fourmies, disposing of nearly 1,800,000 spindles. Of second rank are Reims and Sedan in the Champagne group of wool-manufacturing places. The department of Marne alone counts 275,000 spindles. Notable also are Tarn, with 75,000 spindles, Elbeuf and Louviers in Normandy.

The *silk* industry engages more than 110,000 persons in the south-eastern departments of Drôme, Ardèche, Gard, Rhône, Loire, and Isère, and its production amounts to the annual value at least of 600 million francs. Lyons owes its prosperity to its enormous manufacture of silk stuffs of every kind. According to the Lyons Chamber of Commerce, the silk production of Lyons in 1899 amounted to the value of 415 million francs, which was also the value of 1898, while its production of pure silk in 1899 exceeded that of 1898 to the value of 700,000 francs. St Étienne is specially noted for its manufacture of ribbons.

The *sugar* industry has advanced even to the point of over-production. To insure the export of its products, a complicated system of bounties has been instituted. Sugar refineries are naturally to be found in the departments of the north, in which the culture of beetroot is general—Nord, Pas-de-Calais, Aisne, Oise, Somme. Refineries have also been set up at the seaports of Nantes, Bordeaux, Marseilles, Dunkirk, and Havre, which, however, since 1893 suffered from a severe sugar crisis. The sugar industry in 1898–99 counted 340 works, employing regularly 42,811 men, 3614 women, and 2186 children, and occasionally over 8000 extra hands. The yield of sugar, 347,785 metric tons in 1887–88, 593,647 tons in 1895–96, and 730,067 tons in 1897–98, amounted in 1898–99 to 737,902 tons, and in 1899–1900 to 805,421 tons.

Alcohol.—To the substances from which alcohol is distilled, grain contributes 18 per cent. of the total product; molasses, 32 per cent.; beetroot, 34 per cent.; and grapes, 2 per cent.; the rest being distilled from fruits, &c. The production amounted to 2,068,000 gallons in 1850, 34,782,000 gallons in 1880, 48,708,000 gallons in 1890, and 48,576,000 gallons in 1898. The consumption of alcohol passed from 2·57 pints per head in 1850 to 3·99 pints in 1860, 4·08 pints in 1870, 4·65 pints in 1880, 7·67 pints in 1890, 7·53 pints in 1897, 7·56 in 1898. The departments producing the most alcohol are Nord (16,208,300 gallons in 1898), Pas-de-Calais (7,370,000 gallons), Seine-Inférieure (2,928,000 gallons), Aisne (6,204,000 gallons).

Beer.—The most important breweries are in the north, at Lille, Cambrai, and Dunkirk, and in the east at Nancy. Since 1892 a very considerable number have also been established around Paris, Lyons, and Marseilles. The production, 66 million gallons in 1830, had increased to 264 millions in 1899.

Trade Unions.—These associations of workmen, authorized in 1884, have since developed very rapidly. In that year numbering only 68, by 1890 they had grown to the number of 1006, including 139,962 members; in 1895 they counted 2163, with a membership of 419,781; and in 1899 they counted 2695 associations, with a membership of 492,647. These figures refer exclusively to associations of workers. If to them be added the unions of employers, mixed unions, and agricultural unions, the total number of trade-unions in 1899 was 7081, with 1,192,260 members. There were in 1899, 65 *Bourses du Travail*, or Federations of trade-unions, with 239,449 members.

Wages.—Taking into account all the different industries, the average daily wage per workman was, according to official returns, in Paris 2s. 11d. from 1840 to 1845, 3s. 9d. from 1860 to 1865, and 5s. 1½d. from 1891 to 1893. In the provinces, the average daily wage per workman for these three periods was respectively 1s. 8½d., 2s. 3½d., and 3s. 4d. The average daily wage of the female worker for these periods was respectively in Paris 1s. 3½d., 1s. 5d., and 2s. 6d.; in the provinces, 10d., 1s. 1d., and 1s. 10d.

Commerce.—After, in 1860, embarking in free trade to the largest extent, France has gradually turned round towards protectionism; this system triumphed in the Customs Law of 1892, which imposed more or less considerable duties on imports—a law associated with the name of M. Méline. While raising the taxes both on agricultural products and manufactured goods, this law introduced, between France and all the Powers trading with her, relations different from those in the past. It left the Government free either to apply to foreign countries the general tariff or to enter into negotiations with them for the application, under certain conditions, of a minimum tariff. The *régime* of protection was further accentuated by raising the impost on corn from 5 to 7 francs per hectolitre (2¾ bushels). This system, however, against which a powerful party wages war, has at various times undergone modifications. On the one hand it became necessary, in face of an inadequate harvest, to suspend in 1898 the application of the law on the import of corn. On the other hand, in order to check the decline of exports and exercise the baleful effects of a prolonged customs war, a commercial treaty was in 1896 concluded with Switzerland, carrying with it a reduction, in respect of certain articles, of the imposts which had been fixed by the law of 1892. An accord was likewise in 1898 effected with Italy, which since 1886 had been in a state of economic rupture with France. Lastly, in July 1899, an accord was concluded with the United States of America. Almost all other countries, moreover, share in the benefit of the minimum tariff, and profit by the modifications it may successively undergo.

The *general* commerce with foreign countries, namely, of all goods entering and leaving France, amounted in 1861 to the value of 5745 million francs, in 1880 to 10,725 millions, in 1885 to 8886 millions, in 1890 to 10,292 millions, in 1895 to 9508 millions, and in 1897 to 9941 millions. In 1899 the general commerce figured at 11,381 million francs—an increase of 1440 millions on the amount of 1897, and of 1947 millions on the quinquennial average of 1894–98. Of the 11,381 million francs representing the general trade of France in 1899, the imports engrossed the larger half, namely, 5848 millions, *i.e.*, 710 millions more than in 1897, the exports being valued at 5533 millions, or 990 millions less than in 1897.

The *special* commerce of France, on the other hand, including, namely, the imports for home use and the exports of home produce, amounted in 1899 to the value of 8670 million francs, against a value of 7354 millions in 1897.

The fluctuations undergone by the special commerce of France in the course of the twenty-three years from 1876 to 1899 are shown in the following table:—

Year.	Imports for Home Use (in Millions of Francs).	Exports of Home Produce (in Millions of Francs).	Imports and Exports.
1876	3988	3575	7563
1880	5033	3467	8500
1885	4088	3088	7196
1890	4437	3753	8190
1895	3720	3374	7094
1897	3956	3598	7554
1898	4472	3511	7983
1899	4518	4152	8670

Divided in three classes, the imports for the years specified were, in millions of francs, as follows:—

	1892.	1895.	1897.	1898.	1899.
Food Products	1400	1036	1029	1506	951
Raw Products	2172	2101	2319	2348	2839
Manufactured Goods	615	583	608	618	728
Total	4187	3720	3956	4472	4518

The corresponding exports were:—

	1892.	1895.	1897.	1898.	1899.
Food Products	759	591	721	663	675
Raw Products	822	874	944	932	1210
Manufactured Goods	1879	1909	1933	1916	2267
Total	3460	3374	3598	3511	4152

The principal articles of import were, in millions of francs:—

Articles.	1892.	1895.	1897.	1899.
Raw Wool	319	308	343·7	467·4
Wine	305	212	280·3	267·4
Cereals	487	162	247·4	143·9
Raw Silk	258	226	266·4	370·6
Coal and Coke	185	167	189·5	258·2
Timber and Wood	103	130	154·6	157
Raw Cotton	207	167	205·7	177·6
Oil Seeds	154	157	135·6	166·1
Raw Hides	147	135	116·5	139·6
Coffee	145	177	105·4	89·6
Ores	64	49	62·7	87·9
Cattle	55	112	41·1	32·1
Sugar, Colonial	37	26	32	32·3
Machinery	55	59	67·6	103·6
Flax	61	60	51·4	56·1
Textiles, Woollen	56	42	40	40·7
Textiles, Silk	62	50	52	65·4
Textiles, Cotton	39	34	36·3	43·8
Horses	18	38	39·6	28·7
Fish (Sea)	32	38	32·9	36·6
Leather	24	28	26	32·9

The principal articles of export for the same years, in millions of francs, were:—

Articles.	1892.	1895.	1897.	1899.
Textiles, Woollen	329	323	265·5	264
Textiles, Silk	249	271	270·9	278·3
Textiles, Cotton	96	118	119·3	174·3
Wine	214	222	232·5	210·2
Raw Silk and Yarn	132	126	117·7	179·9
Raw Wool and Yarn	120	153	172·2	271·7
Small Ware	157	154	160·3	183·7
Leather	114	105	102·8	130·4
Leather Goods	112	83	69·4	75·9
Linen and Clothes	130	96	95·4	142·1
Metal Goods, Tools	82	68	79·5	91·5
Cheese and Butter	88	61	86·0	76·2
Spirits	66	48	51·9	47·6
Raw Sugar	36	25	88·6	65·7
Refined Sugar	55	41	45·4	46·2
Raw Hides	74	94	77·1	122·1
Chemical Products	58	62	75·4	83·7
Pottery and Glass Ware	49	49	56·6	65·3
Machinery	35	37	43·8	61·5
Oils	39	27	24·2	21·3

The following were the countries from which the imports (special trade) were mostly drawn, with their respective values, in millions of francs, for the years indicated:—

Countries.	1895.	1897.	1899.
United States	283	438	427
United Kingdom	496	485	590
Germany	310	309	360
Spain	213	247	239
Belgium	288	288	332
Russia	195	236	179
Argentine Republic	180	211	291
Algeria	246	238	271
British India	163	122	179
Italy	115	132	158
China	137	149	227
Turkey	92	107	102
Australia	69	80	95
Switzerland	67	79	93
Brazil	85	68	72
Austria	73	65	78
Sweden	55	63	70
Chile	55	50	66
Japan	59	81	93
Netherlands	46	39	44
Egypt	30	35	34
Hayti	48	26	31
Uruguay	36	27	27
Rumania	21	25	22

The French colonies, including Algeria, exported altogether into France (special trade) goods to the value of 197 million francs in 1881, 254 millions in 1886, 323 millions in 1891, 331 millions in 1896, 393 millions in 1897, and 461 millions in 1899.

The following are the principal countries receiving the exports of France, with their respective values, in millions of francs, for the years named:—

Countries.	1895.	1897.	1899.
United Kingdom	999	1132	1239
Belgium	497	513	605
Germany	334	380	457
Algeria	203	216	260
United States	289	242	255
Switzerland	163	191	216
Italy	134	151	192
Spain	109	99	148
Brazil	76	61	67
Argentine Republic	44	51	53
Turkey	51	49	49
Netherlands	46	46	51
Russia	22	26	43
Mexico	24	20	28
Egypt	19	24	22
Austria	17	15	20
British India	12	12	20
Denmark	15	16	14
Colombia	20	22	14
Japan	13	12	8

The exports from France (special trade) to the French colonies amounted to the value of 238 million francs in 1881, 246 millions in 1886, 280 millions in 1891, 332 millions in 1896, 358 millions in 1897, 477 millions in 1899. Of the goods to the value of 477 millions exported in 1899, 260 millions' worth was destined to Algeria, 46 millions to French Indo-China, 35 millions to Tunisia, 36 millions to Senegal, and 29 millions to Madagascar and dependencies.

The respective shares taken by the principal cities in its general trade, imports and exports combined, were, in millions of francs, in 1893 and 1899:—

	1893.	1899.
Marseilles	1766	2253
Havre	1646	1905
Paris	706	803
Dunkirk	519	741
Bordeaux	647	683
Boulogne	415	479
Rouen	210	262
Calais	175	249
Dieppe	171	342
Belfort, P.C.	178	208
Tourcoing	174	261

Shipping.—Since 1887 the tonnage of steamers has exceeded the tonnage of sailing vessels in the French mercantile service, the latter remaining almost stationary, contrary to what is the case in neighbouring countries, where the tonnage of sailing ships is on the decline. The French mercantile navy numbered in 1880, exclusive of boats engaged in coast-fishing, 15,058 vessels of 919,298 tons, of which 652 were steamers of 277,759 tons; in 1890, 15,111 vessels of 944,013 tons, of which 1110 were steamers of 499,921 tons; in 1893, 14,190 sailing vessels of 396,582 tons with 69,302 crews, and 1186 steamers of 498,841 tons and 14,374 crews; and in 1899, 14,262 sailing vessels of 450,636 tons with 68,031 crews, and 1227 steamers of 507,120 tons with 21,229 crews. Of the sailing vessels of 1899, 150 (14,507 tonnage) frequented European waters, and 264 (213,078 tonnage) the high seas. Of the steamers of 1899, 237 (197,067 tonnage) frequented European waters, and 173 (274,861 tonnage) the high seas—the rest being in the coasting-trade, port-service, and the fisheries. In 1888, 28,176 vessels (13,537,734 tonnage) entered, and 21,319 (9,354,225 tonnage) cleared the ports of France; in 1895, 24,374 vessels (13,221,595 tonnage) entered, and 20,032 vessels (9,272,889 tonnage) cleared; and in 1899 the entrances were 26,464 vessels (17,087,465 tonnage), of which 7828 vessels (4,297,444 tonnage) were under the French flag, while the clearances numbered 21,292 vessels (12,082,903 tonnage), of which 7527 vessels (4,425,880 tonnage) were under the French flag.

For a number of years the state of her mercantile sea-service has keenly engaged the attention of the public authorities of France. In spite, however, of the considerable assistance given to this interest by the Treasury in the shape of bounties, its condition is still recognized as open to improvement. The year 1899 may be regarded as exceptional.

Roads.—The national roads kept up by the State had altogether a length in 1899 of 24,052 miles. Of these 1466 miles were paved roads. The departmental roads maintained at the expense of the departments covered 19,263 miles. The cross-roads (*chemins vicinaux*), distinguished into three classes (*chemins de grande communication, d'intérêt commun*, and *ordinaires*), extended over 379,043 miles. The roads, national, departmental, and *vicinal*, have therefore altogether a length of over 422,300 miles.

Rivers and Canals.—The internal waterways actually navigated in 1899 had altogether a length of 12,269 kilomètres, or 7620 miles, of which 4608 miles were supplied by rivers and lakes, and 3012 miles by canals. There were, besides, 1826 miles of rivers navigable by rafts. The internal waterways, available at all times for boats drawing as much as 5·9 feet of water, had in 1899 a length altogether of 2934 miles—1297 miles river, and 1637 canal.

Railways.—The total railway lines measured in 1860, 4000 miles; in 1890, 20,666 miles; in 1899, 23,592 miles, besides 2754 miles of purely local railway. The following table, referring to lines of general interest open for traffic, indicates the development of railways in recent years:—

Year.	Length in English Miles.	Construction Cost (£1000).	Receipts (£1000).	Expenses (£1000).	Passengers (100,015).	Goods Carried (1000 tons).
1892	21,661	594,600	47,336	26,511	288,078	95,713
1895	22,505	620,840	50,542	27,362	348,852	100,834
1896	23,018	628,480	51,906	27,464	363,009	104,046
1897	23,152	635,920	53,514	27,871	374,755	108,399
1898	23,324	643,121	54,375	28,301	385,222	119,719
1899	23,592	651,315	58,167	29,513	400,437	126,311

The concessions made to the companies are valid for ninety-nine years, and will all terminate at different dates, from 1950 to 1960, when the lines will revert in full right to the State. Under the convention of 1883, the companies are bound to construct a certain number of new lines, the Treasury guaranteeing a certain dividend, ranging from 35 francs 50 centimes to 56 francs, according to the company, per primary share of 500 francs. The periods of State guarantee close, in the case of four of them, at the end of 1914, of a fifth in 1934, and of the last in 1935.

The receipts of the railways of general interest dropped between 1876 and 1899 from 43,300 francs to 38,400 francs, in consequence of the creation of numerous secondary lines with light traffic, and the net proceeds per kilomètre have likewise fallen from 22,000 to 18,800 francs. The profits of the companies, however, have, on the whole, been sensibly on the increase, amounting in 1899, after deductions of all expenses, to 712 million francs, against 593 millions in 1895. The total railway expenses in 1899 were 737 million francs, covered (with a margin) by 1449 million francs of receipts. The capital of the railways of general interest is estimated at 12 milliards of francs.

Narrow-gauge and normal railways of local interest covered on the 1st January 1900, 2759 miles in length, and the tramways, 2317 miles. The receipts of the local lines amounted to £868,676, and the expenses to £653,500. The receipts of the tramways reached £2,936,393, and the expenses £2,325,988.

Posts and Telegraphs.—The receipts of the post-office in 1899 amounted to £10,277,730, and the expenses to £7,708,164. The number of letters carried, including post-cards and printed matter, amounted in 1899 to 2,250,650,992, against 1,825,642,200 in 1892. Of the total carried in 1899, 904,210,126 were letters, and 1,346,440,866 post-cards and printed matter. Post-office orders, inland, were issued to the value of £44,280,016; international orders were issued for £1,940,221, and postal orders for £1,616,176. Bills were collected by the post-office for £16,345,247. The number of telegrams was 43,626,116, and the number of subscribers to the telephone 46,121, of which 22,468, or nearly a half, fell to the share of Paris. Of the total of 43,626,116 telegrams in 1899, 36,065,254 were internal and 7,560,862 international. The pneumatic tubes in Paris measured (1899) 163 miles; 931 urban telephone systems disposed of 11,521 miles of line and 129,606 miles of wire; 1256 inter-urban circuits had 17,439 miles of line and 46,118 miles of wire.

Banks.—The last renewal of the privilege accorded to the *Banque de France* was made in 1897. It is the only establishment which, in consideration of a permanent advance to the Treasury, and under certain other stipulated conditions, is allowed to issue bank notes of legal tender. Besides its central seat at Paris, the *Banque de France* has ninety-five branches in important provincial towns. Its total transactions in 1899 amounted to the value of 17,834,031,400 francs, in which the share of Paris was 9,154,741,200 francs, and of the branches 8,679,290,200 francs. The bullion in stock on the 1st January 1900 amounted to 3030 million francs, 1873 million francs being in gold and 1157 millions in silver. The notes in circulation amounted to the value of 3,983,493,000 francs. The bullion in hand on 1st February 1901 comprised 2,353,945,593 francs in gold and 1,095,261,297 francs in silver, while the notes in circulation valued 4,445,866,425 francs. The average rate of discount was 3 per cent. in 1899, against 2·70 per cent. in 1892, 3 per cent. in 1887, 3·80 per cent. in 1882. Finally, the shares in the bank in 1899, as at the beginning, numbered 182,500; but the number of shareholders tends gradually to increase, the number being 28,299 in 1899, against 26,742 in 1887.

The transactions of the *Crédit Foncier*, which grants loans on land securities, amounted on the 30th June 1899 to the value of 3,895,081,575 francs. Since it started business in 1853 it has lent money to the amount of 4,406,368,040 francs. In 1897 its loans were 214,812,832 francs, of which 90,510,659 francs were to the communes. Among other banking establishments may be mentioned the *Crédit Lyonnais*, *Société Général*, and *Comptoir d'Escompte*.

Savings Banks.—Since 1895 savings banks have experienced an enormous development. They are administered either by the national savings bank, which since 1882 has been connected with the post-office, and numbered, in 1897, 7416 branch offices, or by the private savings banks. The funds, however, are centralized in the *Caisse des Depôts et Consignations*, which had accounts under this head to the value, on the 31st December 1898, of 3473 million francs.

The deposits in the different savings banks amounted to 630 millions francs in 1870, 1810 millions in 1880, 3113 millions in 1890, 4080 millions in 1896, 4271 in 1897. The total number of depositors was on the 31st December 1897, 9,265,408, and on the 31st December 1897 the depositors at the private savings banks numbered 6,772,582. In 1897 the deposits at the national savings banks amounted to 366 million francs, and the withdrawals to 327 millions. At the private savings banks the deposits in 1897 amounted to the value of 719 million francs, and the repayments to 774 millions.

Money.—Since 1880 there has been but a single mint in France, namely, the Mint in Paris. The last of the provincial mints, that at Bordeaux, was done away with in 1879. The nominal value of the coin minted at Paris for France, the colonies, and foreign countries amounted, in francs, to—

1880.	1885.	1890.	1895.	1899.
200,100,000	8,506,000	22,606,000	148,702,000	140,321,212

From 1795 to 1899 there were struck for the use of France :—

Gold-Pieces.	Value in Francs.
100-franc pieces	60,663,200
50- ,, ,, ...	46,893,450
40- ,, ,, ...	204,432,360
20- ,, ,, ...	8,000,517,800
10- ,, ,, ...	1,041,165,620
5- ,, ,, ...	233,440,130
Total	9,587,112,560

From 1874 to 1899 the coin struck in gold amounted to the value of 1,812,585,560 francs. Since 1839 no 40-franc pieces, and since 1869 no 5-franc pieces, have been struck. The silver coins of France struck from 1795 to 1899 were as follows :—

Silver Coins.	Value in Francs.
5-franc pieces . .	5,060,606,240
2- ,, ,, . .	184,863,534
1- ,, ,, . .	235,558,399
50-centime pieces . .	131,620,003 and 50 centimes.
25- ,, ,, . .	7,671,101 ,, 25 ,,
20- ,, ,, . .	8,252,720 ,, 60 ,,
Total . .	5,628,571,998 and 35 centimes.

Since 1875 silver coins have been struck to the value of 559,326,173 francs. Since 1848 the coinage of 25-centime pieces, since 1869 of 20-centime pieces, and since 1878 of 5-franc crowns (*Écus*) has been suspended. But by way of exception 20-franc pieces were put in circulation in 1889.

Since 1852 bronze coins have been struck to the value of 70,549,872 francs, 40 centimes :—

Bronze Coins.	Value in Francs.
10-centime pieces . .	37,266,576 and 40 centimes.
5- ,, ,, . .	29,882,989 ,, 55 ,,
2- ,, ,, . .	2,061,209 ,, 52 ,,
1- ,, ,, . .	1,339,096 ,, 93 ,,
Total . .	70,549,872 and 40 centimes.

Colonies.—Since 1880 France has been making strenuous efforts to increase her colonial empire, which then comprised :—In Asia—the East-Indian factories of Pondichéry, Karikal, Mahé, Yanaon, and Chandernagore; in Africa—Algeria, Senegal and Goree, Gaboon, the islands of Réunion, Ste Marie de Madagascar, Mayotte, and Nossi-Bé; in America—Martinique, Guadeloupe, St Barthélemy in the Antilles group of West Indian islands, Guiana on the continent of South America, and St Pierre and Miquelon in the North Atlantic; in Oceania—the Marquesas islands, Tahiti, and New Caledonia. At the date of 1880, under the influence especially of Jules Ferry, who was a prime mover in the policy of foreign expansion, colonial experiments were made by France in three different zones of the globe: in Western Africa (in Sudan and Guinea) and in Northern Africa (in Tunis), in the Indian Ocean (in Madagascar), and in the far East (in Annam and Tongking). Following on a short expedition and the treaty of Kasr-es-Saïd or Bardo, signed on the 12th May 1881, Tunis was placed under the protectorate of France. It has now become one of the brightest gems in her crown. The year 1880, again, dates precisely the beginning of the penetration of the Sudan by French influence. The French possessions in the Senegal then reached no farther eastwards than Medina. In 1883 the French possessions touched the Niger. The long wars waged against Ahmadou and Samory brought with them a still further extension of conquest and territory. In 1894 Timbuctoo was occupied. French Guinea is likewise of recent foundation, as is also its appendage of Futa Jallon, to which a number of French officers paid a visit between 1881 and 1885. Since the latter year the Ivory Coast has grown French, a result due to the old settlements of Grand Bassam and Assinie. The region of Kong, constituting its hinterland, was explored by Captain Binger, 1887–89. All this territory was delimited by the Franco-Liberian convention of the 8th December 1892 and the Franco-British convention of the 12th July 1893. In respect of the zone of French influence in West Africa, it has been traced in a general manner by the Franco-British convention of 14th June 1898. This convention has at the same time delimited the frontier of Dahomey on the east side, in completion of the previous accord of August 1889. The western frontier of this colony, on the other hand, has been drawn by the Franco-German convention of the 27th July 1897. Dahomey and its king Behanzin were conquered in 1892. Senegal, Sudan, and Guinea form the general government of French Western Africa, in communication with which there are also the Ivory Coast and Dahomey.

French Congo was constituted as a result of the explorations of M. Savorgnan de Brazza (1875–82). Its delimitation was fixed by the convention of the 5th February 1885 concluded with the International Congo Association, by the protocol of December 1885 agreed on with Germany, and by the Franco-Portuguese protocol of May 1886. In the train of territorial and diplomatic difficulties with the Free State, an accord between King Leopold and M. Hanotaux relative to the region of the upper Ubanghi was signed on the 14th April 1894. The expansion of France in this zone, from 1895 to 1897, was crowned by the mission of Marchand, which in 1898 reached the Bahr-el-Ghazal and the Nile. The Franco-British convention of the 21st March 1899 fixed the delimitation of the Congo towards the north-east.

The large island of Madagascar in the Indian Ocean was, after a first expedition, placed in 1885 under the protectorate of France. Following a second expedition (1894–95), Madagascar was in August 1896 declared a French colony.

French Indo-China has since 1862 comprised the territory of Cochin-China, and since 1863 the protectorate of Cambodia. In consequence of a prolonged campaign (1883–84) and of treaties with Annam (6th June 1884) and China (9th June 1885), the protectorate of the Republican Government was proclaimed over Annam and Tongking. Cochin-China, Annam, Tongking, and Cambodia are united under the authority of a common governor-general.

The following table shows the extent of France's colonial empire. It should be noted that the figures for area and population are, as a rule, only estimates, a remark which especially applies to the West African possessions. Detailed notices of the separate colonies will be found under their several heads:—

Colony.	Year of Acquisition.	Area in Square Miles.	Population. 1896.
In Asia—			
India	1679	197	279,100
Annam	1884	88,780	4,000,000
Cambodia	1862	40,530	1,500,000
Cochin-China	1861	23,160	2,400,000
Tongking and Laos	1884–93	210,370	12,500,000
Total in Asia	...	363,037	20,679,100
In Africa—			
Algeria	1830	184,474	4,430,000
Algerian Sahara	1873–1900	123,500	50,000
Tunis	1881	51,000	1,500,000
Sahara, including Tibesti	1875–1900	1,892,000	1,500,000
Senegal	1637	182,000	1,200,000
Sudan Military Districts	1880	183,000	2,000,000
French Guinea	1843	92,000	1,000,000
Ivory Coast	1843	119,500	2,500,000
Dahomey	1893	59,000	1,000,000
Congo and Gaboon	1884	550,000	8,000,000
Bagirmi, Wadai, Kanem	1896–99	126,000	...
Somali Coast	1864	14,000	22,000
Réunion	1649	970	173,200
Comoro Isles	1886	620	53,000
Mayotte	1843	140	11,640
Nossi-Bé	1841	130	9,500
Ste Marie	1750	64	7,670
Madagascar	1896	228,500	2,750,000
Total in Africa	...	3,806,898	26,207,010
In America—			
Guiana	1626	46,850	22,710
Guadeloupe	1634	688	167,100
Martinique	1635	380	187,690
St Pierre and Miquelon	1635	93	6,250
Total in America	...	48,011	383,750
In Oceania—			
New Caledonia and Dependencies	1854–87	7,700	53,000
Establishments in Oceania	1841–81	1,520	29,000
Total in Oceania	...	9,220	82,000
Grand Total	...	4,227,166	47,351,860

Colonial Budget and Administration.—Besides their local budgets, the French colonies figure in the budgets of the mother-country, with drafts on her Treasury steadily increasing since 1875, and now amounting to more than 106 million francs. Of this amount the expenditure on military occupation accounts for more than three-fifths—actually 72 million francs. Neither Tunis nor Algeria figures in these totals. All the expenses of Tunis are comprised in a budget of its own, dating from 1st January 1901. Algeria has likewise a budget of its own, dating from the same time; but the financial charges of the 19th Army Corps (50 million francs), which has its headquarters at Algiers and subdivisions at Oran and Constantine, are always incumbent upon the capital. It should be remembered, however, that her commercial dealings with Algeria repay France in a measure for the sacrifices which she continues to make. Administratively, the foreign possessions of France are divided into two great categories—colonies and protectorates. The latter include Tongking, Annam, and Tunis, over whose native administration is placed a staff of French control, consisting of a resident-superior at Tunis and a resident at Hué, under whom are *contrôleurs*, vice-residents, *chanceliers de residence*, &c. Some of the colonies send representatives to Parliament. In the case of the older colonies, dating from before the constitution of the Third Republic, the departmental organization of France has been applied in whole or in part. The governor of such a colony is assisted by a general elective council exercising deliberative power—as in Martinique, Guadeloupe, Guiana, &c. In the new colonies the governor is assisted by a consultative assembly, or he may even be left uncontrolled. At the head of every colonial administration is the Ministry of the Colonies, which was only separately constituted in 1894. The Ministry of the Colonies is assisted by an elective superior council having consultative attributes.

Fuller details respecting the productions, industries, commerce, and shipping of the colonies will be found under the headings of the various colonies. It may here, however, be noted that the greater part of the French foreign possessions lies within the hot zones of the globe, and that accordingly the chief colonial products are tropical—coffee, sugar, ground-nuts, rice.

Except in the case of Algeria and Tunis, the trade of France with her possessions is not as a rule proportionately great. But the proportion is rapidly increasing, and France is quickly gaining a commanding share of the commerce of her colonies. The following table gives the value of the trade of France with her possessions in 1896 and 1898:—

From or to	Imports.		Exports.	
	1896.	1899.	1896.	1899.
Algeria	£8,152,000	£11,240,000	£9,780,000	£11,400,000
Tunis	1,044,000	1,398,000	1,640,000	2,150,000
West African Colonies	944,000	1,301,000	1,352,000	1,962,000
Madagascar	168,000	268,000	316,000	1,470,000
Réunion	836,000	918,000	664,000	720,000
French India	196,000	160,000	28,000	205,000
Indo-China	712,000	1,563,000	1,468,000	2,242,000
Oceania	476,000	780,000	300,000	603,000
Guiana	84,000	11,000	416,000	401,000
Martinique	752,000	820,000	540,000	760,000
Guadeloupe	652,000	563,000	528,000	500,000
St Pierre and Miquelon	1,220,000	1,278,000	272,000	301,000
Total	£15,236,000	£20,300,000	£17,304,000	£22,714,000

Colonial Defence.—France has not yet a colonial army properly so-called, although it is a problem she has had under discussion for many years. She has, however, the elements of an army in her troops of marines, which have hitherto carried on all her foreign campaigns, and in the native regiments she levies on the spot—tirailleurs, Senegalese, Sudanese, Congolese, Sakalavese, Tongkingese, Annamese, Sudanese Spahis, &c.

AUTHORITIES.—LEVASSEUR. *La France et ses Colonies.* 1889. —MARCEL DUBOIS et KERGOMARD. *Géographie Économique de la France.* 1897. *Notices de l'Atlas Schrader.* 1894.—MAGER. *Atlas Colonial.* 1899.—ADAMS. *The Growth of the French Nation.* London, 1897.—BAUDRILLART. *Les Populations agricoles de la France*, 3 séries, 8. Paris, 1885–93.—BLOCK. *Dictionnaire de l'Administration Française.* Paris, 1898. — BODLEY. *France.* London, 1898. — COUBERTIN. *L'Évolution Française sous la Troisième République.* Paris, 1896; London (translation), 1898. —CURRIER. *Constitutional and Organic Laws of France, 1875–89.* Philadelphia, 1891.—DEBIDOUR. *Histoire des Rapports de l'Église et de l'État, 1789–1870.* Paris, 1898.—DESCHAMPS. *Histoire de la Question Coloniale en France.* Paris, 1891.—LANESSAN. *La république démocratique, la politique intérieure, extérieure, et coloniale de la France.* Paris, 1897.—RÉCLUS. *Le plus belle Royaume sous le Ciel, notre belle France.* Paris, 1899. VIGNON. *L'Expansion de la France.* Paris, 1891.—VIOLLET. *Histoire des Institutions Politiques et Administratives de la France.* Paris, 1898.—ZEVORT. *Histoire de la Troisième République: Presidence de Jules Grévy.* Paris, 1898. Among the numerous OFFICIAL PUBLICATIONS may be noticed the 1896 census volume, the annual tables of customs, the annual statistics published by the Ministry of Commerce, the reports of the administration of Justice, the parliamentary reports on the budget, the decennial and annual statistics of agriculture, the statistics of the mineral and metallurgical production published by the Ministry of Public Works, and the results of the inquiry into the *congrégations* published by the Ministry of Finance, 1901. (P. L.)

3. POLITICAL HISTORY (1870–1900).

Fall of the Second Empire.

On the 8th of May 1870 the doom of the Second Empire was determined by an event which was intended to give it a new lease of life—the plebiscite approving of the reforms introduced by the emperor into the constitution. Napoleon III. had in reality sealed the fate of his dynasty four years previously when, cajoled by Bismarck, he had made France look on, a passive spectator of the defeat of Austria by Prussia. After Sadowa France remained the only obstacle to the preponderance of Prussia on the European continent, and a German victory over the French was foreseen as the probable means of consolidating a united Germany under the headship of the ambitious House of Hohenzollern. In the face of this external peril, wantonly evoked by his unsagacious diplomacy, Louis Napoleon set about making his position more secure at home, and, always a dreamer, conceived that a liberalized Empire would conciliate the entire population of France to his rule. The rapidly ageing Emperor had thus disavowed the principles which in the prime of life he had declared to be essential to the government of the country, and M. Emile Ollivier, an ardent opponent of the autocracy which sprang from the *coup d'état* of 1851, became Prime Minister of the Liberal Empire in January 1870. Napoleon III. perceived too late that his waning popularity was not to be recovered by such empirical remedies; so, against the wish of his liberal minister, he had recourse to an appeal to popular opinion, such as eighteen years before had ratified his arbitrary omnipotence. The plebiscite gave an overwhelming majority to the Empire, but it brought on its downfall. The popular victory made Louis Napoleon believe that he still possessed the confidence of the country, and that external glory would restore his shaken authority. The candidature of a prince of Hohenzollern for the throne of Spain, vacant by revolution, provided a pretext for a quarrel between France and Prussia, which was not unwelcome on either side the Rhine. The French Government declared it would never accept the presence of a German sovereign at Madrid. The king of Prussia announced to the French Ambassador that his cousin had withdrawn his candidature, whereupon Napoleon demanded a promise from William I. never to allow it to be renewed. This the King refused, to the joy of Bismarck, who saw in the unprepared state of France an opportunity for the fulfilment of his life-dream. Subsequent revelations indicate that the Prussian chancellor spared no effort to fan the warlike inclination of the French, which had no need to be stimulated by his unscrupulous provocation. The debates in the Corps Législatif in July 1870 show that the French were bent on war. The voices of MM. Thiers, Buffet, and Jules Favre, united in pleading for delay though they represented widely different schools of politics, were drowned in the clamour for immediate hostilities. War was officially declared on the 19th of July 1870 amid the acclamations of the capital, which adopted with enthusiasm the unfortunate phrase of the prime minister, Émile Ollivier, that he entered on the campaign with a "light heart." Six weeks later France had neither a ruler nor a regular army nor a government. The Emperor had drifted into war regardless of diplomatic or military precautions, without allies, and without an organized system of national defence. An unbroken series of German victories culminated at Sedan with the surrender of Napoleon III. and of the French army to the king of Prussia. Three days after the battle of Sedan the Parisian populace, which, clamouring for war, had sent off the troops with joyous cries of "À Berlin!" invaded the Corps Législatif, and demanded the deposition of the Empire.

Government of National Defence, 1870.

The Third Republic may thus be said to date from the revolution of the 4th of September 1870, when the republican deputies of Paris at the Hôtel de Ville constituted a provisional government under the presidency of General Trochu, military governor of the capital. The Empire had fallen, and the Emperor was a prisoner in Germany. As however since the great Revolution regimes in France have been only passing expedients, not inextricably associated with the destinies of the people, but bound to disappear when accounted responsible for national disaster, the surrender of Louis Napoleon's sword to William of Prussia did not disarm the country. Hostilities were therefore continued. The provisional government had to assume the part of a Committee of National Defence, and while insurrection was threatening in Paris, it had, in the face of the invading Germans, to send a delegation to Tours to maintain the relations of France with the outside world. Paris was invested, and for five months endured siege, bombardment, and famine. Before the end of October the capitulation of Metz, by the treason of Marshal Bazaine, deprived France of the last relic of its regular army. With indomitable courage the garrison of Paris made useless sorties, while an army of irregular troops vainly essayed to resist the invader, who had reached the valley of the Loire. The acting Government of National Defence, thus driven from Tours, took refuge at Bordeaux, where it awaited the capitulation of Paris, which took place on the 29th of January 1871. The same day the preliminaries of peace were signed at Versailles, which, confirmed by the Treaty of Frankfort of the 10th of May, transferred from France to Germany the whole of Alsace, excepting Belfort, and a large portion of Lorraine, including the fortified city of Metz, in addition to a money indemnity of two hundred millions sterling.

Foundation of the Third Republic, 1871.

On the 13th of February 1871 the National Assembly, elected after the capitulation of Paris, met at Bordeaux and assumed the powers hitherto exercised by the Government of National Defence. Since the meeting of the States General in 1789 no representative body in France had ever contained so many men of distinction. Elected to conclude a peace, the great majority of its members were monarchists, Gambetta, the rising hope of the republicans, having discredited his party in the eyes of the weary population by his efforts to carry on the war. The Assembly might thus have there and then restored the monarchy had not the monarchists been divided among themselves as royalist supporters of the Comte de Chambord, grandson of Charles X., and as Orleanists favouring the claims of the Comte de Paris, grandson of Louis Philippe. The majority being unable to unite on the essential point of the choice of a sovereign, decided to allow the Republic, declared on the morrow of Sedan, to liquidate the disastrous situation. Conquently, on the 17th of February the National Assembly elected M. Thiers as "Chief of the Executive Power of the French Republic," the abolition of the Empire being formally voted a fortnight later. The old minister of Louis Philippe, who had led the opposition to the Empire, and had been the chief opponent of the war, was further marked out for the position conferred on him by his election to the Assembly in twenty-six departments in recognition of his tour through Europe after the first defeats, undertaken in the patriotic hope of obtaining the intervention of the Powers on behalf of France. M. Thiers composed a ministry, and announced that the first duty of the Government, before examining constitutional questions, would be to reorganize the forces of the nation in order to provide for the enormous war indemnity which had to be paid to Germany before the territory could be liberated from the presence of the invader. The tacit acceptance of this arrangement by all parties was known as the "*pacte de Bordeaux*." Apart from the pressure of patriotic considerations, it pleased the republican minority to have the government of France officially proclaimed a Republic, while the monarchists thought that pending their choice of a monarch it might popularize their cause not to have it associated with the imposition of the burden of war taxation. From this fortuitous and informal transaction, accepted by a monarchical Assembly, sprang the Third Republic, the most durable regime established in France since the ancient monarchy disappeared in 1792.

The Germans marched down the Champs Elysées on the 1st of March 1871, and occupied Paris for forty-eight hours. The National Assembly then decided to remove its sittings to Versailles; but two days before its arrival at the palace, where the king of Prussia had just been proclaimed German emperor, an insurrection broke out in Paris. The revolutionary element, which had been foremost in proclaiming the Republic on the 4th of September, had shown signs of disaffection during the siege. On the conclusion of the peace the triumphal entry of the German troops, the threatened disbanding of the national guard by an Assembly known to be anti-republican, and the resumption of orderly civic existence after the agitated life of a suffering population isolated by siege, had excited the nerves of the Parisians, always prone to revolution. The Commune was proclaimed on the 18th of March, and Paris was declared to be a free town, which recognized no government but that chosen by the people within its walls, the communard theory being that the State should consist of a federation of self-governing communes subject to no central power. Administrative autonomy was not, however, the real aim of the insurgent leaders. The name of the Commune had always been a rallying sign for violent revolutionaries ever since the Terrorists had found their last support in the municipality of Paris in 1794. In 1871 among the communard chiefs were revolutionaries of every sect, who, disagreeing on governmental and economic principles, were united in their vague but perpetual hostility to the existing order of things. The regular troops of the garrison of Paris followed the National Assembly to Versailles, where they were joined by the soldiers of the armies of Sedan and Metz, liberated from captivity in Germany. With this force the government of the Republic commenced the second siege of Paris, in order to capture the city from the Commune, which had established the parody of a government there, having taken possession of the administrative departments and set a minister at the head of each office. The second siege lasted six weeks under the eyes of the victorious Germans encamped on the heights overlooking the capital. The presence of the enemy, far from restraining the humiliating spectacle of Frenchmen waging war on Frenchmen in the hour of national disaster, seemed to encourage the fury of the combatants. The communards, who had begun their reign by the murder of two generals, concluded it, when the Versailles troops were taking the city, with the massacre of a number of eminent citizens, including the archbishop of Paris, and with the destruction by fire of many of the finest historical buildings, including the Palace of the Tuileries and the Hôtel de Ville. History has rarely known a more unpatriotic crime than that of the insurrection of the Commune; but the punishment inflicted on the insurgents by the Versailles troops was so ruthless that it seemed to be a counter-manifestation of French hatred for Frenchmen in civil disturbance rather than a judicial penalty applied to a heinous offence. The number of Parisians killed by French soldiers in the last week of May 1871 was probably 20,000, though the partisans of the Commune declared that 36,000 men and women were shot in the streets or after summary court-martial.

The Commune.

It is from this point that the history of the Third Republic commences. In spite of the doubly tragic ending of the war the vitality of the country seemed unimpaired. With ease and without murmur it supported the new burden of taxation called for by the war indemnity and by the reorganization of the shattered forces of France. M. Thiers was thus aided in his task of liberating the territory from the presence of the enemy. His proposal at Bordeaux to make the "*essai loyal*" of the Republic, as the form of government which caused the least division among Frenchmen, was discouraged by the excesses of the Commune which associated republicanism with revolutionary disorder. Nevertheless, the monarchists of the National Assembly received a note of warning that the country might dispense with their services unless they displayed governmental capacity, when in July 1871 the republican minority was largely increased at the bye-elections. The next month, within a year of Sedan, a provisional constitution was voted, the title of President of the French Republic being then conferred on M. Thiers. The monarchists consented to this against their will; but they had their own way when they conferred constituent powers on the Assembly in opposition to the republicans, who argued that it was a usurpation of the sovereignty of the people for a body elected for another purpose to assume the power of giving a constitution to the land without a special mandate from the nation. The debate gave Gambetta his first opportunity of appearing as a serious politician. The "*fou furieux*" of Tours, whom M. Thiers had denounced for his efforts to prolong the hopeless war, was about to become the chief support of the aged Orleanist statesman whose supreme achievement was to be the foundation of the Republic.

Republicans and Monarchists after the war.

It was in 1872 that M. Thiers practically ranged himself with Gambetta and the republicans. The divisions in the monarchical party made an immediate restoration impossible. This situation induced some of the moderate deputies, whose tendencies were Orleanist, to support the organization of a Republic which now no longer found its chief support in the revolutionary section of the nation, and it suited the ideas of M. Thiers, whose personal ambition was not less than his undoubted patriotism. Having become unexpectedly Chief of the State at seventy-four he had no wish to descend again to the position of a minister of the Orleans dynasty which he had held at thirty-five. So, while the royalists refused to admit the claims of the Comte de Paris, the old minister of Louis Philippe did his best to undermine the popularity of the Orleans tradition, which had been great among the Liberals under the Second Empire. He moved the Assembly to restore to the Orleans princes the value of their property confiscated under Louis Napoleon. This he did in the well-founded belief that the family would discredit itself in the eyes of the nation by accepting two millions sterling of public money at a moment when the country was burdened with the war indemnity. The incident was characteristic of his wary policy, as in the face of the anti-republican majority in the Assembly he could not openly break with the Right; and when it was suggested that he was too favourable to the maintenance of the Republic he offered his resignation, the refusal of which he took as indicating the indispensable nature of his services. Meanwhile Gambetta, by his popular eloquence, had won for himself in the autumn a triumphal progress, in the course of which he declared at Grenoble that political power had passed into the hands of "*une couche sociale nouvelle,*" and he appealed to the new social strata to put an end to the comedy of a Republic without republicans. When the Assembly resumed its sittings, order having been restored in the land disturbed by war and revolution, the financial system being reconstituted and the reorganization of the army planned, M. Thiers read to the house a presidential message which marked such a distinct movement towards the Left that Gambetta led the applause. "The Republic

1872: Thiers and Gambetta.

exists," said the President, "it is the lawful government of the country, and to devise anything else is to devise the most terrible of revolutions."

The year 1873 was full of events fateful for the history of France. It opened with the death of Napoleon III. at Chislehurst; but the disasters amid which the Second Empire had ended were too recent for the youthful promise of his heir to be regarded as having any connexion with the future fortunes of France, except by the small group of Bonapartists. M. Thiers remained the centre of interest. Much as the monarchists disliked him, they at first shrank from upsetting him before they were ready with a scheme of monarchical restoration, and while Gambetta's authority was growing in the land. But when the Left Centre took alarm at the return of radical deputies at numerous bye-elections the reactionaries utilized the divisions in the republican party, and for the only time in the history of the Third Republic they gave proof of parliamentary adroitness. The date for the evacuation of France by the German troops had been advanced, largely owing to M. Thiers' successful efforts to raise the war indemnity. The monarchical majority, therefore, thought the moment had arrived when his services might safely be dispensed with, and the campaign against him was ably conducted by a coalition of Legitimists, Orleanists, and Bonapartists. The attack on M. Thiers was led by the Duc de Broglie, the son of another minister of Louis Philippe and grandson of Madame de Staël. Operations began with the removal from the chair of the Assembly of M. Jules Grévy, a moderate republican, who was chosen president at Bordeaux, and the substitution of M. Buffet, an old minister of the Second Republic who had rallied to the Empire. A debate on the political tendency of the Government brought M. Thiers himself to the tribune to defend his policy. He maintained that a conservative Republic was the only regime possible, seeing that the monarchists in the Assembly could not make a choice between their three pretenders to the throne. A resolution, however, was carried which provoked the old statesman into tendering his resignation. This time it was not declined, and the majority with unseemly haste elected as President of the Republic Marshal MacMahon, Duc de Magenta, an honest soldier of royalist sympathies, who had won renown and a ducal title on the battlefields of the Second Empire. In the eyes of Europe the curt dismissal of the aged liberator of the territory was an act of ingratitude. Its justification would have been the success of the majority in forming a stable monarchical government; but the sole result of the 24th of May 1873 was to provide a definite date to mark the opening of the era of anti-republican incompetency in France which has lasted for a generation, and has been perhaps the most effective guardian of the Third Republic.

Resignation of Thiers.

Marshal MacMahon President of the Republic.

The political incompetency of the reactionaries was fated never to be corrected by the intelligence of its princes or of its chiefs, and the year which saw M. Thiers dismissed to make way for a restoration saw also that restoration indefinitely postponed by the fatal action of the legitimist pretender. The Comte de Paris went to Frohsdorf to abandon to the Comte de Chambord his claims to the crown as the heir of the July Monarchy, and to accept the position of dauphin, thus implying that his grandfather Louis Philippe was a usurper. With the "Government of Moral Order" in command the restoration of the monarchy seemed imminent, when the royalists had their hopes dashed by the announcement that "Henri V." would accept the throne only on the condition that the nation adopted as the standard of France the white flag—at the very sight of which Marshal MacMahon said the rifles in the army would go off by themselves. The Comte de Chambord's refusal to accept the tricolour was probably only the pretext of a childless man who had no wish to disturb his secluded life for the ultimate benefit of the Orleans family which had usurped his crown, had sent him as a child into exile, and outraged his mother the Duchesse de Berry. Whatever his motive, his decision could have no other effect than that of establishing the Republic, as he was likely to live for years, during which the Comte de Paris' claims had to remain suspended. It was not possible to leave the land for ever under the Government improvised at Bordeaux when the Germans were masters of France; so the majority in the Assembly decided to organize another provisional Government on more regular lines, which might possibly last till the Comte de Chambord had taken the white flag to the grave, leaving the way to the throne clear for the Comte de Paris. On the 19th of November 1873 a Bill was passed which instituted the Septennate, whereby the executive power was confided to Marshal MacMahon for seven years. It also provided for the nomination of a commission of the National Assembly to take in hand the enactment of a constitutional law. Before this an important constitutional innovation had been adopted. Under M. Thiers there were no changes of ministry. The President of the Republic was perpetual prime minister, constantly dismissing individual holders of portfolios, but never changing at one moment the whole council of ministers. Marshal MacMahon, the day after his appointment, nominated a cabinet with a vice-President of the Council as premier, and thus inaugurated the system of ministerial instability which has been the most conspicuous feature of the government of the Third Republic. Under the Septennate the ministers, monarchist or moderate republican, were socially and perhaps intellectually of a higher class than those who governed France during the last twenty years of the 19th century. But the duration of the cabinets was just as brief, thus displaying the fact, already similarly demonstrated under the Restoration and the July Monarchy, that in France parliamentary government is an importation not suited to the national temperament.

The Comte de Chambord.

The Septennate.

The Duc de Broglie was the prime minister in MacMahon's first two cabinets which carried on the government of the country up to the first anniversary of M. Thiers' resignation. M. de Broglie's defeat by a coalition of Legitimists and Bonapartists with the Republicans displayed the mutual attitude of parties. The Royalists, chagrined that the fusion of the two branches of the Bourbons had not brought the Comte de Chambord to the throne, vented their rage on the Orleanists, who had the chief share in the Government without being able to utilize it for their dynasty. The Bonapartists, now that the memory of the war was receding, were winning elections in the provinces, and were further encouraged by the youthful promise of the Prince Imperial. The republicans had so improved their position that the Duc d'Audiffret-Pasquier, great-nephew of the chancellor Pasquier, tried to form a coalition ministry with M. Waddington, afterwards ambassador of the Republic in London, and other members of the Left Centre. Out of this uncertain state of affairs was evolved the Constitution which has lasted the longest of all those that France has tried since the abolition of the old monarchy in 1792. Its birth was due to chance. Not being able to restore a monarchy, the National Assembly was unwilling definitively to establish a republic, and as no limit was set by the law on the duration of its powers it might have continued the

Constitution voted, 1875.

provisional state of things had it not been for the Bonapartists. That party displayed so much activity in agitating for a plebiscite, that when the rural voters at bye-elections began to rally to the Napoleonic idea, alarm seized the constitutionalists of the Right Centre who had never been persuaded by M. Thiers' exhortations to accept the Republic. Consequently in January 1875 the Assembly, having voted the general principle that the legislative power should be exercised by a Senate and a Chamber of Deputies, without any mention of the executive regime, accepted by a majority of one a momentous resolution proposed by M. Wallon, a member of the Right Centre. It provided that the President of the Republic should be elected by the absolute majority of the Senate and the Chamber united as a National Assembly, that he should be elected for seven years, and be eligible for re-election. Thus by one vote the Republic was formally established, "the Father of the Constitution" being M. Wallon, who began his political experiences in the Legislative Assembly of 1849, and survived to take an active part in the Senate to the very end of the century.

The Republic being thus established, General de Cissey, who had become prime minister, made way for M. Buffet, but retained his portfolio of War in the new coalition cabinet, which contained some distinguished members of the two central groups, including M. Léon Say. A fortnight previously, at the end of February 1875, were passed two statutes defining the legislative and executive powers in the Republic, and organizing the Senate. These joined to a third enactment, voted in July, form the body of laws known as the "Constitution of 1875," which though twice revised, lasted without essential alteration to the end of the 19th century. The legislative power was conferred on a Senate and a Chamber of Deputies, which might unite in congress to revise the Constitution, if they both agreed that revision was necessary, and which were bound so to meet for the election of the President of the Republic when a vacancy occurred. It was enacted that the President so elected should retain office for seven years, and be eligible for re-election at the end of his term. He was also held to be irresponsible, except in the case of high treason. The other principal prerogatives bestowed on the presidential office by the Constitution of 1875 were the right of initiating laws concurrently with the members of the two chambers; the promulgation of the laws; the right of dissolving the Chamber of Deputies before its legal term on the advice of the Senate, and that of adjourning the sittings of both houses for a month; the right of pardon; the disposal of the armed forces of the country; the reception of diplomatic envoys, and, under certain limitations, the power to ratify treaties. The Constitution relieved the President of the responsibility of private patronage, by providing that every act of his should be countersigned by a minister. The Constitutional Law provided that the Senate should consist of 300 members, 75 being nominated for life by the National Assembly, and the remaining 225 elected for nine years by the departments and the colonies. Vacancies among the life members, after the dissolution of the National Assembly, were filled by the Senate until 1884, when the nominative system was abolished, though the survivors of it were not disturbed. The law of 1875 enacted that the elected senators, who were distributed among the departments on a rough basis of population, should be elected for nine years, a third of them retiring triennially. It was provided that the senatorial electors in each department should be the deputies, the members of the *conseil général* and of the *conseils d'arrondissement*, and delegates nominated by the municipal councils of each commune. As the municipal delegates composed the majority in each electoral college, Gambetta called the Senate the Grand Council of the Communes; but in practice the senators elected have always been the nominees of the local deputies and of the departmental councillors (*conseillers généraux*).

Provisions of the Constitution of 1875.

Scrutin d'arrondissement and scrutin de liste.

The Constitutional Law further provided that the deputies should be elected to the Chamber for four years by direct manhood suffrage, which had been enjoyed in France ever since 1848. The laws relating to registration, which is of admirable simplicity in France, were left practically the same as under the Second Empire. From 1875 to 1885 the elections were held on the basis of *scrutin d'arrondissement*, each department being divided into single-member districts. In 1885 *scrutin de liste* was tried, the department being the electoral unit, and each elector having as many votes as there were seats ascribed to the department without the power to cumulate—like the voting in the City of London when it returned four members. In 1889 *scrutin d'arrondissement* was resumed. The payment of members continued as under the Second Empire, the salary now being fixed at 9000 francs a year in both houses, or about a pound sterling a day. The Senate and the Chamber were endowed with almost identical powers. The only important advantage given to the popular house in the paper constitution was its initiative in matters of finance, but the right of rejecting or of modifying the financial proposals of the Chamber was successfully upheld by the Senate. In reality the Chamber of Deputies has overshadowed the upper house. The Constitution did not prescribe that ministers should be selected from either house of parliament, but in practice the deputies have been in cabinets in the proportion of five to one in excess of the senators. Similarly the very numerous ministerial crises which have taken place under the Third Republic have with the rarest exceptions been caused by votes in the lower chamber. Among minor differences between the two houses ordained by the Constitution was the legal minimum age of their members, that of senators being forty and of deputies twenty-five. It was enacted, moreover, that the Senate, by presidential decree, could be constituted into a High Court for the trial of certain offences against the security of the State.

The Constitution thus produced, the fourteenth since the Revolution of 1789, was the issue of a monarchical Assembly forced by circumstances to establish a republic. It was therefore distinguished from others which preceded it in that it contained no declaration of principle and no doctrinal theory. The comparative excellence of the work must be recognized, seeing that it has lasted. But it owed its duration, as it owed its origin and its character, to the weakness of purpose and to the dissensions of the monarchical parties. The first legal act under the new Constitution was the selection by the expiring National Assembly of seventy-five nominated senators, and here the reactionaries gave a crowning example of that folly which has ever marked their conduct each time they have had the chance of scoring an advantage against the Republic. The principle of nomination had been carried in the National Assembly by the Right and opposed by the Republicans. But the quarrels of the Legitimists with the Duc de Broglie and his party were so bitter that the former made a present of the nominated element in the Senate to the Republicans in order to spite the Orleanists; so out of seventy-five senators nominated by the monarchical Assembly fifty-seven Republicans were chosen. Without this suicidal act the Republicans would have been in a woeful minority in the Senate when parliament met in 1876 after the first elections under the new system of

1876: Political parties under the new Constitution.

parliamentary government. The slight advantage which, in spite of their self-destruction, the reactionaries maintained in the upper house was outbalanced by the republican success at the elections to the Chamber. In a house of over 500 members only about 150 monarchical deputies were returned, of whom half were Bonapartists. The first cabinet under the new Constitution was formed by M. Dufaure, an old minister of Louis Philippe like M. Thiers, and like him born in the 18th century. The premier now took the title of President of the Council, the Chief of the State no longer presiding at the meetings of ministers, though he continued to be present at their deliberations. Although the republican victory at the elections was greatly due to the influence of Gambetta, none of his partisans was included in the ministry, which was composed of members of the two central groups. At the end of 1876 M. Dufaure retired, but nearly all his ministers retained their portfolios under the presidency of M. Jules Simon, a pupil of Victor Cousin, who first entered political life in the Constituent Assembly of 1848, and was later a leading member of the opposition in the last seven years of the Second Empire.

The premiership of M. Jules Simon came to an end with the abortive *coup d'état* of 1877, commonly called from its date the *Seize Mai*. After the election of Marshal MacMahon to the presidency, the clerical party, irritated at the failure to restore the Comte de Chambord, commenced a campaign in favour of the restitution of the temporal power to the Pope. It provoked the Italian Government to make common cause with Germany, as Prince Bismarck was likewise attacked by the French clericals for his ecclesiastical policy. At last M. Jules Simon, who was a liberal most friendly to Catholicism, had to accept a resolution of the Chamber, inviting the ministry to adopt the same disciplinary policy towards the Church which had been followed by the Second Empire and the Monarchy of July. It was on this occasion that Gambetta used his famous expression, "*Le cléricalisme, voilà l'ennemi.*" Some days later a letter appeared in the *Journal Officiel*, dated 16th May 1877, signed by President MacMahon, informing M. Jules Simon that he had no longer his confidence, as it was clear that he had lost that influence over the Chamber which a president of the Council ought to exercise. The dismissal of the prime minister and the presidential acts which followed did not infringe the letter of the new Constitution; yet the proceeding was regarded as a *coup d'état* in favour of the clerical reactionaries. The Duc de Broglie formed an anti-republican ministry, and Marshal MacMahon, in virtue of the presidential prerogative conferred by the law of 1875, adjourned parliament for a month. When the Chamber reassembled the republican majority of 363 denounced the coalition of parties hostile to the Republic. The President, again using his constitutional prerogative, obtained the authorization of the Senate to dissolve the Chamber. Meanwhile the Broglie ministry had put in practice the policy, favoured by all parties in France, of replacing the functionaries hostile to it with its own partisans. But in spite of the administrative electoral machinery being thus in the hands of the reactionaries, a republican majority was sent back to the Chamber, the sudden death of M. Thiers on the eve of his expected return to power, and the demonstration at his funeral, which was described as a silent insurrection, aiding the rout of the monarchists. The Duc de Broglie resigned, and Marshal MacMahon sent for General de Rochebouet, who formed a cabinet of unknown reactionaries, but it lasted only a few days, as the Chamber refused to vote supply. M. Dufaure was then called back to office, and his moderate republican ministry lasted for the remainder of the MacMahon presidency.

The Seize Mai, 1877.

Thus ended the episode of the *Seize Mai*, condemned by the whole of Europe from its inception. Its chief effects were to prove again to the country the incompetency of the monarchists, and by associating in the public mind the Church with this ill-conceived venture, to provoke reprisals from the anti-clericals when they came into power. After the storm, the year 1878 was one of political repose. The first international exhibition held at Paris after the war displayed to Europe how the secret of France's recuperative power lay in the industry and artistic instinct of the nation. Marshal MacMahon presided with dignity over the fêtes held in honour of the exhibition, and had he pleased he might have tranquilly fulfilled the term of his Septennate. But in January 1879 he made a difference of opinion on a military question an excuse for resignation, and M. Jules Grévy, the president of the Chamber, was elected to succeed him by the National Assembly, which thus met for the first time under the Constitutional Law of 1875.

1879: Jules Grévy President of the Republic.

Henceforth the executive as well as the legislative power was in the hands of the republicans. The new President was a leader of the bar, who had first become known in the Constituent Assembly of 1848 as the advocate of the principle that a republic would do better without a president. M. Waddington was his first prime minister, and Gambetta was elected president of the Chamber. The latter, encouraged by his rivals in the idea that the time was not ripe for him openly to direct the affairs of the country, thus put himself, in spite of his immense influence, in a position of official self-effacement from which he did not emerge until the jealousies of his own party-colleagues had undermined the prestige he had gained as chief founder of the Republic. The most active among them was M. Jules Ferry, minister of Education, who having been a republican deputy for Paris at the end of the Empire, was one of the members of the provisional Government proclaimed on 4th September 1870. Borrowing Gambetta's cry that clericalism was the enemy, he commenced the work of reprisal for the *Seize Mai*. His educational projects of 1879 were thus anti-clerical in tendency, the most famous being article 7 of his education bill, which prohibited members of any "unauthorized" religious orders exercising the profession of teaching in any school in France, the disability being applied to all ecclesiastical communities, excepting four or five which had been privileged by special legislation. This enactment, aimed chiefly at the Jesuits, was advocated with a sectarian bitterness which will be associated with the name of Jules Ferry long after his more statesmanlike qualities are forgotten. The law was rejected by the Senate, M. Jules Simon being the eloquent champion of the clericals, whose intrigues had ousted him from office. The unauthorized orders were then dissolved by decree; but though the forcible expulsion of aged priests and nuns gave rise to painful scenes, it cannot be said that popular feeling was excited in their favour, so grievously had the Church blundered in identifying itself with the conspiracy of the *Seize Mai*.

Jules Ferry.

Meanwhile the death of the Prince Imperial in Zululand had shattered the hopes of the Bonapartists, and M. de Freycinet, a former functionary of the Second Empire, had become prime minister at the end of 1879. He had retained M. Jules Ferry at the ministry of Education, but unwilling to adopt all his anti-clerical policy, he resigned the premiership into his hands in September 1880. The constitution of the first Ferry cabinet secured the further exclusion from office of Gambetta. The previous month he had, as president of the Chamber, accompanied M. Grévy on an official visit to Cherbourg, and the acclamations called forth all over France by his speech, which was a hopeful defiance to Germany, encouraged the wily Chief of the State to aid the republican conspiracy against the hero of the Republic. In 1881 the only political question before the country was the destiny of Gambetta. His influence in the Chamber was such that in spite of the opposition of the prime minister he carried his electoral scheme of *scrutin de liste*, descending from the presidential chair to defend it. Its rejection by the Senate caused no conflict between the houses. The check was inflicted not on the Chamber, but on Gambetta, who counted on his popularity to carry the lists of his nominated candidates in all the republican departments in France as a quasi-plebiscitary demonstration in his favour. His rivals dared not openly quarrel with him. There was the semblance of a reconciliation between him and Jules Ferry, and his name was the rallying-cry of the Republic at the general election, which was conducted on the old system of *scrutin d'arrondissement*.

The triumph for the Republic was great, the combined force of reactionary members returned being less than one-fifth of the new Chamber. M. Grévy could no longer abstain from asking Gambetta to form a ministry, but he had bided his time till jealousy of the "occult power" of the president of the Chamber had undermined his position in parliament. Consequently, when on the 14th of November 1881 Gambetta announced the composition of his cabinet, ironically called the "*grand ministère*," which was to consolidate the Republic and to be the apotheosis of its chief, a great feeling of disillusion fell on the country, for his colleagues were untried politicians. The best known was M. Paul Bert, a man of science, who as the "reporter" in the Chamber of the Ferry Education Bill had distinguished himself as an aggressive freethinker, and he inappropriately was named minister of Public Worship. All the conspicuous republicans who had held office refused to serve under Gambetta. His cabinet was condemned in advance. His enemies having succeeded in ruining its composition, declared that the construction of a one-man machine was ominous of dictatorship, and the "*grand ministère*" lived for only ten weeks.

Gambetta Prime Minister.

Gambetta was succeeded in January 1882 by M. de Freycinet, who having first taken office in the Dufaure cabinet of 1877, and having continued to hold office at intervals until 1899, was the most successful specimen of a "*ministrable*"—as recurrent portfolio-holders have been called under the Third Republic. His second ministry lasted only six months. The failure of Gambetta, though pleasing to his rivals, discouraged the republican party and disorganized its majority in the Chamber. M. Duclerc, an old minister of the Second Republic, then became president of the Council, and before his short term of office was run Gambetta died on the last day of 1882, without having had the opportunity of displaying his capacity as a statesman or an administrator. He was only forty-four at his death, and his fame rests on the unfulfilled promise of a brief career. The men who had driven him out of public life and had shortened his existence were the most ostentatious of the mourners at the great pageant with which he was buried, and to have been of his party was in future the popular trade-mark of his republican enemies.

Death of Gambetta.

Gambetta's death was followed by a period of anarchy, during which Prince Napoleon, the son of Jerome, king of Westphalia, placarded the walls of Paris with a manifesto. The Chamber thereupon voted the exile of the members of the families which had reigned in France. The Senate rejected the measure, and a conflict arose between the two houses. M. Duclerc resigned the premiership in January 1883 to his minister of the Interior, M. Fallières, a Gascon lawyer, who eventually became president of the Senate at the end of the century, and he held office for three weeks, when M. Jules Ferry became president of the Council for the second time. Several of the closest of Gambetta's friends accepted office under the old enemy of their chief, and the new combination adopted the epithet "opportunist," which had been invented by Gambetta in 1875 to justify the expediency of his alliance with Thiers. The Opportunists thenceforth formed an important group standing between the Left Centre, which was now excluded from office, and the Radicals. It claimed the tradition of Gambetta, but the guiding principle manifested by its members was that of securing the spoils of place. To this end it often allied itself with the Radicals, and the Ferry cabinet practised this policy in 1883 when it removed the Orleans princes from the active list in the army as the illogical result of the demonstration of a Bonaparte. How needless was this proceeding was shown a few months later when the Comte de Chambord died, as his death, which finally fused the Royalists with the Orleanists, caused no commotion in France.

Opportunism.

The year 1884 was phenomenal in the sense that it passed without a change of ministry. M. Jules Ferry displayed real administrative ability, and as an era of steady government seemed to be commencing, the opportunity was taken to revise the Constitution. The two Chambers therefore met in congress, and enacted that the republican form of government could never be the subject of revision, and that all members of families which had reigned in France were ineligible for the presidency of the Republic—a repetition of the adventure of Louis Bonaparte in the middle of the century being thus made impossible. It also decided that the clauses of the law of 1875 relating to the organization of the Senate should no longer have a constitutional character. This permitted the reform of the Upper House by ordinary parliamentary procedure. So an organic law was passed to abolish the system of nominating senators, and to increase the number of municipal delegates in the electoral colleges in proportion to the population of the communes. The French nation, for the first time since it had enjoyed political life, had revised a Constitution by pacific means without a revolution. Gambetta being out of the way, his favourite electoral system of *scrutin de liste* had no longer any terror for his rivals, so it was voted by the Chamber early in 1885. Before the Senate had passed it into law the Ferry ministry had fallen at the end of March, after holding office for twenty-five months, a term rarely paralleled in the annals of the Third Republic. This long tenure of power had excited the dissatisfaction of jealous politicians, and the news of a slight disaster to the French troops in Tongking called forth all the pent-up rancour which M. Jules Ferry had inspired in various groups. By the exaggerated news of defeat Paris was excited to the brink of a revolution. The approaches of the Chamber were invaded by an angry mob, and Jules Ferry was the object of public hate more bitter than any man had called forth in France since Louis Napoleon on the days after Sedan. Within the Chamber he was attacked in all quarters. The Radicals took the lead, supported by the Monarchists, who remembered the anti-clerical rigour of the Ferry laws, by the Left Centre, not sorry for the tribulation of the group which had supplanted it, and by place-hunting republicans of all shades. The attack was led by a politician who disdained office. M. Clémenceau, who had originally

Revision of the Constitution, 1884.

Tongking.

come to Paris from the Vendée as a doctor, had as a radical leader in the Chamber used his remarkable talent as an overthrower of ministries, and nearly every one of the eight ministerial crises which had already occurred during the presidency of M. Grévy had been hastened by his mordant eloquence.

The next prime minister was M. Brisson, a radical lawyer and journalist, who in April 1885 formed a cabinet of "concentration"—that is to say, it was recruited from various groups with the idea of concentrating all the republican forces in opposition to the reactionaries. M. de Freycinet and M. Carnot, afterwards President of the Republic, represented the moderate element in this ministry, which superintended the general elections under *scrutin de liste.* That system was recommended by its advocates as a remedy for the rapid decadence in the composition of the Chamber. Manhood suffrage, which had returned to the National Assembly a distinguished body of men to conclude peace with Germany, had chosen a very different type of representative to sit in the Chamber created by the Constitution of 1875. At each succeeding election the standard of deputies returned grew lower, till Gambetta described them contemptuously as "*sous-vétérinaires,*" indicating that they were chiefly chosen from the petty professional class, which represented neither the real democracy nor the material interests of the country. His view was that the election of members by departmental lists would ensure the candidature of the best men in each region, who under the system of single-member districts were apt to be neglected in favour of local politicians representing narrow interests. When his death had removed the fear of his using *scrutin de liste* as a plebiscitary organization, parliament sanctioned its trial. The result was not what its promoters anticipated. The composition of the Chamber was indeed transformed, but only by the substitution of reactionary deputies for republicans. Of the votes polled, forty-five per cent. were given to the Monarchists, and if they had obtained one-half of the abstentions the Republic would have come to an end. At the same time the character of the republican deputies returned was not improved; so the sole effect of *scrutin de liste* was to show that the electorate, weary of republican dissensions, was ready to make a trial of monarchical government, if only the reactionary party proved that it contained statesmen capable of leading the nation. So menacing was the situation that the Republicans thought it wise not further to expose their divisions in the presidential election which was due to take place at the end of the year. Consequently, on the 28th of December 1885 M. Grévy, in spite of his growing unpopularity, was elected President of the Republic for a second term of seven years.

Elections of 1885.

The Brisson cabinet at once resigned, and on the 7th of January 1886 its most important member, M. de Freycinet, formed his third ministry, which had momentous influence on the history of the Republic. The new minister of War was General Boulanger, a smart soldier of no remarkable military record; but being the nominee of M. Clémenceau, he began his official career by taking radical measures against commanding officers of reactionary tendencies. He thus aided the Government in its campaign against the families which had reigned in France, whose situation had been improved by the result of the elections. The fêtes given by the Comte de Paris to celebrate his daughter's marriage with the heir-apparent of Portugal moved the republican majority in the Chambers to expel from France the heads of the houses of Orleans and of Bonaparte, with their eldest sons. The names of all the princes on the army list were erased from it, the decree being executed with unseemly ostentation by General Boulanger, who had owed early promotion to the protection of the Duc d'Aumale, and on that prince protesting he was exiled too. Meanwhile General Boulanger took advantage of M. Grévy's unpopularity to make himself a popular hero, and at the review, held yearly on the 14th of July, the anniversary of the fall of the Bastille, his acclamation by the Parisian mob showed that he was taking an unexpected place in the imagination of the people. He continued to work with the Radicals, so when they turned out M. de Freycinet in December 1886, one of their group, M. Goblet, a lawyer from Amiens, formed a ministry, and retained Boulanger as minister of War. M. Clémenceau, however, withdrew his support from the General, who was nevertheless loudly patronized by the violent radical press. His bold attitude towards Germany in connexion with the arrest on the German frontier of a French official named Schnaebele so roused the enthusiasm of the public, that M. Goblet was not sorry to resign in May 1887 in order to get rid of his too popular colleague.

General Boulanger.

To form the twelfth of his ministries, M. Grévy called upon M. Rouvier, an Opportunist from Marseilles, who had first held office in Gambetta's short-lived cabinet. General Boulanger was sent to command a *corps d'armée* at Clermont-Ferrand; but the popular press and the people clamoured for the hero who was said to have terrorized Prince Bismarck, and they encouraged him to play the part of a plebiscitary candidate. There were grave reasons for public discontent. Parliament in 1887 was more than usually sterile in legislation, and in the autumn session it had to attend to a scandal which had long been rumoured. The son-in-law of M. Grévy, M. Daniel Wilson, a prominent deputy who had been an under Secretary of State, was accused of trafficking the decoration of the Legion of Honour, and of using the Elysée, the President's official residence, where he lived, as an agency for his corrupt practices. The evidence against him was so clear that his colleagues in the Chamber put the Government into a minority in order to precipitate a presidential crisis, and on M. Grévy refusing to accept this hint, a long array of politicians, representing all the republican groups, declined his invitation to aid him in forming a new ministry, all being bent on forcing his resignation. Had General Boulanger been a man of resolute courage he might at this crisis have made a *coup d'état*, for his popularity in the street and in the army increased as the Republic sank deeper into scandal and anarchy. At last, when Paris was on the brink of revolution, M. Grévy was prevailed on to resign. The candidates for his succession were two ex-prime ministers, MM. Jules Ferry and de Freycinet, and M. Floquet, a barrister, who had been conspicuous in the early days of the National Assembly for his sympathy with the Commune. The Monarchists had no candidate ready, and resolved to vote for M. Ferry, because they believed that if he were elected his unpopularity with the democracy would cause an insurrection in Paris and the downfall of the Republic. M. de Freycinet and M. Floquet each looked for the support of the Radicals, and each had made a secret compact, in the event of his election, to restore General Boulanger to the War Office. But M. Clémenceau, fearing the election of M. Jules Ferry, advised his followers to vote for an "outsider," and after some manœuvring the congress elected by a large majority M. Sadi Carnot.

The Wilson scandal.

The new President, though the nominee of chance, was an excellent choice. The grandson of Lazare Carnot, the "organizer of victory" of the Convention, he was also a man of unsullied probity. The tradition of his family name, only less glorious than that of Bonaparte in the annals of the Revolution, was welcome to France, almost ready to throw herself into the arms of a soldier of fortune, while his blameless repute reconciled some of those whose opposition to the Republic had been quickened by the mean vices of M. Grévy.

M. Carnot President of the Republic, 1887.

But the name and character of M. Carnot would have been powerless to check the Boulangist movement without the incompetency of its leader, who was getting the democracy at his back without knowing how to utilize it. The new President's first prime minister was M. Tirard, a senator who had held office in six of M. Grévy's ministries, and he formed a cabinet of politicians as colourless as himself. The early months of 1888 were occupied with the trial of M. Wilson, who was sentenced to two years' imprisonment for fraud, and with the conflicts of the Government with General Boulanger, who was deprived of his command for coming to Paris without leave. M. Wilson appealed against his sentence, and General Boulanger was elected deputy for the department of the Aisne by an enormous majority. It so happened that the day after his election a presidential decree was signed on the advice of the minister of War removing General Boulanger from the army, and the Court of Appeal quashed M. Wilson's conviction. Public feeling was profoundly moved by the coincidence of the release of the relative of the ex-President by the judges of the Republic on the same day that its ministers expelled from the army the popular hero of universal suffrage.

As General Boulanger had been invented by the Radicals it was thought that a Radical cabinet might be a remedy to cope with him, so M. Floquet became President of the Council in April 1888, M. de Freycinet taking the portfolio of War which he retained through many ministries.

Boulangism.

M. Floquet's chief achievement was a duel with General Boulanger, in which, though an elderly civilian, he wounded him. Nothing, however, checked the popularity of the military politician, and though he was a failure as a speaker in the Chamber, several departments returned him as their deputy by great majorities. The Bonapartists had joined him, and while in his manifestoes he described himself as the defender of the Republic, the mass of the Monarchists, with the consent of the Comte de Paris, entered the Boulangist camp, to the dismay both of old-fashioned Royalists and of many Orleanists, who resented his recent treatment of the Duc d'Aumale. The centenary of the taking of the Bastille was to be celebrated in Paris by an international exhibition, and it appeared likely that it would be inaugurated by General Boulanger, so irresistible seemed his popularity. In January 1889 he was elected member for the metropolitan department of the Seine with a quarter of a million votes, and by a majority of eighty thousand over the candidate of the Government. Had he marched on the Elysée the night of his election, nothing could have saved the parliamentary Republic; but again he let his chance go by. The Government in alarm proposed the restoration of *scrutin d'arrondissement* as the electoral system for *scrutin de liste.* The change was rapidly enacted by the two Chambers, and was a significant commentary on the respective advantages of the two systems. M. Tirard was again called to form a ministry, and he selected as minister of the Interior M. Constans, originally a professor at Toulouse, who had already proved himself a skilful manipulator of elections when he held the same office in 1881. He was therefore given the supervision of the machinery of centralization with which it was supposed that General Boulanger would have to be fought at the general election. That incomplete hero, however, saved all further trouble by flying the country when he heard that his arrest was imminent. The Government, in order to prevent any plebiscitary manifestation in his favour, passed a law forbidding a candidate to present himself for a parliamentary election in more than one constituency; it also arraigned the General on the charge of treason before the Senate sitting as a high court, and he was sentenced in his absence to perpetual imprisonment. Such measures were needless. The flight of General Boulanger was the death of Boulangism. He alone had saved the Republic which had done nothing to save itself. Its Government had, on the contrary, displayed throughout the crisis an anarchic feebleness and incoherency which would have speeded its end had the leader of the plebiscitary movement possessed sagacity or even common courage.

Boulanger's flight.

The elections of 1889 showed how completely the reactionaries had compromised their cause in the Boulangist failure. Instead of 45 per cent. of the votes polled as in 1885, they obtained only 21 per cent., and the Comte de Paris, the pretender of constitutional monarchy, was irretrievably prejudiced by his alliance with the military adventurer who had outraged the princes of his house. A period of calm succeeded the storm of Boulangism, and for the first time under the Third Republic parliament set to work to produce legislation useful for the State, without rousing party passion, as in its other period of activity when the Ferry education laws were passed. Before the elections of 1889 the reform of the army was undertaken, the general term of active compulsory service was made three years, while certain classes hitherto dispensed from serving, including ecclesiastical seminarists and lay professors, had henceforth to undergo a year's military training. The new parliament turned its attention to social and labour questions, as the only clouds on the political horizon were the serious strikes in the manufacturing districts, which displayed the growing political organization of the socialist party. Otherwise nothing disturbed the calm of the country. The young Duc d'Orléans vainly tried to ruffle it by breaking his exile in order to claim his citizen's right to perform his military service. The cabinet was rearranged in March 1890, M. de Freycinet becoming prime minister for the fourth time, and retaining the portfolio of War. All seemed to point to the consolidation of the Republic, and even the Church made signals of reconciliation. Cardinal Lavigerie, a patriotic missionary and statesman, entertained the officers of the fleet at Algiers, and proposed the toast of the Republic to the tune of the "Marseillaise" played by his *pères blancs.* The royalist Catholics protested, but it was soon intimated that the Archbishop of Algiers' demonstration was approved at Rome. The year 1891 was one of the four in the annals of the Republic which passed without a change of ministry, but the agitations of 1892 were to counterbalance the repose of the two preceding years.

The first crisis arose out of the peacemaking policy of the Pope. Following up his intimation to the Archbishop of Algiers, Leo XIII. published in February 1892 an encyclical, bidding French Catholics accept the Republic as the firmly-established form of government. The papal injunction produced a new political group called the "Ralliés," the majority of its members being Monarchists who rallied to the Republic in obedience to the Vatican. The most conspicuous among them was M. de Mun, an eloquent exponent in the Chamber of legitimism and Christian socialism. The extreme Left mistrusted the adhesion of the new converts to the Republic, and ecclesiastical questions were the constant subjects of acrimonious debates in parliament. In the course of one of them M. de Freycinet found himself in a minority. He ceased to be prime minister, being succeeded by

The Papal encyclical, 1892.

M. Loubet, a lawyer from Montélimar, who had previously held office for three months in M. Tirard's first cabinet; but M. de Freycinet continued to hold his portfolio of War. The confusion of the republican groups kept pace with the disarray of the reactionaries, and outside parliament the frequency of anarchist outrages did not increase public confidence. The only figure in the Republic which grew in prestige was that of M. Carnot, who in his frequent presidential tours dignified his office, though his modesty made him unduly efface his own personality.

When the autumn session of 1892 began, all other questions were overwhelmed by the bursting of the Panama scandal. The company associated for the piercing of the isthmus of Panama, undertaken by M. de Lesseps, the maker of the Suez canal, had become insolvent some years before. Fifty millions sterling subscribed by the thrift of France had disappeared, but the rumours involving political personages in the disaster were so confidently asserted to be reactionary libels, that a minister of the Republic, afterwards sent to penal servitude for corruption, obtained damages for the publication of one of them. It was known that M. de Lesseps was to be tried for misappropriating the money subscribed; but considering the vast sums lost by the public, little interest was taken in the matter till it was suddenly stirred by the dramatic suicide of a well-known Jewish financier closely connected with republican politicians, driven to death it was said by menaces of blackmail. Then succeeded a period of terror in political circles. Every one who had a grudge against an enemy found vent for it in the press, and the people of Paris lived in an atmosphere of delation. Unhappily it was true that ministers and members of parliament had been subsidized by the Panama company. M. Floquet, the president of the Chamber, avowed that when prime minister he had laid hands on £12,000 of the company's funds for party purposes, and his justification of the act threw a light on the code of public morality of the parliamentary Republic. Other politicians were more seriously implicated on the charge of having accepted subsidies for their private purposes, and emotion reached its height when the cabinet ordered the prosecution of two of its members for corrupt traffic of their offices. These two ministers were afterwards discharged, and they seem to have been accused with recklessness; but their prosecution by their own colleagues proved that the statesmen of the Republic believed that their high political circles were sapped with corruption. Finally, only twelve senators and deputies were committed for trial, and the only one convicted was a minister of M. de Freycinet's third cabinet, who pleaded guilty to receiving large bribes from the Panama company. The public regarded the convicted politician as a scapegoat, believing that there were numerous delinquents in parliament, more guilty than he, who had not even been prosecuted. This feeling was aggravated by the sentence passed, but afterwards remitted, on the aged M. de Lesseps, who had involved French people in misfortune only because he too sanguinely desired to repeat the triumph he had achieved for France by his great work in Egypt.

The Panama scandal.

Within the nation the moral result of the Panama affair was a general feeling that politics had become under the Republic a profession unworthy of honest citizens. The sentiment evoked by the scandal was one of sceptical lassitude rather than of indignation. The reactionaries had crowned their record of political incompetence. At a crisis which gave legitimate opportunity to a respectable and patriotic Opposition they showed that the country had nothing to expect from them but incoherent and exaggerated invective. If the scandal had come to light in the time of General Boulanger the parliamentary Republic would not have survived it. As it was, the sordid story did little more than produce several changes of ministry. M. Loubet resigned the premiership in December 1892 to M. Ribot, a former functionary of the Empire, whose ministry lived for three stormy weeks. On the first day of 1893 M. Ribot formed his second cabinet, which survived till the end of March, when he was succeeded by his minister of Education, M. Charles Dupuy, an ex-professor who had never held office till four months previously. M. Dupuy, having taken the portfolio of the Interior, supervised the general election of 1893, which took place amid the profound indifference of the population, except in certain localities where personal antagonisms excited violence. An intelligent Opposition would have roused the country at the polls against the regime compromised by the Panama affair. Nothing of the sort occurred, and the electorate preferred the doubtful probity of their republican representatives to the certain incompetence of the reactionaries. The adversaries of the Republic polled only 16 per cent. of the votes recorded, and the chief feature of the election was the increased return of socialist and radical-socialist deputies. When parliament met it turned out the Dupuy ministry, and M. Casimir-Périer quitted the presidency of the Chamber to take his place. The new prime minister was the bearer of an eminent name, being the grandson of the statesman of 1831, and the great-grandson of the owner of Vizille, where the États du Dauphiné met in 1788, as a prelude to the assembling of the States General the next year. His acceptance of office aroused additional interest because he was a minister possessed of independent wealth, and therefore a rare example of a French politician free from the imputation of making a living out of politics. Neither his repute nor his qualities gave long life to his ministry, which fell in four months, and M. Dupuy was sent for again to form a cabinet in May 1894.

Before the second Dupuy ministry had been in office a month M. Carnot died by the knife of an anarchist at Lyons. He was perhaps the most estimable politician produced by the Third Republic. Although the standard of political life was not elevated under his presidency, he at all events set a good personal example, and to have filled unscathed the most conspicuous position in the land during a period unprecedented for the scurrility of libels on public men was a testimony to his blameless character. As the term of his septennate was near, parliament was not unprepared for a presidential election, and M. Casimir-Périer, who had been spoken of as his possible successor, was elected by the Congress which met at Versailles on 27th June 1894, four days after M. Carnot's assassination. The election of one who bore respectably a name not less distinguished in history than that of Carnot seemed to ensure that the Republic would reach the end of the century under the headship of a President of exceptional prestige. But instead of remaining Chief of the State for seven years, in less than seven months M. Casimir-Périer astonished France and Europe by his resignation. Scurrilously defamed by the socialist press, the new President found that the Republicans in the Chamber were not disposed to defend him in his high office; so, on 15th January 1895, he seized the occasion of the retirement of the Dupuy ministry to address a message to the two houses intimating his resignation of the presidency, which, he said, was endowed with too many responsibilities and not sufficient powers.

Assassination of President Carnot.

M. Casimir-Périer President of the Republic, 1894.

This time the Chambers were unprepared for a presidential vacancy, and to fill it in forty-eight hours was necessarily a matter of hap-hazard. The choice of the congress fell on M. Félix Faure, a merchant of Havre, who, though minister of Marine in the retiring cabinet, was one of the least-known politicians who had held office. The selection was a good one, and introduced to the presidency a type of politician unfortunately rare under the Third Republic—a successful man of business. M. Félix Faure had a fine presence and polished manners, and having risen from a humble origin he displayed in his person the fact that civilization descends to a lower social level in France than elsewhere. Although he was in a sense a man of the people the Radicals and Socialists in the Chambers had voted against him. Their candidate, like almost all democratic leaders in France, had never worked with his hands,—M. Brisson, the son of an attorney at Bourges, a member of the Parisian bar, and perpetual candidate for the presidency. Nevertheless the Left tried to take possession of President Faure. His first ministry, composed of moderate republicans and presided over by M. Ribot, lasted until the autumn session of 1895, when it was turned out and a radical cabinet was formed by M. Léon Bourgeois, an ex-functionary, who when a prefect had been suspected of reactionary tendencies.

M. Félix Faure President of the Republic 1895.

The Bourgeois cabinet of 1895 was remarkable as the first ministry formed since 1877 which did not contain a single member of the outgoing cabinet. It was said to be exclusively radical in its composition, and thus to indicate that the days of "republican concentration" were over, and that the Republic, being firmly established, an era of party government on the English model had arrived. The new ministry, however, on analysis did not differ in character from any of its predecessors. Seven of its members were old office-holders of the ordinary "ministrable" type. The most conspicuous was M. Cavaignac, the son of the general who had opposed Louis Bonaparte in 1848, and the grandson of J. B. Cavaignac, the regicide member of the Convention. Like M. Carnot and M. Casimir-Périer, he was, therefore, one of those rare politicians of the Republic who possessed some hereditary tradition. An ambitious man, he was now classed as a Radical on the strength of his advocacy of the income-tax, the principle of which has never been popular in France, as being adverse to the secretive habits of thrift cultivated by the people, which are a great source of the national wealth. The radicalism of the rest of the ministry was not more alarming in character, and its tenure of office was without legislative result. Its fall, however, occasioned the only constitutionally interesting ministerial crisis of the twenty-four which had taken place since M. Grévy's election to the presidency sixteen years before. The Senate, disliking the fiscal policy of the Government, refused to vote supply in spite of the support which the Chamber gave to the ministry. The collision between the two houses did not produce the revolutionary rising which the Radicals predicted, and the Senate actually forced the Bourgeois cabinet to resign amid profound popular indifference.

The new prime minister was M. Méline, who began his long political career as a member of the Commune in 1871, but was so little compromised in the insurrection that M. Jules Simon gave him an under-secretaryship in his ministry of 1876. After that he was once a cabinet minister, and was for a year president of the Chamber. He was chiefly known as a protectionist; but it was as leader of the Progressists, as the Opportunists now called themselves, that he formed his cabinet in April 1896, which was announced as a moderate ministry opposed to the policy of the Radicals. It is true that it made no attempt to tax incomes, but otherwise its achievements did not differ from those of other ministries, radical or concentration, except in its long survival. It lasted for over two years, and lived nearly as long as the second Ferry cabinet. Its existence was prolonged by certain incidents of the Franco-Russian alliance. The visit of the Tsar to Paris in October 1896, being the first official visit paid by a European sovereign to the Republic, helped the Government over the critical term at which ministries usually succumbed, and it was further strengthened in parliament by the invitation to the President of the Republic to return the Imperial visit at St Petersburg in 1897. The Chamber came to its normal term that autumn; but a law had been passed fixing May as the month for general elections, and the ministry was allowed to retain office till the dissolution at Easter 1898.

Franco-Russian alliance.

The long duration of the Méline Government was said to be a further sign of the arrival of an era of party government with its essential accompaniment, ministerial stability. But in the country there was no corresponding sign that the electorate was being organized into two parties of Progressists and Radicals; while in the Chamber it was ominously observed that persistent opposition to the moderate ministry came from nominal supporters of its views, who were dismayed at one small band of fellow-politicians monopolizing office for two years. The last election of the century was therefore fought on a confused issue, the most tangible results being the further reduction of the Monarchists, who secured only 12 per cent. of the total poll, and the advance of the Socialists, who obtained nearly 20 per cent. of the votes recorded. The Radicals returned were less numerous than the Moderates, but with the aid of the Socialists they nearly balanced them. A new group entitled Nationalist made its appearance, supported by a miscellaneous electorate representing the malcontent element in the nation of all political shades from monarchist to revolutionary-socialist. The Chamber, so composed, was as incoherent as either of its predecessors. It refused to re-elect the radical leader, M. Brisson, as its president, and then refused its confidence to the moderate leader M. Méline. M. Brisson, the rejected of the Chamber, was sent for to form a ministry, on 28th June 1898, which survived till the adjournment, only to be turned out when the autumn session began. M. Charles Dupuy thus became prime minister for the third time with a cabinet of the old concentration pattern, and for the third time in less than five years under his premiership the presidency of the Republic became vacant. M. Félix Faure had increased in pomposity rather than in popularity. His contact with European sovereigns seems to have made him over-conscious of his superior rank, and he cultivated habits which austere republicans make believe to be the monopoly of frivolous courts. The regular domesticity of middle-class life may not be disturbed with impunity when age is advancing, and M. Félix Faure died with tragic unexpectedness on 16th February 1899. The joys of his high office were so dear to him that nothing but death would have induced him to lay it down before the term of his septennate. There was therefore no candidate in waiting for the vacancy; and as Paris was in an agitated mood the majority in the Congress elected M. Loubet President of the Republic, because he happened to hold the second place of dignity in the State, the presidency of the Senate, and was moreover a politician who had the confidence of the republican groups as an adversary of plebiscitary pretensions. His only competitor was M. Méline, whose ambitions were not realized, in spite of the alliance of his Progressist supporters with the Monarchists and Nationalists. The Dupuy ministry lasted till June 1899, when a new cabinet was formed by

1899: Death of President Faure.

M. Loubet President of the Republic.

M. Waldeck-Rousseau, who, having held office under Gambetta and Jules Ferry, had relinquished politics for the bar, of which he had become a distinguished leader. Though a moderate republican, he was the first prime minister to give portfolios to socialist politicians. This was the distinguishing feature of the last cabinet of the century—the thirty-seventh which had taken office in the twenty-six years which had elapsed since the resignation of M. Thiers in 1873.

It is now necessary to go back a few years in order to refer to a matter which, though not political in its origin, in its development filled the whole political atmosphere of France in the closing period of the 19th century. Soon after the failure of the Boulangist movement a journal was founded at Paris called the *Libre Parole.* Its editor, M. Drumont, was known as the author of *La France Juive*, a violent anti-Semitic work, written to denounce the influence exercised by Jewish financiers in the politics of the Third Republic. It may be said to have started the anti-Semitic movement in France, where hostility to the Jews had not the pretext existing in those lands which contain a large Jewish population exercising local rivalry with the natives of the soil, or spoiling them with usury. That state of things existed in Algeria, where the indigenous Jews were made French citizens during the Franco-Prussian war to secure their support against the Arabs in rebellion. But political anti-Semitism was introduced into Algeria only as an offshoot of the movement in continental France, where the great majority of the Jewish community were of the same social class as the politicians of the Republic. Primarily directed against the Jewish financiers, the movement was originally looked upon as a branch of the anti-capitalist propaganda of the Socialists. Thus the *Libre Parole* joined with the revolutionary press in attacking the repressive legislation provoked by the dynamite outrages of the anarchists, clerical reactionaries who supported it being as scurrilously abused by the anti-Semitic organ as its republican authors. The Panama affair, in the exposure of which the *Libre Parole* took a prominent part soon after its foundation, was also a bond between anti-Semites and Socialists, to whom, however, the Monarchists, always incapable of acting alone, united their forces. The implication of certain Jewish financiers with republican politicians in the Panama scandal aided the anti-Semites in their special propaganda, of which a main thesis was that the government of the Third Republic had been organized by its venal politicians for the benefit of Jewish immigrants from Germany, who had thus enriched themselves at the expense of the laborious and unsuspecting French population. The *Libre Parole,* which had become a popular organ with reactionaries and with malcontents of all classes, enlisted the support of the Catholics by attributing the anti-religious policy of the Republic to the influence of the Jews, skilfully reviving bitter memories of the enaction of the Ferry decrees, when sometimes the laicization of schools or the expulsion of monks and nuns had been carried out by a Jewish functionary. Thus religious sentiment and race prejudice were introduced into a movement which was at first directed against capital; and the campaign was conducted with the weapons of scurrility and defamation which had made an unlicensed press under the Third Republic a demoralizing national evil.

Anti-Semitic movement.

An adroit feature of the anti-Semitic campaign was an appeal to national patriotism to rid the army of Jewish influence. The Jews, it was said, not content with directing the financial, and thereby the general policy of the Republic, had designs on the French army, in which they wished to act as secret agents of their German kindred. In October 1894 the *Libre Parole* announced that a Jewish officer of artillery attached to the general staff, Captain Alfred Dreyfus, had been arrested on the charge of supplying a Government of the Triple Alliance with French military secrets. Tried by court-martial, he was sentenced to military degradation and to detention for life in a fortress. He was publicly degraded at Paris in January 1895, a few days before M. Casimir-Périer resigned the presidency of the Republic, and was then transported to the Île du Diable on the coast of French Guiana. His conviction, on the charge of having betrayed to a foreign power documents relating to the national defence, was based on the alleged identity of his handwriting with that of an intercepted covering-letter, which contained a list of the papers thus treasonably communicated. The possibility of his innocence was not raised outside the circle of his friends; the Socialists, who subsequently defended him, even complained that common soldiers were shot for offences less than that for which this richly-connected officer had been only transported. The secrecy of his trial did not shock public sentiment in France, where all civilians charged with crime are interrogated by a judge in private, and where all accused persons are presumed guilty until they have proved their innocence. In a land subject to invasion there was less disposition to criticize the decision of a military tribunal acting in the defence of the nation even than there would have been in the case of a doubtful judgment passed in a civil court. The country was practically unanimous that Captain Dreyfus had got his deserts. A few, indeed, suggested that had he not been a Jew he would never have been accused; but the greater number replied that an ordinary French traitor of Gentile birth would have been forgotten from the moment of his condemnation. The pertinacity with which some of his co-religionists set to work to show that he had been irregularly condemned seemed to justify the latter proposition. But it was not a Jew who brought about the revival of the affair. Colonel Picquart, an officer of great promise, became head of the Intelligence department at the War Office, and in 1896 informed the Minister of his suspicion that the letter on which Dreyfus had been condemned was written by a certain Major Esterhazy. The military authorities, not wishing to have the case reopened, sent Colonel Picquart on foreign service, and put in his place Colonel Henry. The all-seeing press published various versions of the incident, and the anti-Semitic journals denounced them as proofs of a Jewish conspiracy against the French army.

Condemnation of Captain Dreyfus.

At the end of 1897 M. Scheurer-Kestner, an Alsatian devoted to France and a republican senator, tried to persuade his political friends to reopen the case; but M. Méline, the prime minister, declared in the name of the Republic that the Dreyfus affair no longer existed. The fact that the senator who championed Dreyfus was a Protestant encouraged the clerical press in its already marked tendency to utilize anti-Semitism as a weapon of ecclesiastical warfare. But the religious side-issues of the question would have had little importance had not the army been involved in the controversy, which had become so keen that all the population, outside that large section of it indifferent to all public questions, was divided into "Dreyfusards" and "anti-Dreyfusards." The strong position of the latter was due to their assuming the position of defenders of the army, which, at an epoch when neither legislature nor Government inspired respect, and when the Church was the object of polemic, was the only institution in France to unite the nation by appealing to its martial and patriotic instincts. That is the explanation of the enthusiasm of the public for generals and other officers by whom the trial of Dreyfus and

Dreyfusards and anti-Dreyfusards.

subsequent proceedings had been conducted in a manner repugnant to those who do not favour the arbitrary ways of military dictatorship, which, however, are not unpopular in France. The acquittal of Major Esterhazy by a court-martial, the conviction of M. Zola by a civil tribunal for a violent criticism of the military authorities, and the imprisonment without trial of Colonel Picquart for his efforts to exculpate Dreyfus, were practically approved by the nation. This was shown by the result of the general elections in May 1898. The clerical reactionaries were almost swept out of the Chamber, but the overwhelming republican majority was practically united in its hostility to the defenders of Dreyfus, whose only outspoken representatives were found in the socialist groups. The moderate ministry of M. Méline was succeeded in June 1898 by the radical ministry of M. Brisson. But while the new prime minister was said to be personally disposed to revise the sentence on Dreyfus, his civilian minister of War, M. Cavaignac, was as hostile to revision as any of his military predecessors—General Mercier, under whom the trial took place, General Zurlinden, and General Billot, a republican soldier devoted to the parliamentary regime.

The radical minister of War in July 1898 laid before the Chamber certain new proofs of the guilt of Dreyfus, in a speech so convincing that the house ordered it to be placarded in all the communes of France. The next month Colonel Henry, the chief of the Intelligence department, confessed to having forged those new proofs, and then committed suicide. M. Cavaignac thereupon resigned office, but declared that the crime of Henry did not prove the innocence of Dreyfus. Many, however, who had hitherto accepted the judgment of 1894, reflected that the offence of a guilty man did not need new crime for its proof. It was further remarked that the forgery had been committed by the intimate colleague of the officers of the general staff, who had zealously protected Esterhazy, the suspected author of the document on which Dreyfus had been convicted. An uneasy misgiving became widespread; but partisan spirit was too excited for it to cause a general revulsion of feeling. Some journalists and politicians of the extreme Left had adopted the defence of Dreyfus as an anti-clerical movement in response to the intemperate partisanship of the Catholic press on the other side. Other members of the socialist groups, not content with criticizing the conduct of the military authorities in the Dreyfus affair, opened a general attack on the French army,—an unpopular policy which allowed the anti-Dreyfusards to utilize the old revolutionary device of making the word "patriotism" a party cry. The defamation and rancour with which the press on both sides flooded the land obscured the point at issue. However, the Brisson ministry just before its fall remitted the Dreyfus judgment to the criminal division of the Cour de Cassation — the supreme court of appeal in France. M. Dupuy formed a new cabinet in October 1898, and made M. de Freycinet minister of War, but that adroit office-holder, though a civilian and a Protestant, did not favour the anti-military and anti-clerical defenders of Dreyfus. The refusal of the Senate, the stronghold of the Republic, to re-elect M. Scheurer-Kestner as its vice-president, showed that the opportunist minister of War understood the feeling of parliament, which was soon displayed by an extraordinary proceeding. The divisional judges, to whom the case was remitted, showed signs that their decision would be in favour of a new trial of Dreyfus. The republican legislature, therefore, disregarding the principle of the separation of the powers, which is the basis of constitutional government, took the arbitrary step of interfering with the judicial authority. It actually passed a law withdrawing the partly-heard cause from the criminal chamber of the Cour de Cassation, and transferring it to the full court of three divisions, in the hope that a majority of judges would thus be found to decide against the revision of the sentence on Dreyfus.

Political results of Dreyfus agitation.

This flagrant confusion of the legislative with the judicial power displayed once more the incompetence of the French rightly to use parliamentary institutions; but it left the nation indifferent. It was during the passage of the bill that the President of the Republic suddenly died. M. Félix Faure was said to be hostile to the defenders of Dreyfus and disposed to utilize the popular enthusiasm for the army as a means of making the presidential office independent of parliament. The Chambers, therefore, in spite of their anti-Dreyfusard bias, were determined not to relinquish any of their constitutional prerogative. The military and plebiscitary parties were now fomenting the public discontent by noisy demonstrations. The president of the Senate, M. Loubet, as has been mentioned, was known to have no sympathy with this agitation, so he was elected President of the Republic by a large majority at the congress held at Versailles on 18th February 1899. The new President, who was unknown to the public, though he had once been prime minister for nine months, was respected in political circles; but his elevation to the first office of the State made him the object of that defamation which had become the chief characteristic of the partisan press under the Third Republic. He was recklessly accused of having been an accomplice of the Panama frauds, by screening certain guilty politicians when he was prime minister in 1892, and because he was not opposed to the revision of the Dreyfus sentence he was wantonly charged with being bought with Jewish money. Meanwhile the united divisions of the Cour de Cassation were, in spite of the intimidation of the legislature, reviewing the case with an independence worthy of praise in an ill-paid magistracy which owed its promotion to political influence. Instead of justifying the suggestive interference of parliament it revised the judgment of the court-martial, and ordered Dreyfus to be re-tried by a military tribunal at Rennes. The Dupuy ministry, which had wished to prevent this decision, resigned, and M. Waldeck-Rousseau formed a heterogeneous cabinet in which Socialists, who for the first time took office, had for their colleague as minister of War General de Galliffet, whose chief political fame had been won as the executioner of the Communards after the insurrection of 1871. Dreyfus was brought back from the Devil's Island, and in August 1899 was put upon his trial a second time. His old accusers, led by General Mercier, the minister of War of 1894, redoubled their efforts to prove his guilt, and were permitted by the officers composing the court a wide license according to English ideas of criminal jurisprudence. The published evidence did not, however, seem to connect Dreyfus with the charges brought against him. Nevertheless the court, by a majority of five to two, found him guilty, and with illogical inconsequence added that there were in his treason extenuating circumstances. He was sentenced to ten years' detention, and while it was being discussed whether the term he had already served would count as part of his penalty, the ministry completed the inconsequency of the situation by advising the President of the Republic to pardon the prisoner. The result of the second trial satisfied neither the partisans of the accused, who desired his rehabilitation, some of them reproaching him for accepting a pardon, nor his adversaries, whose vindictiveness was unsated by the penalty he had already suffered. But the great mass of the French people, who are always ready to treat a public question with indifference, were

Second trial of Dreyfus.

glad to be rid of a controversy which had for years infected the national life.

The Dreyfus affair was severely judged by foreign critics as a miscarriage of justice resulting from race-prejudice. If that simple appreciation rightly describes its origin, it became in its development one of those scandals symptomatic of the unhealthy political condition of France, which on a smaller scale had often recurred under the Third Republic, and which were made the pretext by the malcontents of all parties for gratifying their animosities. That in its later stages it was not a question of race-persecution was seen in the curious phenomenon of journals owned or edited by Jews leading the outcry against the Jewish officer and his defenders. That it was not a mere episode of the rivalry between Republicans and Monarchists, or between the advocates of parliamentarism and of military autocracy, was evident from the fact that the most formidable opponents of Dreyfus, without whose hostility that of the clericals and reactionaries would have been ineffective, were republican politicians. That it was not a phase of the anti-capitalist movement was shown by the zealous adherence of the socialist leaders and journalists to the cause of Dreyfus; indeed, one remarkable result of the affair was its diversion of the socialist party and press for several years from their normal campaign against property. The Dreyfus affair was utilized by the reactionaries against the Republic, by the clericals against the non-Catholics, by the anti-clericals against the Church, by the military party against the parliamentarians, and by the revolutionary socialists against the army. It was also conspicuously utilized by rival republican politicians against one another, and the chaos of political groups was further confused by it. The controversy was conducted with the unseemly weapons which in France have made parliamentary institutions a by-word and an unlicensed press a national calamity; while the judicial proceedings arising out of it showed that at the end of the 19th century the French conception of liberty was as peculiar as it had been during the Revolution a hundred years before.

Real character of the Dreyfus agitation.

An epilogue to the Dreyfus affair was the trial for treason before the Senate, at the end of 1899, of a number of persons, mostly obscure followers either of M. Déroulède the poet, who advocated a plebiscitary republic, or of the Duc d'Orleans, the pretender of the constitutional monarchy. On the day of President Faure's funeral M. Déroulède had vainly tried to entice General Roget, a zealous adversary of Dreyfus, who was on duty with his troops, to march on the Elysée in order to evict the newly-elected President of the Republic. Other demonstrations against M. Loubet ensued, the most offensive being a concerted assault upon him on the racecourse at Auteuil in June 1899. The subsequent resistance to the police of a band of anti-Semites threatened with arrest, who barricaded themselves in a house in the Rue Chabrol, in the centre of Paris, and, with the marked approval of the populace, sustained a siege for several weeks, indicated that the capital was in a condition not far removed from anarchy. M. Déroulède, indicted at the assizes of the Seine for his misdemeanour on the day of President Faure's funeral, had been triumphantly acquitted. It was evident that no jury would convict citizens prosecuted for political offences, and the Government therefore decided to make use of the article of the Law of 1875, which allowed the Senate to be constituted a High Court for the trial of offences endangering the State. A respectable minority of the Senate, including M. Wallon, the venerable "Father of the Constitution" of 1875, vainly protested that the framers of the law intended to invest the upper legislative Chamber with judicial power only for the trial of grave crimes of high treason, and not of petty political disorders which a well-organized government ought to be able to repress with the ordinary machinery of police and justice. The outvoted protest was justified by the proceedings before the High Court, which, undignified and disorderly, displayed both the fatuity of the so-called conspirators and the feebleness of the Government which had to cope with them. The trial proved that the plebiscitary faction was destitute of its essential factor, a chief to put forward for the headship of the State, and that it was resolved, if it overturned the parliamentary system, not to accept under any conditions the Duc d'Orleans, the only pretender before the public. It was shown that royalists and plebiscitary republicans alike had utilized as an organization of disorder the anti-Semitic propaganda which had won favour among the masses as a nationalist movement to protect the French from foreign competition. The evidence adduced before the High Court revealed, moreover, the curious fact that certain Jewish royalists had given to the Duc d'Orleans large sums of money to found anti-Semitic journals as the surest means of popularizing his cause.

The State trial of 1899.

The last year of the 19th century, though uneventful for France, was one of political unrest. This, however, did not take the form of ministerial crises, as, for the fourth time since responsible cabinets were introduced in 1873, a whole year, from 1st January to 31st December, elapsed without a change of ministry. The prime minister, M. Waldeck-Rousseau, though his domestic policy exasperated a large section of the political world, including one half of the Progressive group which he had helped to found, displayed qualities of statesmanship always respected in France, but rarely exhibited under the Third Republic. He had proved himself to be what the French call "*un homme de gouvernement*"—that is to say, an authoritative administrator of unimpassioned temperament capable of governing with the arbitrary machinery of Napoleonic centralization. His alliance with the Extreme Left and the admission into his cabinet of socialist deputies, showed that he understood which wing of the Chamber it was best to conciliate in order to keep the government in his hands for an abnormal term. The advent to office of Socialists disquieted the respectable and prosperous commercial classes, which in France take little part in politics, though they had small sympathy with the nationalists, who were the most violent opponents of the Waldeck-Rousseau ministry. The alarm caused by the handing over of important departments of the State to socialist politicians arose upon a danger which is not always understood beyond the borders of France. Socialism in France is not a scientific doctrine propagated by earnest reformers, as it is in some European countries. It is a movement appealing to the revolutionary instincts of the French democracy, advocated in vague terms by the members of rival groups or sects. Thus the increasing number of socialist deputies in parliament had produced no legislative results, and their presence in the cabinet was not feared on that account. The fear which their office-holding inspired was due to the immense administrative patronage which the centralized system confides to each member of the Government. French ministers are wont to bestow the places at their disposal on their political friends, so the prospect of administrative posts being filled all over the land by revolutionaries caused some uneasiness. Otherwise the presence of Socialists on the ministerial bench seemed to have no other effect than that of partially muzzling the socialist groups in the Chamber. The Opposition to the Government was

French parties at the close of the 19th century.

heterogeneous. It included the few Monarchists left in the Chamber, the Nationalists, who resembled the Boulangists of twelve years before, and who had added anti-Semitism to the articles of the revisionist creed, and a number of republicans, chiefly of the old Opportunist group, which had renewed itself under the name of Progressist at the time when M. Waldeck-Rousseau was its most important member in the Senate.

The ablest leaders of this Opposition were all malcontent Republicans; and this fact seemed to show that if ever any form of monarchy were restored in France, political office would probably remain in the hands of the accomplished place-hunters of the Third Republic. Thus the most conspicuous opponents of the cabinet were three ex-prime ministers, MM. Méline, Charles Dupuy, and Ribot. These and other republican "ministrables" had their normal appetite for office whetted in 1900 by the international exhibition at Paris. It brought the ministers of the day into unusual prominence, and endowed them with large subsidies voted by parliament for official entertainments. The exhibition was planned on too ambitious a scale to be a financial success. It also called forth the just regrets of those who deplored the tendency of Parisians under the Third Republic to turn their once brilliant city into an international casino. Its most satisfactory feature was the proof it displayed of the industrial inventiveness and the artistic instinct of the French. The political importance of the exhibition lay in the fact that it determined the majority in the Chamber not to permit the foreigners attracted by it to the capital to witness a ministerial crisis. Few strangers of distinction, however, came to it, and not one sovereign of the great Powers visited Paris: but the ministry remained in office, and M. Waldeck-Rousseau had uninterrupted opportunity of showing his governmental ability. The only change in his cabinet took place when General de Galliffet resigned the portfolio of war to General André. The army, as represented by its officers, had shown symptoms of hostility to the ministry in consequence of the pardon of Dreyfus. The new minister of War repressed such demonstrations with proceedings of the same arbitrary character as those which had called forth criticism in England when used in the Dreyfus affair. In both cases the high-handed policy was regarded either with approval or with indifference by the great majority of the French nation, which ever since the Revolution has shown that its instincts are in favour of authoritative government. The emphatic support given by the radical groups to the autocratic policy of M. Waldeck-Rousseau and his ministers was not surprising to those who have studied the history of the French democracy. It has always had a taste for despotism since it first became a political power in the days of the Jacobins, to whose early protection General Bonaparte owed his career. On the other hand liberalism has always been repugnant to the masses, and the only period in which the Liberals governed the country was under the regime of limited suffrage—during the Restoration and the Monarchy of July.

The most important event in France during the last year of the century, not from its political result, but from the lessons it taught, was perhaps the Paris municipal election. The quadrennial renewal of all the municipal councils of France took place in May 1900. The municipality of the capital had been for many years in the hands of the extreme Radicals and the revolutionary Socialists. The Parisian electors now sent to the Hôtel de Ville a council in which the majority were Nationalists, in general sympathy with the anti-Semitic and plebiscitary movements. The nationalist councillors did not, however, form one solid party, but were divided into five or six groups, representing every shade of political discontent, from monarchism to revisionist-socialism. While the electorate of Paris thus pronounced for the revision of the Constitution, the provincial elections, as far as they had a political bearing, were favourable to the ministry and to the Republic. M. Waldeck-Rousseau accepted the challenge of the capital, and dealt with its representatives with the arbitrary weapons of centralization which the Republic had inherited from the Napoleonic settlement of the Revolution. Municipal autonomy is unknown in France, and the town council of Paris has to submit to special restrictions on its liberty of action. The prefect of the Seine is always present at its meetings as agent of the Government, and the minister of the Interior can veto any of its resolutions. The Socialists, when their party ruled the municipality, clamoured in parliament for the removal of this administrative control. But now being in a minority they supported the Government in its anti-autonomic rigours. The majority of the municipal council authorized its president to invite to a banquet, in honour of the international exhibition, the provincial mayors and a number of foreign municipal magnates, including the Lord Mayor of London. The ministers were not invited, and the prefect of the Seine thereupon informed the president of the municipality that he had no right, without consulting the agent of the Government, to offer a banquet to the provincial mayors; and they, with the deference which French officials instinctively show to the central authority, almost all refused the invitation to the Hôtel de Ville. The municipal banquet was therefore abandoned, but the Government gave one in the Tuileries gardens, at which no less than 22,000 mayors paid their respects to the Chief of the State. These events showed that, as in the Terror, as at the *coup d'état* of 1851, and as in the insurrection of the Commune, the French provinces were never disposed to follow the political lead of the capital, whether the opinions prevailing there were Jacobin or reactionary. These incidents displayed the tendency of the French democracy, in Paris and in the country alike, to submit to and even to encourage the arbitrary working of administrative centralization. The elected mayors of the provincial communes, urban and rural, quitted themselves like well-drilled functionaries of the State, respectful of their hierarchical superiors, just as in the days when they were the nominees of the Government; while the population of Paris, in spite of its perennial proneness to revolution, accepted the rebuff inflicted on its chosen representatives without any hostile demonstration. The municipal elections in Paris afforded fresh proof of the unchanging political ineptitude of the reactionaries. The dissatisfaction of the great capital with the government of the Republic might, in spite of the reluctance of the provinces to follow the lead of Paris, have had grave results if skilfully organized. But the anti-republican groups, instead of putting forward men of high ability or reputation to take possession of the Hôtel de Ville, chose their candidates among the same inferior class of professional politicians as the Radicals and the Socialists whom they replaced on the municipal council.

Paris and the provinces.

It is not easy for contemporary spectators to sum up the chief results to France of thirty years of parliamentary Republic. The most striking phenomenon, perhaps, has been the survival of the centralized system of administration with all its arbitrary powers untouched. Its existence side by side with an incompatible parliamentary system has been one of the causes of the failure of the latter. Yet in all the years that the Republicans have been masters of France they have made no effort to decentralize or to weaken the administrative machinery which Napoleon constructed to be manipulated by strong and autocratic hands. One effect of the ill-assorted union of the two systems has been to aggravate the unsound finance which has marked the parliamentary career of the Third Republic. In the Constitution of 1875 there is nothing to prevent private members of parliament from proposing the increase of public expenditure. The greatest economic authorities in France, the last survivors of liberalism like M. Léon Say, have vainly advocated the sound English practice which confines financial initiative to the Government of the day. The deputies, especially the Radicals and the Socialists, have maintained the prerogative of private members to increase the estimates. The chief reason for this has been that under the centralized system every French constituency contains an army of functionaries appointed and paid by the State. Under the parliamentary regime the nomination of these officials has fallen into the hands of members of parliament. Consequently the aim of deputies has been to increase their power of patronage, and to promote the creation of needless posts paid for by the taxpayer, instead of using their influence to cut down expenditure. A less rich and less industrious nation would have succumbed under this wanton drain on its resources. These have been further reduced by the decrease of population under the Third Republic in the majority of the departments, though that of the capital has increased owing to immigration from the provinces. The lack of testamentary liberty in France, and the consequent compulsory division of property, have popularized the principles attributed to Malthus. The decreasing birth-rate, in this period of universal conscription on the Continent, has compromised the security of France, as in a single-handed conflict with Germany her armies would be overwhelmed by mere force of numbers. It is also, according to French pessimists, one of the reasons of the declining influence of France among nations. France contained almost one-fifth of the population of Europe at the beginning of the 19th century, while at its end she had less than one-tenth. The United Kingdom, in spite of its enormous colonial expansion, increased its population between 1800 and 1900 by 156 per cent. The inhabitants of France are only 46 per cent. more numerous than at the beginning of the century, and her vast colonies languish for need of a surplus population to develop them.

Results of the Third Republic.

The alleged decline of the prestige of France under the Third Republic is ascribed to a variety of causes. During the first seven decades of the 19th century, whatever her vicissitudes, France exercised in Europe a great influence, which was scarcely checked even after the hour of defeat in 1815. Until the fall of the Second Empire the French used to say with reason: "Quand la France joue du violon, toute l'Europe se met à danser." The insurrection of the Commune in 1871 evoked no echo beyond the frontier. Europe had ceased to follow the lead of France, at all events in her revolutionary movements, which in 1830 and in 1848 had been followed by political commotions all over the Continent, and even in England. If the disasters which the Republic at its birth inherited from the Empire were the first cause of the depreciated influence of France, it is certain that the Republic has done nothing to restore it, and it is not easy to gainsay French critics who complain that their country has lost prestige under that regime. Some of these pessimists say: the Chief of the State at the end of the 17th century was Louis XIV.; at the end of the 18th century Napoleon Bonaparte; at the end of the 19th century M. Émile Loubet. If it is galling to the pride of the people that France should pass into the 20th century under the headship of an unknown citizen of no achievement, who represents none of the brilliant qualities of the nation, the contrast with the gorgeous dawns of other centuries supplies one consolation. The presence of M. Loubet and of his predecessors at the head of the French executive, in the place of a more decorative monarch or series of monarchs, has been a great factor in the preservation of the peace of Europe. Under the Second Empire France was not boycotted—to use a word which has been adopted in the French language—by the sovereigns of Europe. Under the Third Republic the Chiefs of the State have had no personal relations with crowned heads such as had Napoleon III., for even the relations of the Tsar Nicholas II. with the rulers of the Republic have been of a somewhat patronizing character. But while France during the Second Empire was flattered at having a ruler admitted within the hierarchy of monarchs, whose mere word could agitate the bourses and the chanceries of Europe, she had to pay for the prestige of her Emperor by a series of wars, the last of which ended with the invasion and the mutilation of the land. If the monotony of peace be of greater advantage to a country than the varying vicissitudes of war, it cannot be denied that the Third Republic compares favourably not only with the Second Empire, but with the age of Louis XIV., or with the epic and reconstructive period of the first Napoleon. It must, however, be said in justice to the Second Empire that its warlike career before its disastrous end was coincident with an epoch of national prosperity; while under the peaceful Third Republic France has lost her commercial supremacy on the Continent, though a considerable industrial development has taken place in Paris and in certain populous centres.

The Third Republic has not been fruitful in statesmen to raise the renown of the nation. Three chief causes may be suggested for this dearth. First, the failure of the parliamentary system to attract the best or even the second best men of the nation to take part in politics. Next, ministerial instability, which has prevented politicians from having the opportunity essential to developing their administrative powers. Third, the impersonal system of government, which has been carried to such an extent that not only have superior men been discouraged, but it has condemned its possessors to political ostracism, for fear lest their qualities should induce the people to hail a dictator. It was thus that Gambetta's career was cut short. Neither has the Republic produced much useful legislation. The French are not a parliamentary nation, and with their confused ideas on the separation of the powers they have never apprehended that the right function of a legislature is to legislate. The two chief reforms accomplished by the parliament of the Republic in the 19th century were the reorganization of public education and of the army. The development under the Republic of the educational system, already of high excellence in France, would have had better results had not the legislation on the subject been marked with sectarian animosity. The aim of the educational laws associated with the name of Jules Ferry was not only the elevation of the standard of public instruction, which they undoubtedly effected, but also the hindrance of the work of Roman Catholic schools and colleges. The anti-religious tendency of State education in France is exaggerated by its adversaries; yet the Ferry laws have never been accepted by the entire nation. A very large minority has refused the advantages offered to its children gratuitously in the primary schools, and for a modest price in the secondary establishments. So considerable is that minority that at the end of the 19th century the anti-clericals in parliament moved the Government to introduce legislation limiting the ecclesiastical teaching-orders, while they further demanded that education in a State school should be made an essential condition of public employment, civil or military. Thus the dawn of the new century was clouded with reviving controversies between secular and dogmatic education—which, based on the intolerant pretensions of the extreme Voltairean and Ultramontane schools of thought, have no counterpart in a land of many sects like England. Apart from this question, one disadvantage of the development of education in France is connected with the growth of centralized bureaucracy under the parliamentary Republic. A new generation of half-educated young men, disdaining manual toil, seek a career in petty official posts, which are often needlessly created for them at the cost of the taxpayer. From the same unsatisfactory class, unfitted for productive labour, come the journalists of mediocre talent who multiply in the land. A cheap and unlicensed press has become a national evil in France, since many of the most widely circulated organs of every political shade—socialist, anti-Semitic, clerical, and anti-clerical—are merely organs of violence and defamation, propagating in every corner of the territory the spirit of bitterness and dissension which is a deplorable feature of social life under the Third Republic.

The reorganization of the army may be looked upon with more satisfaction. In spite of the excesses of militarism the French army is an admirable institution. The whole manhood of France passes through its ranks. The period of self-denying discipline imposed upon Frenchmen of all classes after the close of their school-days, which are more laboriously employed than those of the youth of England, has produced a new nation. Compulsory military service is accepted, not with enthusiasm, but without murmuring. The working of the system in France, from the point of view of national life, seems to be not less satisfactory than in Germany, and thus to encourage nations which need, but dread, conscription. The composition of the French army, recruited from every social class, has had much to do with the place it has taken in the heart and imagination of the people, similar to that which monarchical tradition occupies in certain other countries. Thus in a land where all the regimes of a century have been only temporary expedients, it is looked upon as a permanent institution handed down from a historical past and superior to party rivalries. This explains the attitude of the nation towards the assailants of the army, even where the latter have had some show of justice in their attacks. The severe training which all Frenchmen have to undergo, in boyhood at school and on the threshold of life in the army, has a two-sided effect. A minority of the nation considers that it has been so hard worked in youth that it is justified in making no further effort in manhood. In the rich reactionary upper class this feeling takes the form of lives wasted in frivolity. The men of the middle class who have this disposition swell the crowd of State-paid functionaries or take to journalism or to politics. But the great masses of the nation, frugal and industrious by instinct, unconsciously profit from their years of early discipline, in which their natural habits of good order and diligence are developed. The women of France are no less hard-working than the men, and it was the quiet workers of both sexes, of the great class which abstains from politics, who paid the war indemnity to Germany in the first days of the Republic. It is their labours which have since counterbalanced the improvident finance of the politicians. Without these qualities, to which are due the industrial enterprises and the artistic creations of the last generation of the 19th century, France would not have remained in the front rank of nations. The political future of the land was never more uncertain than at the opening of the 20th century; but France contains two elements of stability which seem likely to survive all vicissitudes. On the one hand there are the industry and frugality of the people, which, though menaced by the scourge of intemperance, are still unequalled in Europe. On the other hand is the system of administration constructed by Napoleon, which, though incompatible with parliamentary government, may perhaps survive it, as it seems essential to the orderly existence of France, having survived all the changes of regime of a century. (J. E. C. B.)

4. Literature since 1880.

The salient feature of the history of French literature from 1880 to 1900 is the progress of a reaction against what was somewhat inaccurately called the Realistic school. The Romantic school was paramount during the first half of the 19th century, and it was not until after 1850 that the Naturalistic movement prevailed. This movement derived its origin from the naturalist philosophy, which developed in France under two different forms:—(1) The simple theory of sensation of Condillac; (2) the Positivism of Comte. From the first we get the sensuous realism of Gautier and Flaubert; from the second the naturalism of M. Zola. Gautier develops the theory of "art for art's sake" in his Preface to *Mademoiselle de Maupin*, which was the manifesto of a school represented by Gautier, Flaubert, Bouilhet, and, with certain modifications, by Leconte de Lisle, Théodore de Banville, and the Goncourts. In the period here under consideration the representatives of this school are the "Parnassian" poets; among the novelists, the Goncourts alone, and they only in a modified degree, belong to this category.

The watchword of the Utilitarian school was "Art for Utility's sake," and its philosophy was that propounded by Auguste Comte in 1830 and popularized by Taine. The doctrine that science, based on the only trustworthy data, those of the senses, should be the sole guide of the human mind was adopted by M. Zola and his disciples. The aim of the school was to do away with all convention; to institute a searching and exhaustive inquiry into human nature; to discover the human "document"; to present what they termed a "slice of life" without beginning or end, the personality of the author being eliminated. These theories, however, were never rigidly practised by their propounders. M. Zola himself admitted that "the realistic novel was a corner of nature seen through a temperament." Not only were the leaders of the school forced to relax the severity of their precepts, but it soon became apparent that the term was in reality a misnomer, and that in many cases the theories of the school were merely confuted by the practice of its disciples. For if Defoe, Lesage, and Tolstoi are realists in the true sense of the word, then assuredly is M. Zola something different. So far from seeing life "steadily" and seeing it "whole," as Matthew Arnold inculcated, Zola confines himself to the study of the baser and the brutal elements in man and nature while he eliminates the soul; moreover, he saw the elements to which he confined himself through the distorting glass of a pessimistic and imaginative temperament, so that he evokes monstrous and monotonous visions for us, phantasmagorias of ugliness and crime, sordid and sombre panoramas which are impressive from their very size and from the violence and heaviness with which the coarse colours are laid on the canvas. His work, however, is not lacking in an element of grandeur; thus we get the epic of the train, the mine, the shop, and the battlefield, but never truly realistic studies of contemporary life.

The Realistic school may be said, therefore, to have merely succeeded in substituting one convention for another; but this is only true so far as concerns the theories of the school and those authors who slavishly adhered to it. Maupassant, for instance, who belongs to the Realistic school, was a true Realist, not because he adopted any particular theories, but because he was enabled by his temperament to look on life with penetrating eyes, and by his talent to depict what he saw with unsurpassed vividness. But both by his clearness of vision and by the lucidity, the purity, and the masculine directness of his style he was a classic; and this, as we have already said, is the case of all true Realists such as Defoe and Lesage.

The Realistic school did not fail to produce in its turn a reaction and a revolt against its conventions. Authors who have since attained to the fulness of their powers, such as MM. Brunetière, Lemaître, Bourget, and Anatole France, protested against the conventions of the Realistic school and strove to counteract its influence. It is this counter-movement which has continued up to the present day. Another important factor in the origin of the new phase has been the influence of foreign literatures. The novels of George Eliot, Tolstoi, and Tourgeneff exercised a wide influence in France, and helped to reveal the limited range of the French Naturalist school; for in these foreign novels Nature was depicted in her entirety and not only in her baser aspects. At the same time a revolt arose against the aridity of the Realists, against their inability to look beyond the objects and facts within their immediate ken, and their total elimination of the life of the soul and the region of ideas. This tendency gave birth to a renascence of idealism. In 1889 M. Bourget wrote in the preface to his novel *Le Disciple*, after quoting Littré's well-known saying respecting the ocean of the unknown and the comparatively infinitesimal results of science: "A ceux qui te diront que derrière cet océan il y a le vide, l'abîme du noir et de la mort, aie le courage de répondre, vous ne le savez pas. Et puisque tu sais, puisque tu éprouves qu'une âme est en toi, travaille à ce que cette âme ne meure pas en toi avant toi-même." The younger generation turned once more to the region of ideas, and the tendency of French literature from 1889 up to the present day has been termed Idealist. Again, just as M. Taine's theories were adopted in a distorted form by the Naturalistic school, the philosophy of M. Renan was an important factor in the origin of the new tendency. But since no movement ever stops halfway, but continues naturally until it reaches its extreme limit, this tendency went farther than M. Renan's idealism, and passed on into mysticism; though this movement, as we look at it now, seems to be split up into singularly various elements, for together with the existence of symbolism and mysticism, incredulity and sensualism have survived, and a brutally cynical element has appeared which has been christened "*rosserie*." Doubtless it may be argued that the idealism of the new generation is skin-deep, that it is mystical without being Christian; it is at the same time probable that when we can look back upon the present period from a standpoint which will enable us to see it in its true perspective and proportion, the whole movement will seem to have been fairly named idealistic. Amidst the restlessness, the mobility, the shifting phases of this generation in France—the sudden and shortlived enthusiasms, at one time for Norwegian and other Northern literatures, at another for Neo-Hellenism and a Latin Renascence—there is perhaps a definite trend towards Faith in the largest sense of the word, towards an imperious necessity of believing, to which the thirst of knowledge is subordinated; and this movement, while to some critics it may have the appearance of being retrograde and reactionary, is perhaps in reality a renascence of the national genius of France, another example of the elasticity of the French temperament. On the one hand we have a young school who feel this necessity of faith in the largest sense; on the other hand we have writers like M. Bourget and M. Brunetière appearing as the plain, outspoken champions of catholicism; writers like MM. Lemaître and Barrès appearing as the prophets of national energy. Again, in works such as *Pour la Couronne* by M. Coppée, and M. Rostand's *Cyrano de Bergerac*, we have a renascence of another kind—a return from the complicated minstrelsy of intimate rhythms and obscure suggestions practised in later years by Symbolists (which has proved to be productive of some beautiful music and much unintelligible discord), to the simpler and more commonplace song of an earlier day. It is a message that we have heard before; but it is precisely this message, old and eternally new, which we demand of the poets at perennially recurring intervals, when man is momentarily wearied of writers whose sole aim is to lay stress on the burden of existence and to point out the ugliness of the world.

Poets.—The progress of French poetry from 1880 onwards can be divided into two main branches:—(1) The successors of the Parnassians who maintained the Parnassian tradition; (2) the Symbolists, decadents, &c. Besides these two branches there is a group of poets who, although contemporary with the Parnassians, scarcely belong to them—we will designate these as the Provincial and Rustic poets, although they do not all hail from the provinces or exclusively confine themselves to pastoral themes; and finally, there are those contemporary poets of the present day who cannot yet be classified in any definite manner, since they represent widely varying tendencies and currents.

The Parnassian school was founded by MM. L. Xavier de Ricard (born 1843) and Catulle Mendès, who chose as their tetrarchs and judges Théophile Gautier, Leconte de Lisle, Baudelaire, and Banville. The *Parnasse contemporain*, an anthology of new poetry, was published in instalments. The first appeared on 2nd March 1866, the eighteenth and last in June of the same year. There were thirty-seven contributors, of whom the most important were Gautier, Banville, Heredia, Vacquerie, Baudelaire, Sully Prudhomme. A second *Parnasse* was published in 1871, a third in 1876. Finally M. Lemerre published a complete anthology in four volumes. Among the members of this brilliant group none was more richly gifted by nature than M. Catulle Mendès (born 1841). The fairies of literature seem all to have attended his baptism and, each one conferred on him her particular gift; no wicked fairy was there to confer some saving flaw, some great defect productive of a correspondingly predominant quality—"Master of all styles, he is supreme in none." With Mr Swinburne's power of assimilation, he lacks Mr Swinburne's lyrical genius; his talent is always under perfect control; he rides Pegasus so well, with such consummate mastery and ease, that the horse cannot ever escape from the earth and soar into the heavens. His poetry (and he is not only a poet, but a novelist and a writer of short stories) is in turn realistic, romantic, neo-Hellenic, heroic in the vein of Victor Hugo and lyrical in the manner of Heine, appearing under the titles of *Philoméla*, *Soirs Moroses*, *Pantéleia*, *Contes épiques*, *Intermède*. It is his extreme versatility and power of assimilation which have perhaps prevented him from attaining to greatness or to supreme excellence in any one line; his poems give one the impression of exquisitely manufactured imitations; parodies in earnest, what the French call *pastiches*. The work of M. Sully Prudhomme (born 1839) bears far more resemblance to that of Lamartine than to that of Leconte de Lisle and his disciples. He might be called a French Matthew Arnold; his poems have the same charm and dignity, the same accent of stoical resignation, the same pensive note of melancholy as of an ivory lyre; but although his work is philosophical, he is a poet who thinks and not a philosopher who turns to rhyme for recreation.

M. François Coppée (born 1842) furnishes a signal example of the influence of Realism on French poetry; he has proved to be the most popular of the Parnassians; no sharper contrast could be found to his sentimental realism, his choice of familiar themes and humble subject-matter, than the spirit which inspires the verse of J. M. de Heredia (born 1842), the artificer of sonnets which are unequalled not only for the sweetness of their versification and for the metrical perfection which they exhibit, but also for the wide range of vision which is evoked by their disciplined utterance.

Less celebrated than most of the Parnassians, but equal almost to the greatest in accomplishment, André Lemoyne (born 1822) is the poet of landscape. His poems remind us of the painting of Corot. He produces delicate and musical pieces, impregnated with a particular atmosphere, which have a charm not unlike that of Collins's *Ode to Evening*. Side by side with Lemoyne, André Theuriet (born 1833), the author of the graceful *Chemin des Bois*, deserves to be mentioned. M. Léon Dierx (born 1838), elected at the death of Mallarmé to be "Prince of Poets," has published but little. His verse, which is above all things artistic, and masterly in technique, is essentially characteristic and representative of the true Parnassian school. His *Lèvres closes* was published in 1868.

Guy de Maupassant, Anatole France, and Alphonse Daudet all began their literary careers by a short sojourn among the Parnassians. Another teller of tales—and tales as little edifying as it is possible to find—who was endowed with true lyrical and imaginative gifts, is Armand Silvestre (1837–1901), the poet of *La Chanson des heures* (1878), *Ailes d'or* (1880), *Le Chemin des étoiles* (1885). His poems are pervaded by a vague pantheism, and seem to be woven out of a rainbow haze of dreams, their chief merit lying in the way in which they seem to flower in an endless succession of monotonous and sumptuous images. The list of Parnassians would be incomplete without mentioning Jean Cazalis (born 1840), M. Albert Mérat (born 1840), and M. Fréderic Plessis (born 1851), the classic poet of *La Lampe d'Argile*.

The influence of the Realistic school, which was at its height in 1880, can be traced in all the productions of this Parnassian school, for while their poetry escaped from the contagion of ugliness and brutality, it was none the less objective in character, and chose for its themes, as the case might be, detailed landscapes, historical scenes accurately reproduced, or realistic studies of modern life. The attention to detail and concision of style which were sought after and attained, left little to individual interpretation. A reactionary movement, such as that which arose against the novel, appeared here also, and hence the Symbolist school came into being, which aimed at greater freedom, a less strict prosody, and a more musical poetry. But it must be borne in mind that this Symbolist movement was a revolt against the precepts of the Parnassians and the legacy of the Romantic school, and it can only be called a reaction against naturalism, in so far as the influence of naturalism is to be traced in the poetry of the Parnassians. The Parnassians had borrowed from the plastic arts; the Symbolists aimed at the vagueness, mystery, suggestiveness of music, *de la musique avant toute chose*. The high priests of this movement were Paul Verlaine (1844–1896), remarkable much less for his theories than for his exquisite practice, in which he showed himself a lyric poet of the first order, comparable with Shelley and Heine, and not without certain affinities to the earliest French singers, such as Charles d'Orléans; and Stéphane Mallarmé (1842–1898) perhaps less remarkable for his practice than for his theory. He not only advocated vagueness of music and of sound, but mistiness of imagery and of sense—in fact, obscurity. Then followed a riot of rebellious rhymers, for whom sense capitulated unconditionally to sound and sensibility. M. Vielé-Griffin (born 1864) and M. Gustave Kahn (born 1859) gave us *vers libres* which, but for their typographical arrangement, are indistinguishable from prose. Indeed, the extreme limit of this school is reached in the *ballades* of M. Paul Fort (born 1872), which are actually printed as prose. In the verse of these disciples of the Symbolist school rhyme is often reduced to assonance, and poetry tends to become less and less subject to any exterior discipline; it is made instead to depend upon an intimate rhythm, which varies with every different poet, the result, should the poet have a sensitive ear, being often in the highest degree musical. Verlaine and Mallarmé can only be said to have exercised a pernicious influence on the least gifted of their disciples, and in many ways their influence was wholly beneficent. The tyranny of the rhyme was broken, prosody became more supple, and a freer rhythm was introduced. The phase must by no means be considered an abnormal one. In the Symbolist movement French poetry reverted more or less to what it was in 1820, to the suggestive imagery and musical vagueness of Lamartine. French poetry at that epoch was moving naturally towards the ideal of the Symbolists, when it was deflected from its course by the appearance of Victor Hugo, who fashioned a new instrument for lyrical poetry to suit his visionary genius and his command of magnificent rhetoric; and the instrument subsisted and was played upon by generations of more and more dexterous artists, until the Symbolists shattered it.

By far the most gifted of the disciples of the Symbolist school is M. Henri de Regnier (born 1864), the singer of *Lendemains* (1886), *Aréthuse* (1895), and *Les Jeux rustiques et divins* (1897). We find in his work a harmonious combination of old traditions and modern innovations. He has adopted and practised the precept of André Chénier—

> "Sur des pensers nouveaux faisons des vers antiques,"

and his work, especially his latest volume, testifies more perhaps to the influence of André Chénier than to that of contemporary writers; it is, nevertheless, stamped with originality. He takes ancient myths and interprets them anew, using mythological symbols as a vehicle for the expression of modern ideas; he is symbolical without being obscure. He is particularly successful in the choice of an imagery which has a kind of subdued splendour that harmonizes well with the grave music of his dreams; throughout his poetry there is a vein of impassioned meditation, suggestive, dreamy, and melodious. The melancholy note of his song and the sumptuousness of his imagery remind one of poems such as Mr Swinburne's *Triumph of Time*. He presents affinities to Mr Swinburne and also to Keats, especially to the early poems of Keats, such as the Bacchic song in Canto IV. of *Endymion*. His poems abound with extremely beautiful lines, and *Les Médailles d'Argile* (1900) showed a great advance on his earlier works, and contained the promise of still finer performance.

M. Albert Samain (1859–1900) was also a dreamer; he had an exquisite sense for half tones, subtle shades, elusive scents and fugitive murmurs, and he rendered the same in musically murmured verse. M. Francis Vielé-Griffin is the boldest among the initiators of the new movement, and his poetry breaks away from all traditions; but his work, which is not without charm of melody, is almost entirely unintelligible and incoherent. The disciples of the Symbolist school have given most of their work to the world through the medium of a Review entitled *Le Mercure de France.* The principal contributors to this periodical are MM. Robert de Souza, Francis Jammes (born 1868), Laurent Tailhade (born 1854—author of *Jardin des rêves,* 1880), and M. Jean Moréas (born 1856), the poet of various volumes from *Les Syrtes* of 1884 to *Les Stances* of 1901.

Alongside of, and contemporary with, the Parnassians, there flourished what we have called the Provincial poets. Of these the most important are M. Jules Breton (born 1827), author of *Les Champs et la Mer;* M. Charles de Pomairols, a disciple of Lamartine (of whom he has given us a fine study); and Alfred de Vigny, whose work has some of the gravity and elevation of his masters. M. Gabriel Vicaire (1848–1900), native of Bresse, published his *Émaux Bressans* in 1884, a volume of fresh and delightful and spontaneous lyrics. The Provence produced M. Jean Aicard (born 1848). Finally, in Paris itself we find M. Déroulède, the French Körner, the patriotic singer of *Chants du Soldat* (born 1846); and M. Richepin (born 1849), author of *La Chanson des Gueux, Les Caresses, Les Blasphèmes, La Mer,* and several dramas in verse—*Nana-Sahib, Par le Glaive,* and *Le Flibustier.* M. Richepin is one of the most interesting and curious figures in contemporary French poetry; romantic by temperament, he had made no attempt to modify his proclivities; his dramas might almost have been written in 1830. In *La Chanson des Gueux* he celebrated the tramps and beggars of Paris; in *Les Caresses* he is frankly pagan and sensual, and in these poems as well as in *Les Blasphèmes* he reminds one of the more extravagant excesses of Mr Swinburne's early work. For sheer virtuosity and skill in versification he can hold his own not only with all his contemporaries, but with the most accomplished French rhymers of the past; his verse has the quality of vigour, sonority, and colour in the highest degree. Like Mr Swinburne, M. Richepin is a scholar, and his erudition is a little too evident; in his violence and extravagancies there is the same suspicion of insincerity and rhetoric that we find in the more violent poems of Mr Swinburne, and he never attains to Mr Swinburne's purely poetic inspiration. He remains an astonishing versifier rather than a great poet.

We now come to the representative poets of the present day. One of the most notable is certainly M. Maurice Bouchor (born 1865), author of *Les Symboles* (1888); his poetry has a note of high seriousness and religious feeling. Deserving of mention are M. Georges Leygues, author of *Le Coffret Brisé* (1882); M. Edmond Haraucourt, a brilliant disciple of Leconte de Lisle, author of *L'Âme Nue* (1885); M. Jean Rameau, author of *Le Chemin des Étoiles* (1888); M. André Rivoire's poems in the *Revue de Paris* have attracted attention. The poems of the Vicomte de Borelli, author of *Rana* and *Alain Chartier,* performed at the Comédie Française (1889), are particularly interesting as being the work not of a professional man of letters, but of a soldier.

The poetry of M. Edmond Rostand (born 1864) is looked upon with scorn by the contributors to the *Mercure de France,* and, partly perhaps because it so instantaneously and emphatically won the suffrages of the great public, older critics have been chary in their appreciation. Doubtless M. Rostand is first and foremost a dramatist, and his poetry is better heard than read: but although it is neither the poetry of the Parnassians (to which it stands in the same relation that the poetry of Mr Kipling holds to the poetry of Tennyson), nor of the Symbolists, yet poetry of a kind it is, brilliant, witty, full of fancy, fertile—too fertile, perhaps—in invention; it assimilates the character of French poetry of many epochs. M. Rostand is an astounding juggler rather than a supreme artist in words; and although it would be unjust to accuse him of a fatal fluency—for while everything that he touches turns into poetry, the result is gold and not tinsel—yet this marvellous facility has the danger of turning him from the main road along which he determines to travel, into byways of attractive episodes, or of causing him to forget in ingenious detail the main architectural design of his fabric. As far as largeness of aim and design are concerned, his most important work so far has been *L'Aiglon,* but it cannot be said to be on the whole so satisfactory as *Cyrano de Bergerac,* which contains what is without doubt the best verse he has so far given us. M. Rostand's qualities and defects are equally well displayed, if on a smaller scale, in his earlier plays—*Les Romanesques, La Princesse Lointaine,* and *La Samaritaine.*

Novelists.—Among the novelists of the later half of the 19th century, the only two of importance who may be said to belong to the Idealistic, if not to the Romantic, school are Octave Feuillet (1821–1890) and Victor Cherbuliez (1829–1899). Whatever charges of artificiality or sentimentality may be brought against the work of Feuillet, his novels are likely to survive, owing to the perfection of their construction and the purity and grace of their style. Cherbuliez, who to a greater degree than Feuillet held aloof from the tendencies of the contemporary novel, was perhaps more of a moralist and a humorist than a novelist. His ingenious and complicated stories, although they do not fail to entertain us, betray inexperience of life, and they justify Maupassant's criticism that Cherbuliez did not deserve to be called an Idealist merely because his observation of life happened to be inaccurate. His best novels are *Un Cheval de Phidias, Le Prince Vitale,* and *Le Grand Œuvre.*

Towards the year 1880 the Naturalist movement had reached its zenith, and the inevitable reaction did not fail to set in. But before dealing with it, it will be well to consider the work of the Naturalists as it existed in 1880. It can be divided into two branches—on the one hand, the Impressionists, whose object it was to interpret nature, and to whom the impressions received from nature were a means of expressing their personality; and on the other the Naturalists proper, whose aim was to achieve absolute and objective reality, and whose failure to do so was productive of so many curious and interesting results. To the Impressionists belong the two Goncourts, the most literary of all French writers of the century, whose work may be summed up in one word, *nervosity,* and who, in their determination to render the vibration of their impressions, dared any discord; Alphonse Daudet; and Pierre Loti, who in reality belongs to a class all by himself, since he is not a novelist at all, but a poet and a painter in words. To the Naturalistic school proper belong M. Zola, whose *L'Assommoir* appeared in 1887; and Guy de Maupassant, whose masterpiece, *Boule de Suif,* appeared in 1880.

J. K. Huysmans (born 1848) began as a Naturalist, and in his work we see more strikingly manifested than elsewhere not only the tendencies of the Naturalist school and the reaction they produced, but the extreme limit of this reaction; in fact, the transition from naturalism to mysticism. Huysmans' first books appeared in 1878–79, *À Rebours* in 1884, *Là-Bas* in 1891. In his early stories, *Marthe* (1876), *Les Sœurs Vatard* (1879), *Sac au Dos*

(1880), the hideousness of hideous things is depicted with Flemish minuteness; the world seems to reek in his nostrils; he goes out of his way to choose the most repulsive subjects, and seems to enjoy a bitter satisfaction in dwelling on the most sordid aspects of his loathsome vision. The extreme sensibility of his temperament, however, led him farther; his pessimism reaches its lowest degree in a study of Satanism in *Là-Bas*, and from blasphemy to belief the transition is a natural one, since in order to blaspheme it is necessary first to believe. Disgusted with himself and the horror of his life, the author of *Là-Bas* seeks refuge in a Trappist convent. We then get an account of this experience in *En Route* (1895). This is by far his most interesting and important work, remarkable for the absence of all literary catholicism such as that affected by Baudelaire, for the poignant sincerity with which his moral crisis is depicted, and for the sheer beauty of many scenes and passages. *La Cathédrale* (1898) consists almost entirely of a description of the Cathedral of Chartres.

The reactionary movement which is illustrated by the career of Huysmans was headed by M. Paul Bourget (born 1852), who deserves the credit of reinstating psychology in the position from which it had been ousted by the physiology of the Naturalists. In his critical essays M. Bourget attempts to discover and to define the fundamental moral idea forming the basis of the work of the writers whom he studies, in his novels his aim is to analyse the soul of man. He chose for his field of observation the fashionable world of Paris, and consequently he is the psychologist and novelist of Society. The chief excellence of his work, and at the same time its cardinal defect, lies in his system of explanation. His characters do not reveal themselves to the reader by their acts and words, the author explains them to us himself. If we eliminate the dissertations from his novels, we are left with "novelette" plots of the most commonplace description; on the other hand, it is precisely in dissertations that his great talents are manifest, when the subject of the book is purely an analytic study which admits of dissertation.

M. Edouard Rod (born 1857) began as a disciple of M. Zola, but was soon, chiefly owing to the influence of foreign literature, led into the current of reaction. His work is widely different in tone from that of any of his contemporaries, and is impregnated with a rarer atmosphere. He is in the highest degree preoccupied by moral ideas and questions of conscience, yet he is capable at the same time, in *La Vie Privée de Michel Tessier* (1893) and *Le Ménage du Pasteur Naudié* (1898), of creating living characters, and of interesting us in their careers. If his work is lacking in the more salient qualities of brilliancy and colour, it is nevertheless admirable on account of the harmony of its proportions and the delicacy of touch which it manifests. The titles of his remaining works are *Le Sens de la Vie*, *Les Trois Cœurs*, *La Sacrifiée*, *Le Silence*, *Les Roches Blanches*, *Dernier Refuge Là-Haut*.

M. Paul Margueritte (born 1860) is another instance of a Naturalist converted. He began as a disciple of the Goncourts, and in 1887 signed a manifesto against M. Zola. The work, indisputably his masterpiece, to which he owed his celebrity is *La Force des Choses* (1891). His other works are *Jours d'épreuve* (1889), *Ma Grande* (1893), *La Tourmente* (1893), *Le Désastre* (1898), with its sequel *Les Tronçons du Glaive* (1900), a historical study of the war of 1870, written in collaboration with his brother. He is affiliated to the Goncourts by his nervous temperament, but no novelist of the present day has a more trenchant style, a greater precision of touch. In *La Force des Choses* and *Ma Grande* he has produced two human dramas remarkable for sincerity and truth, and for their poignant simplicity and pathos.

The work of J. H. Rosny (the name stands for two brothers who work in collaboration) has first and foremost the merit of originality. His conception of art is widely different from that of the Naturalistic school, and yet, although he began as a disciple of M. Zola, and later repudiated him, he cannot be said to belong to the reactionary movement. His work stands entirely apart from that of his contemporaries. Science forms his one preoccupation, and it positively overloads his work. His descriptive passages teem with allusions to chemistry, physical science, and natural history. His cult for science forms the basis of his work, the starting-point of his literary theories and of his moral ideas. His moral aim is to replace the Christian precepts of humility by a rational form of altruism, in which virtue is to be a means of developing superior beings to the fullest possible extent, and the effort of this morality is to tend towards the progressive amelioration of this life; his cult is that of "La bonne humanité." His early works, such as *Nell Horn*, in which he depicts scenes of London and Parisian life, and even *Vamireh* (1891), a prehistoric novel, betray the influence of the Naturalist school. *Daniel Valgraive* (1891), *L'Impérieuse Bonté* (1894), *L'Indomptable*, and *Renouveau*, *L'Autre Femme*, *Résurrection* are very different in character. The two first are inspired by the preoccupation of social and individual morality. Besides *Vamireh* he has written other prehistoric novels, *Erymah* and *Les Profondeurs de Kyamo.* His best work suffers from incoherence, from the neglect of composition, an indulgence in grotesque detail and barbarous verbal inventions, and a pedantic use of scientific phraseology. But all his work is redeemed by a certain greatness of soul, by the excellence of "sincerity and strength," by the enthusiasm rising from deep conviction, and by the largeness and nobility of his ideas; moreover, in spite of all its defects, his style has moments of simplicity, freshness, and majesty. His work resembles a rugged mountain on which we struggle over perilous steeps and through dark caverns, rewarded every now and then by intermittent glimpses of snowy splendours and dazzling horizons.

M. Marcel Prévost (born 1862) affords the greatest possible contrast to Rosny; his talent is vivacious, elegant, and insinuating; he has confined himself entirely to love stories, and moves on this ground with masterly ease, analysing the subtler shades with a delicate dexterity. He published *Le Scorpion* in 1887, *Mademoiselle Jauffre* in 1889. No wittier book appeared during the period 1880–1900 than the first series of his *Lettres de femmes* (1892). His particular deftness and cleverness found perhaps a larger scope in *Les Demi-Vierges* (1894); yet with all his grace and amenity he is a moralist, since in his love stories he strips passion of its poetry and leaves the bare materialism and vanity which lie beneath it; at the same time his attraction for what he affects to despise and condemn is clearly evident.

M. Paul Ernest Hervieu (born 1857) has of late years entirely devoted himself to the stage, but he made his reputation by two novels, *Peints par Eux Mêmes* (1893) and *L'Armature* (1895). The first of these two is ironical as to matter, and lucid and trenchant as to style; the second is a novel written with the purpose of showing that in modern society the only solid element is money, and that all other things, such as virtue, affection, &c., are but a brittle ornamentation. He proves himself an accomplished analyst in both these works, and he seems to delight in revealing the sore places which are hidden by the brilliant trappings of the world of fashion.

M. Maurice Barrès (born 1862) began by two books, *Sous l'œil des Barbares* and *Un homme libre*, which are devoted to the psychology of his own personality: in both he reveals himself as a writer of exquisite prose; but they suffer from the defect of being almost entirely unintelligible. In *Le Jardin de Bérénice* we find the same qualities, and with a considerable attenuation the same defect. In *Du Sang, de la Mort, et de la Volupté*, a work of singular inequality, the obscurity has entirely disappeared; impressions of certain landscapes and places are rendered with a wonderful delicacy, and the book abounds in passages of great beauty. *Les Déracinés* (1898) marks a fresh and a greater transformation. The book is a vehement protest against the dangers of individualism; unfortunately the interest awakened by its social theories is somewhat lessened by a want of cohesion in the construction. The book, however, is not only exceedingly interesting, but entirely human.

M. Anatole France (born 1844) has written novels, but can scarcely be called a novelist. He lacks the necessary qualities of invention and logical sequence; it is repugnant to his temperament to construct a plot; his novels follow his wayward fancy, and his characters talk more than they act. In *Le Lys Rouge* (1894) he attempts the psychological novel, but it differs from other works of the kind; for while it is perhaps inferior as a novel, it is far superior as a piece of literature; the characters, who are essentially alive, interest us more by what they say than by what they do. It is the deep philosophy and the liquid and inimitable style which interest and enchant us—that is to say, M. France himself, the showman more than the puppets. In 1897 M. France published the first volume of his *Histoire Contemporaine*, *L'Orme du Mail*, which has been followed by three other volumes, in which he invented a new form of novel, a novel without a plot, which enables him to study contemporary life from every side and aspect. Each volume of this series (*Le Mannequin d'Osier*, *L'Anneau d'Améthyste*, *Monsieur Bergeret à Paris*) is a masterpiece of satire and irony, and exhibits the cunning candour, the captivating grace and witchery which distinguish M. France's style.

A small group of novelists chose country life as their exclusive field of observation. Of these the most important are M. Ferdinand Fabre (1830–1898); M. Léon Cladel (born 1835), author of *Le Bouscassié*, *La Fête votive de Saint Bartholomée Porte-Glaive*, and *L'Homme de la Croix-aux-Bœufs*; M. Emile Pouvillon (born 1840), a writer of exquisite pastorals (*Césette*, *Jean de Jeanne*, and *Petites Âmes*); and M. André Theuriet (born 1833), author of *Sauvageonne*, *Les Mauvais Ménages*, and *Dans les Roses*, a delicate painter of provincial life and manner.

Among women authors, by far the most talented is the inimitable "Gyp" (Countess de Martel de Janville; born 1850), the modern Lucian, whose dialogues are unsurpassed for lightness of touch and sharpness of observation. Her masterpieces in this form remain *Autour du Mariage* (1883) and *Autour du Divorce* (1886), but she has also shown herself an accomplished novelist in *Le Mariage de Chiffon* (1894) and in *Bijou* (1896).

The most notable of the followers of "Gyp" in the line of light dialogue and sharp observation is Marie Anne de Bovet, author of *Roman de Femmes* (1895) and *Petites Rosseries* (1898).

M. René Bazin (born 1853), who belongs in reality to the old Idealist school, published *De toute son Âme* (1897). His best work is *La Terre qui meurt* (1899).

Criticism.—In the domain of criticism the period which begins in 1880 is still overshadowed by the great names of Renan, Taine, and in a lesser degree of Edmond Scherer (1815–1889). M. Sarcey continued from the year 1869 to 1900 to contribute his theatrical criticism to the newspaper *Le Temps* with unbroken regularity; but the true representatives of criticism during the period are MM. Brunetière, Anatole France, P. Bourget, and Jules Lemaître. M. Lemaître (born 1853) together with M. France (born 1844) were the initiators of the subjective Impressionist school of criticism, which must be traced immediately to the influence of Renan and ultimately to that of Montaigne. MM. France and Lemaître laid down the principle that impersonal and objective criticism did not exist, and that criticism was nothing else but the record of the adventures of the soul among masterpieces. The value of criticism of this kind varies with the value of the critic who practises it; in the case of MM. Lemaître and France it is hardly necessary to say that its value is consequently very great. M. Lemaître, who was for some time dramatic critic to the *Journal des Débats*, went over in that capacity to the *Revue des Deux Mondes* in 1895; in 1898 he deserted dramatic criticism altogether, and devoted himself to political work. Dramatic criticism was, in the case of M. Lemaître, a pretext for writing moral essays; and his collected articles on theatrical matters (published in ten volumes of *Impressions de Théâtre*) are in reality deeply interesting and subtle studies of contemporary society. His *Contemporains* (essays on writers who have become famous since 1870) have the same character. The impressions of books and plays which he gives to us with such apparent negligence have a philosophic value which results from the acuteness and subtlety of his intelligence and his incredible agility of mind; and his style has the supreme quality of perfect naturalness and ease, where all effort is either absent or concealed. Besides his critical work M. Lemaître has written plays (*Sérénus* and *Myrrha*) and two volumes of exquisitely graceful short stories. M. Anatole France's critical work is contained in the four volumes of *La Vie Littéraire*. These volumes form in reality a *Journal intime*—a sentimental journey through the world of books; they are distinguished by the same intensely personal and magically graceful style that characterizes M. France's work in another field.

M. Émile Faguet (born 1847), since 1876 professor at the Sorbonne, a disciple of Taine, has written four volumes on the four literary centuries of France, in which he reveals a great power of analysis. He succeeded M. Lemaître as dramatic critic to the *Journal des Débats*. He has also published two volumes of *Politiques et moralistes des XIXième siècle*.

M. René Doumic, the literary critic of the *Revue des Deux Mondes*, is a polemical writer, endowed with keen intelligence and an incisive style; he has already produced much brilliant work, notably four volumes of *Études sur la littérature Française*, 1896, 1897–1900. *Portraits d'Écrivains* and *Écrivains d'aujourdhui — Les Jeunes* (1895).

History.—From 1880 to the present day the three greatest names in French historical writing are Renan, Taine, and Fustel de Coulanges. The younger generation is divided into two schools: M. Thureau-Dangin remains faithful to classical traditions; M. Sorel is a disciple of Taine; the remaining historians seem to aim at a compromise between the two schools. The following is a list of the most important: Duc de Broglie (1821–1901)—*L'Église et l'Empire Romain au IVième siècle* (1856–66), *Le Secret du Roi* (1878), *Frédéric II. et Louis XV.* (1884), *Marie Thérèse Impératrice* (1888); Gaston Boissier (born 1823); Émile Ollivier (born 1825)—*Le 19 Janvier* (1869), *Le Ministère du 2 Janvier* (1875), *L'Église et l'État au Concile du Vatican* (1878), *l'Empire Libéral* (1894); Thureau-Dangin (born 1837) — *Un homme d'autrefois*, *L'histoire de la Monarchie de Juillet* (1886–92); Ernest Lavisse (born 1843)—*Études sur l'histoire de Prusse* (1879), *Vue Générale de l'histoire politique de l'Europe* (1890), *La Jeunesse du Grand Frédéric* (1891), *Le Grand Frédéric avant l'avènement* (1893); Albert Sorel (born 1842)—*Histoire diplomatique de la guerre Franco-Allemande* (1875), *La question d'Orient au XVIIIième siècle* (1877), *L'Europe et la Révolution Française* (1885–92); Henry Houssaye (born 1848)—*Histoire d'Alcibiade* (1873); *1814: Histoire de la campagne de France* (1888); *1815:* &c. (1893); *Waterloo* (1899); Gabriel Hanotaux (born 1853)—*Histoire de Richelieu* (1893–96); Albert Vandal (born 1853)—*L'alliance mise sous Napoleon* (1891–96).

Le Vicomte Melchior de Vogüé (born 1848) must be classed among historians, although he is at the same time an essayist and a philosopher. It was he who revealed the modern Russian novelists (Tolstoi, Tourgeneff, Dostoiewski) to the French public. His *Souvenirs et Visions*, *Regards historiques*, and *Devant le Siècle* contain brilliant studies of foreign literature, ancient and modern, historical studies, and criticisms of contemporary French literature. He has many points of resemblance to Chateaubriand, both in his imaginative power and his brilliant and poetic style.

Conclusion.—French literature in the later half of the 19th century could not boast of a constellation of poets such as those who were the pride and glory of the Romantic period; on the other hand, the balance is weighed down by two of the greatest men of genius that the century produced in Europe—Taine and Renan. Apart from his monumental historical achievement, M. Renan's incomparable style, with its unstudied grace, its inevitable perfection, its complete harmony between the idea and the expression, entitles him to the rank of the greatest prose writer of the century. There is nothing in this epoch, it is true, to equal the vast and many-stringed lyre of Victor Hugo, the lyrical passion of Musset, the seraphic organ-music of Lamartine, the great solemn echoes that fell from the ivory tower of Alfred de Vigny. Yet if we review the last half-century we can reckon three great poets—Baudelaire, Banville, and Leconte de Lisle; and in the work of Leconte de Lisle, and in that of his most brilliant disciple, M. de Heredia, we have examples of a lofty poetic vision, combined with an absolute perfection of technique—rhymes and verses which truly seem to be of gold. Besides these four prominent names there remain the delicate poetry of M. Sully Prudhomme, which follows more or less the traditional lines of French poetry, but joins to grace of diction an austere pensiveness, and the genius of Paul Verlaine, a lyric poet of the first order, who departs so far from the path of tradition that, since all things move in a circle, he can only be compared to the earliest French lyrists. In the poetry of Verlaine we are aware of a new note of pure lyricism without any admixture of rhetoric, a note that is like an "unbodied joy."

Turning to writers of fiction, if we embrace the period 1850–1900 in our review, the genius of Gustave Flaubert overshadows all other writers; if we confine ourselves to the Third Republic, we can count at least three writers of genius—Zola, Daudet, and Maupassant; and in addition to these, two whom it is impossible to classify in any definite category, so original and so personal is their exquisite art—M. Pierre Loti and M. Anatole France, who have both of them contributed invaluable jewels to the treasure-house of French literature.

In the region of criticism no period has ever been more fertile, and the historians of the early part of the century have found worthy successors in Fustel de Coulanges, Thureau-Dangin, and Albert Sorel.

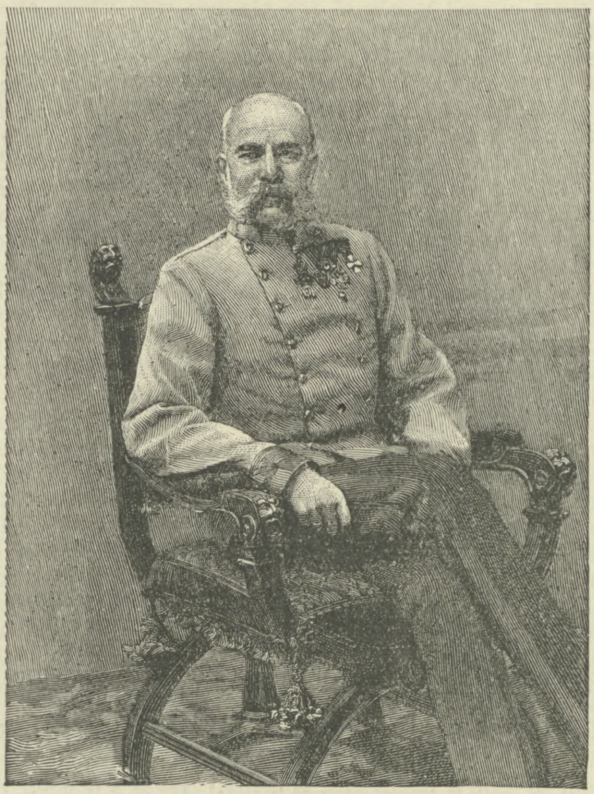
In the domain of the theatre we have had a renascence of poetical drama, of which M. Rostand is the most prominent exponent, and the appearance of a whole group of writers of subtle, delicate, and powerful dramas and comedies, such as Lemaître, Donnay, Hervieu, Porto-Riche, Lavedan, and François de Curel.

On the whole, the French literature of the second half of the 19th century can be said to rival in greatness and importance that of the first fifty years, and to claim a no less close examination from the comparative student of literature.

For French Drama and Art, see DRAMA and SCHOOLS OF PAINTING. (M. BA.)

France, Anatole (1844——), French critic, essayist, and novelist (whose real name is Jacques Anatole Thibault), was born in Paris on the 16th April 1844. His father was a bookseller, one of the last of the booksellers, if we are to believe the Goncourts, into whose establishment men came, not merely to order and buy, but to dip, and turn over pages, and discuss. M. France himself speaks of the pleasure with which, as a child, he used to listen to the nightly talks on literary subjects which took place in his father's shop. Nurtured in an atmosphere so essentially bookish, he turned naturally to literature. In 1868 his first work appeared, a study of Alfred de Vigny, a poet whom many lovers of French poetry regard with a quite peculiar affection. A volume of verse followed in 1873, *Les Poëmes dorés*, dedicated to Leconte de Lisle, and, as such a dedication suggests, an outcome of the "Parnassian" movement; and yet another volume of verse appeared in 1876, *Les Noces Corinthiennes.* But the poems in these volumes, though unmistakably the work of a man of great literary skill and cultured taste, are scarcely the poems of a man with whom verse is the highest form of expression. He was to find his richest vein in prose. And his prose is exquisite. He himself, avowing his preference for a simple, or seemingly simple, style as compared with the *artistic* style, vaunted by the Goncourts—a style compounded of neologisms and "rare" epithets, and startling forms of expression—observes: "A simple style is like white light. It is complex, but not to outward seeming. In language, a beautiful and desirable simplicity is but an appearance, and results only from the good order and sovereign economy of the various parts of speech." And thus one may say of M. France's own style that its beautiful translucency is the result of many qualities—felicity, grace, the harmonious grouping of words, a perfect measure. M. France is a sceptic. The essence of his philosophy, if a spirit so light, evanescent, elusive, can be said to have a philosophy, is doubt. He is a doubter in religion, metaphysics, morals, politics, æsthetics, science—a most genial and kindly doubter, and not at all without doubts even as to his own negative conclusions. Sometimes M. France's doubts are expressed in his own person — as in the *Jardin d'Épicure*, from which the above extracts are taken, or *Le Livre de mon Ami*, which may be accepted, perhaps, as partly autobiographical; sometimes, as in *La Rôtisserie de la Reine Pédauque*, and *Les Opinions de M. Jérôme Coignard*, or *L'Orme du Mail*, *Le Mannequin d'Osier*, and *L'Anneau d'Améthyste*, he entrusts the expression of his opinions, dramatically, to some fictitious character,—the Abbé Coignard, for instance, projecting, as it were, from the 18th century some very effective criticisms on the popular political theories of contemporary France—or the M. Bergeret of the three last-named novels, dealing in similar wise with some modern problems, and particularly, in *L'Anneau d'Améthyste*, with the humours and follies of the anti-Dreyfusards. All this makes a piquant combination. Nor should reference be omitted to works more distinctly of fancy, such as *Balthasar*, the story of one of the Magi, or *Thaïs*, the story of an actress and courtesan of Alexandria, whom a hermit converts, but with the loss of his own soul. Lightly as M. France bears his erudition, it is very real and extensive. As a critic—see the *Vie Littéraire*, reprinted mainly from *Le Temps*—he is graceful and appreciative. Academic in the best sense, he has found a place in the *Académie Française*, taking the seat vacated by Lesseps. He was received into that august body on the 24th December 1896. In the *affaire* Dreyfus he sided with M. Zola.

Francis Joseph I., Emperor of Austria, king of Bohemia, &c. &c., and apostolic king of Hungary (1830——), born 18th August 1830, was the eldest son of the Archduke Francis Charles, second son of the reigning emperor Francis I. His mother, the Archduchess Sophie, was daughter of Maximilian I., king of Bavaria. She was a woman of great ability and strong character,



The Emperor Francis Joseph I.
(*From a photograph by Carl Pietzner, Vienna.*)

and during the years which followed the death of the Emperor Francis was probably the most influential personage at the Austrian Court; for the Emperor Ferdinand, who succeeded in 1835, was physically and mentally incapable of performing the duties of his office; as he was childless, Francis Joseph was in the direct line of succession. During the disturbances of 1848 he spent some time in Italy, where, under Radetzky, at the battle of St Lucia, he had his first experience of warfare. At the end of that year, after the rising of Vienna and capture of the city by Windischgrätz, it was clearly desirable that there should be a more vigorous ruler at the head of the empire, and Ferdinand, now that the young archduke was of age, was able to carry out the abdication which he and his wife had long desired. All the preparations were made with the utmost secrecy; on 2nd December 1848, in the archiepiscopal palace at Olmütz, whither the Court had fled from Vienna, the emperor abdicated. His brother, the archduke, resigned his rights of succession to his son, and Francis Joseph was proclaimed emperor. Ferdinand retired to Prague, where he died in 1875. The new emperor was naturally during the first years of his reign completely in the hands of Prince Felix Schwarzenberg, to whom, with Windischgrätz and Radetzky, he owed it that Austria had emerged from the revolution apparently stronger than it had been before. The first task was to reduce Hungary to obedience, for the Magyars, who refused to acknowledge the act of 2nd December, at which they had not been represented, proclaimed a republic. In the war which followed the emperor himself took part, but it was not brought to a successful conclusion till the help of the Russians had been called in. The new reign began, therefore, under sinister omens, with the suppression of liberty in Italy, Hungary, and Germany. In 1853 a Hungarian named Lebenyi attempted to assassinate the emperor, and succeeded in inflicting a serious wound with a knife. With the death of Schwarzenberg in 1852 the personal government of the emperor really began, and with it that long series of experiments of which Austria has been the subject. Generally it may be said that throughout his long reign he has been the real ruler of his dominions; he has kept in his hands not only the appointment and dismissal of his ministers, but has himself directed their policy, and owing to the great knowledge of affairs, the unremitting diligence and clearness of apprehension, to which all who have transacted business with him have borne testimony, has been able to keep a very real control even of the details of government. The introduction of parliamentary government in 1866 necessarily made some change in his position, and so far as concerns Hungary he fully accepted the doctrine that ministers were responsible to parliament. In the other half of the empire this has not been possible (see the article on Austria), and the authority and influence of the emperor have been even increased by the contrast with the weaknesses and failures of the parliamentary system. The most noticeable features in his reign have been the repeated and sudden changes of policy, which, while they arise from the extreme difficulty of finding any system by which the empire can be governed, also are due to the personal idiosyncrasies of the emperor. First we have autocratic centralization under Bach; the personal influence of the emperor is seen in the conclusion of the Concordat with Rome, by which the work of Joseph II. was undone and the full power of the Papacy restored. The foreign policy of this period brought about the complete isolation of Austria, and the "ingratitude" towards Russia, as shown during the period of the Crimean War, which has become proverbial, caused a permanent estrangement between the two great Eastern empires and the imperial families. The system led inevitably to bankruptcy and ruin; the war of 1859, by bringing it to an end, saved Austria. After the first defeat Francis Joseph hastened to Italy; he commanded in person at Solferino, and by a meeting with Napoleon arranged the terms of the peace of Villafranca. The next six years, both in home and foreign policy, were marked by great vacillation. In order to meet the universal discontent and the financial difficulties constitutional government was introduced; a parliament was established in which all races of the empire were represented, and in place of centralized despotism was established Liberal centralization under Schmerling and the German Liberals. The opposition of the Magyars and Slavs continued, and the emperor had really withdrawn his confidence from Schmerling long before the Constitution was suspended in 1865 as a first step to a reconciliation with Hungary. In the complicated German affairs the emperor in vain sought for a minister on whose knowledge and advice he could depend. He was guided in turn by the inconsistent advice of Schmerling, Rechberg, Mensdorff, not to mention more obscure counsellors, and it is not surprising that Austria was repeatedly outmatched and outwitted by Prussia. In 1863, at the Fürsten Tag in Frankfurt, the emperor made an interesting attempt by his personal influence to solve the German question. The origin of the plan is still obscure. He invited all the German rulers to meet him in conference, and before them he laid a plan for the reform of the Confederation. The effect of the movement was immense; he seemed for a moment to have regained the position in Germany which his ancestors had held. He was welcomed to the ancient free city with enthusiasm. He himself presided at the discussions, and all the princes celebrated

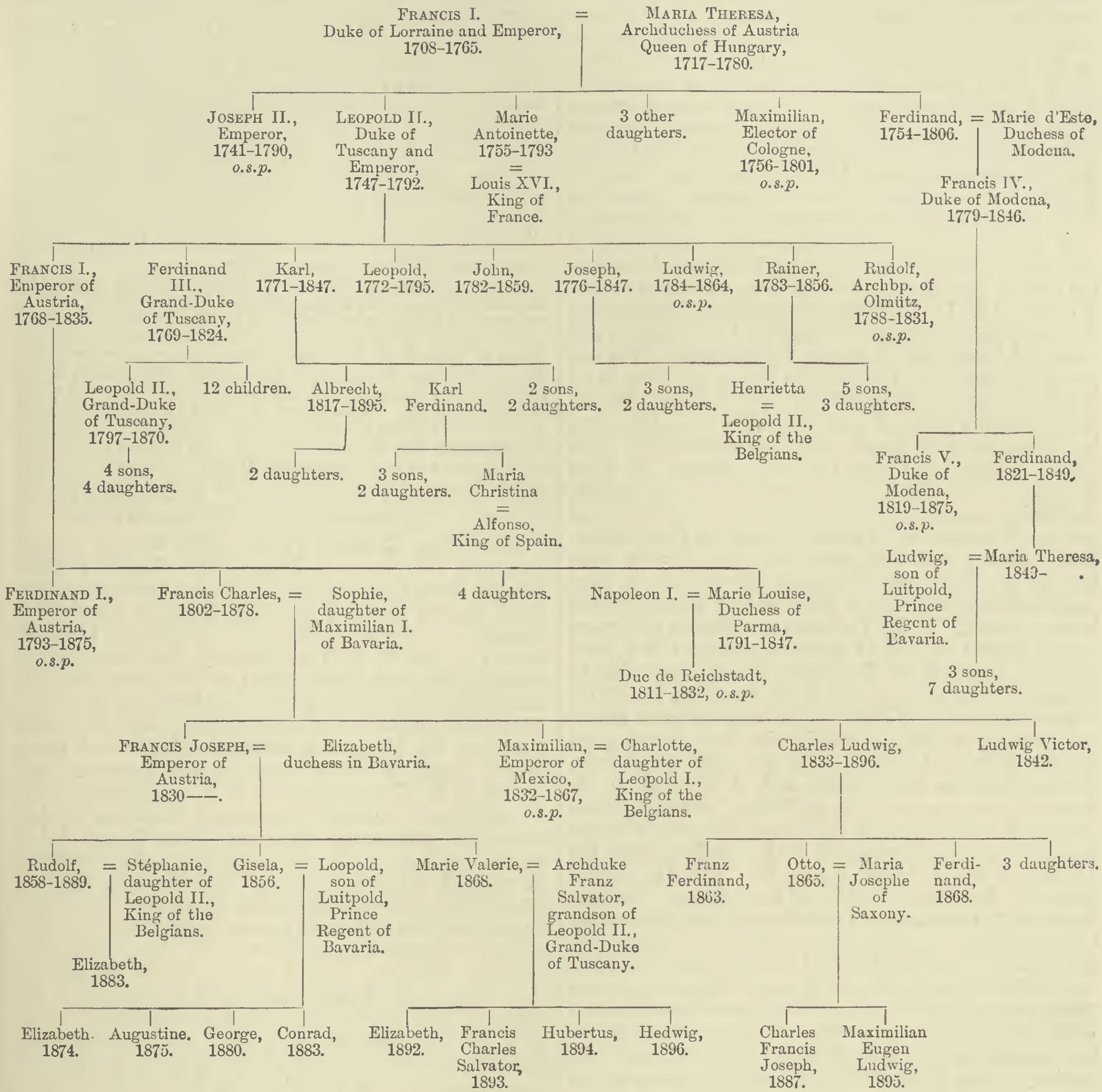


TABLE SHOWING THE DESCENT OF THE HABSBURG-LORRAINE DYNASTY.

the skill which he showed in the conduct of the debate; but the attempt failed, for the king of Prussia refused the invitation. The war with Prussia in 1866 was not of his seeking; he took no part in the campaign, but by a sudden resolution after the battle of Königgrätz telegraphed to Napoleon asking for his mediation, and offering him Venetia. The defeat made the reconciliation with Hungary, which the emperor had long desired, necessary. Deák was summoned to Vienna, and in a personal interview with the emperor explained the demands of the Magyars. At last the mistakes with which the reign was opened were repaired; Beust was appointed minister, and in 1867 the emperor and empress were solemnly crowned at Buda-Pest with the crown of St Stephen. (For the later history we must refer to the article on AUSTRIA-HUNGARY.) The influence of the emperor is to be seen first in the loyal adhesion to the constitutional system which he himself inaugurated. There is probably no other instance in history of a ruler, brought up as he was in the strictest school of absolute government, accepting without reserve the restrictions of parliamentary government, notwithstanding the great discouragement caused by the party struggles.

The emperor has also shown his desire to reconcile the Slavs to the crown as he did the Magyars; but though he has on more than one occasion held out hopes that he would be crowned king of Bohemia, the project has always been abandoned. In 1869 and 1870 he showed his prudence by refusing to be led into a war of revenge against Prussia, and in later years he fully accepted the reconciliation with Germany and Italy, the two Powers which were built up on the defeat of Austria—in this, as in internal affairs, refusing to allow prejudices, which would have been only natural for a man in his position, to influence his policy. He has therefore become one of the chief elements in the system on which the peace of Europe depends, just as in the government of his own dominions it is his personal influence which alone is able to maintain some authority over the parties and races, the discord of which threatens the disruption of the empire.

In his private life the emperor has been the victim of terrible catastrophes—his wife, his brother, and his only son having been destroyed by sudden and violent deaths. He married in 1854 ELIZABETH, daughter of Maximilian Joseph, duke in Bavaria, who belonged to the younger and non-royal branch of the house of Wittelsbach. The empress, who shared the remarkable beauty common to all her family, took little part in the public life of Austria. After the first years of married life she was seldom seen in Vienna, and spent much of her time in travelling. She built a castle of great beauty and magnificence, called the Achilleion, in the island of Corfu, where she often resided. In 1867 she accompanied the emperor to Buda-Pest, and took much interest in the reconciliation with the Magyars. She became a good Hungarian scholar, and spent much time in Hungary. An admirable horsewoman, in later years she repeatedly visited England and Ireland for the hunting season. In 1897 she was assassinated at Geneva by an Italian anarchist; previous attempts had been made on her and her husband's life during a visit to Trieste. There was one son of the marriage, the Crown Prince RUDOLPH (1857–1889). A man of much ability and promise, he was a good linguist, and showed great interest in natural history. He published two works, *Fifteen Days on the Danube*, and *A Journey in the East*, and also promoted the publication of an important illustrated work giving a full description of the whole Austro-Hungarian monarchy; he personally shared the labours of the editorial work. In 1881 he married Stéphanie, daughter of the king of the Belgians. On 30th January 1889 he committed suicide at Mayerling, a country house near Vienna. He left one daughter, Elizabeth, who was betrothed to Count Alfred Windischgrätz in 1901. In 1900 his widow, the Crown Princess Stéphanie, married Count Lonyay; by this she sacrificed her rank and position within the Austrian monarchy. Besides the crown prince the empress gave birth to three daughters, of whom two survive: Gisela (born 1857), who married a son of the prince regent of Bavaria; and Marie Valerie (born 1868), who married the Archduke Franz Salvator of Tuscany.

Owing to the composite nature of the Austro-Hungarian monarchy the person of the reigning monarch and all questions connected with the succession have a more fundamental importance than in other States, for it is by the dynasty alone that the empire is bound together. The rules of succession are determined by the Pragmatic Sanction and by the family code of the archducal house of Austria, by which, as in other German princely families, women are excluded from the succession so long as there are any male heirs. The table on page 309 shows the descent of the different branches of the family from the Emperor Francis and Maria Theresa, the founders of the present dynasty of Habsburg-Lorraine. In default of heirs-male of the present emperor the succession will go to his brother. The next brother, the Archduke Ferdinand, accepted the position of emperor of Mexico, and was shot by the Mexicans in 1867. The fourth brother is unmarried. The third brother, Karl Ludwig (died 1895), left three sons. The eldest, Franz Ferdinand, is therefore heir-presumptive. On the death of Francis V., last duke of Modena, without male issue, the emperor assumed the title of duke of Modena, and the Archduke Franz Ferdinand, who inherited the great wealth of the family of Este, assumed the style of archduke of Austria-Este. If he succeed to the empire the Este possessions will pass to his second brother. It will be remembered that the duchy of Modena was annexed to the kingdom of Italy in 1859, so that the family is no longer reigning. The title and possessions came into the house of Austria by the marriage of the Archduke Ferdinand with the heiress of the house of Este in 1777. It is Maria of Modena, the only daughter of the last duke of Modena (married to a son of the prince regent of Bavaria), who is regarded by some as the direct representative of the house of Stewart. In 1900 the Archduke Franz Ferdinand married the Countess Sophie Chotek, who received the title of princess of Hohenberg. As the countess is not of equal birth, the archduke, before the marriage took place, had to take an oath recognizing, that in virtue of the family code any children of the marriage would be incapable of succession. A large party in the Hungarian parliament contended, however, that the conception of a morganatic marriage was unknown in Hungary, and that therefore this was an arbitrary and illegal alteration in the law of succession. To meet this a special law was carried through the Hungarian Diet declaring the children excluded from the succession to the throne of Hungary.

The grand-duchy of Tuscany, which was originally acquired by the house of Lorraine in exchange for the duchy of Lorraine, which was annexed to France, was generally held by a younger branch of the family. The duchy was in 1859 annexed to the kingdom of Italy. A son of Leopold II., the last reigning duke, was the Archduke JOHANN NEPOMUCK SALVATOR (born 1852). He attained a high position in the Austrian army, and was the author of several works on military affairs. The opinions expressed in these accentuated differences which had arisen between him and the military authorities, especially the Archduke Albrecht. In 1887 he retired from active service; in 1889 he resigned all rights and titles which belonged to him as archduke, and under the name of JOHN ORTH assumed the command of a sailing-vessel. He was probably lost at sea during a voyage from Buenos Aires to Valparaiso in 1896.

Franck, César (1822–1890), French musical composer, was born at Liége, 10th December 1822. Though one of the most remarkable of modern composers, César Franck laboured for many years in comparative obscurity. After some preliminary studies at Liége he came to Paris in 1837 and entered the Conservatoire, obtaining the prize for the organ in 1841, after which he settled down in the French capital as teacher of the piano. His earliest compositions date from this period, and include four trios for piano and strings, besides several piano pieces. *Ruth*, a biblical cantata, was produced with success at the Conservatoire in 1846. An opera entitled *Le Valet de Ferme* was written about this time, but has never been performed. For many years Franck led a retired life, devoting himself to teaching and to his duties as organist, first at Saint-Jean-Saint-François, then at Ste Clotilde, where he acquired a great reputation as an improviser. He also wrote a mass, heard in 1861, and a quantity of motets, organ pieces, and other works of a religious character. Franck was appointed professor of the organ at the Paris Conservatoire in 1872, and the following year he was naturalized a Frenchman. Until then he was esteemed as a clever and conscientious musician, but he was now about to prove his title to something more. A revival of his early oratorio, *Ruth*, had brought his name again before the public, and this was followed by the production of *Rédemption*, a work for solo, chorus, and orchestra, given under the direction of M. Colonne on 10th April 1873. The serious character of the music and its unconventionality perhaps rather disconcerted the general public, but the work nevertheless made its mark, and Franck became the central figure of an enthusiastic circle of pupils and adherents whose devotion atoned for the comparative indifference of the masses. His creative power now manifested itself in a series of works of varied kinds, and the name of Franck began gradually to emerge from its obscurity. The following is an enumeration of his subsequent compositions:

Rebecca (1881), a biblical idyll for solo, chorus, and orchestra; *Les Béatitudes*, an oratorio composed between 1870 and 1880, perhaps his greatest work; the symphonic poems, *Les Éolides* (1876), *Le Chasseur Maudit* (1883), *Les Djinns* (1884), for piano and orchestra; *Psyche* (1888), for orchestra and chorus; symphonic variations for piano and orchestra (1885); symphony in D (1889); quintet for piano and strings (1880); sonata for piano and violin (1886); string quartet (1889); prelude, choral and fugue for piano (1884); prelude, aria and finale for piano (1889); various songs, notably "La Procession" and "Les Cloches du Soir." Franck also composed two four-act operas, *Hulda* and *Ghiselle*, both of which were produced at Monte Carlo after his death, which took place in Paris, 9th November 1890. The second of these was left by the master in an unfinished state, and the instrumentation was completed by several of his pupils. César Franck's influence on the younger French composers of the present has been very great. Yet it is impossible to accept him as a typical representative of French music. A Belgian by birth, he came of German stock, and heredity in this instance undoubtedly asserted itself. A more sincere, modest, self-respecting composer probably never existed. In the centre of the brilliant French capital he was able to lead a laborious existence consecrated to his threefold career of organist, teacher, and composer. He never sought to gain the suffrages of the public by unworthy concessions, but kept straight on his path, ever mindful of an ideal to be reached and never swerving therefrom. His compositions are not likely ever to obtain popularity in the widest sense of the word, but their great qualities of originality and nobility will cause them to be more and more prized by musicians. It may be said that several of the more prominent French composers of our day learned the practice of their art under César Franck. (A. He.)

Franeker, a Netherlands town, in the province of Friesland, 10 miles west of Leeuwarden, on the Harlingen-Leeuwarden railway. It is at the junction of many roads and waterways, and has a considerable market for agricultural produce, butter, cheese, and flax. It has also potteries and shipbuilding yards. Population (1900), 7114.

Frankfort, capital of Clinton county, Indiana, U.S.A., 40 miles from Indianapolis, at an altitude of 857 feet. It is at the intersection of the Chicago, Indianapolis, and Louisville, the Lake Erie and Western, the Toledo, St Louis and Kansas City, and the Vandalia railways. Population (1880), 2803; (1890), 5919; (1900), 7100, of whom 144 were foreign-born, and 90 negroes.

Frankfort, capital of Franklin county, Kentucky, U.S.A., and the capital of the State, on the Kentucky river, at an altitude of 560 feet. It has three railways, the Chesapeake and Ohio, the Louisville and Nashville, and the Frankfort and Cincinnati. Population (1880), 6958; (1890), 7892; (1900), 9487, of whom 266 were foreign-born, and 3316 negroes.

Frankfort-on-Main, a town of Prussia, province Hesse-Nassau, standing on the right bank of the Main, 24 miles above its confluence with the Rhine at Mainz. Since 1899 Frankfort has been the headquarters of the 18th German Army Corps. The restoration of the cathedral, begun in 1869, was finished in 1890. The church of St Leonhard was restored in 1882. The most noteworthy of the new churches are St Peter's (1893–95), in the North German Renaissance style, with a tower 256 feet high, standing north from the Zeil; Christ church (1883); and the Luther church (1894). A new synagogue was built in 1881. Several of the old houses incorporated in the Römer, and the Römer itself, were restored during the years 1888–98. The Judengasse, down to 1806 the sole Jews' quarter, has been pulled down, with the exception of the ancestral house of the Rothschild family, which has been restored and retains its ancient façade. The Thurn-und-Taxis Palace is incorporated with the imposing pile of the post-office, a new building of 1892–94, with a monument of the Emperor William I. (1895) in front of it. In the same quarter, *i.e.*, north of the Zeil, are the Exchange (1879), with a commercial museum, and the law courts (1884–89), in the German Renaissance style. The municipal library, which now contains some 215,000 volumes, was enlarged and rebuilt in 1891–93. The fine bridge, originally used by the Main-Neckar railway, has been given over to road traffic, and two new iron bridges at Gutleuthof and Niederrad carry the railway traffic from the south to the north bank of the Main, where all lines converge in a central station of the State railways. This station, which was built in 1883–88, and has replaced the three stations belonging to private companies which stood in juxtaposition on the Anlagen near the Mainzer Thor, lies some half-mile to the west. The intervening ground upon which the railway lines and buildings stood was sold for building sites, the sum thus obtained being more than sufficient to cover the cost of the majestic central station, which, in addition to spacious and handsome halls for passenger accommodation, has three glass-covered spans of 180 feet width each. The so-called Leinwand-Haus, a 14th-century building, reconstructed in 1892, contains a valuable historical museum and the town archives. Behind the Goethe-Haus was opened in 1897 the Goethe Museum, together with a library of some 20,000 volumes, representative of the Goethe period of German literature. There may also be mentioned the industrial art exhibition of the Polytechnic Association; two conservatories of music; Schopenhauer's house, on the Main side; monuments to Schopenhauer (1895), the Emperor William I. (1896), and Clemens Brentano; a commercial high school (1901) and a commercial museum; technical improvement, higher industrial, industrial art, commercial, and other schools; and a large number of banks. In 1891 the International Electro-Technical Exhibition was held here. Of recent years, Frankfort, or rather Sachsenhausen (on the left bank of the Main) and Bockenheim have developed considerable industrial activity, especially in publishing and printing, brewing, and the manufacture of quinine. Other sources of employment are the cutting of hair for making hats, the production of fancy goods, type, machinery, soap and perfumery, ready-made clothing, chemicals, electro-technical apparatus, and metal wares. Market-gardening is extensively carried on in the neighbourhood, and Frankfort itself is a seat of floriculture. Cider is extensively manufactured. Here is a trade arbitration court, for the settlement of disputes arising out of labour contracts. Since the completion of the canalization of the Main past the town the trade of Frankfort, especially the transit trade, has largely increased. A total of 4103 vessels of 1,560,700 tons entered and cleared together by river in 1898. Population (1885), 154,513; (1890), 179,985; (1895), 229,279; (1900), 288,489. In 1895 the town of Bockenheim was incorporated in Frankfort-on-Main. Old Frankfort life is described in Goethe's *Wahrheit und Dichtung* and in Heine's *Rabbi von Bacharach.* See also the series of plates entitled *Frankfurt, die freie Stadt, in Bauwerken und Strassenbildern*, by Reiffenstein (Frankfurt, 1894–98), and Dietz, *Frankfürter Bürgerbuch, geschichtliche Mitteilungen* (*ib.* 1896). (J. T. Be.)

Frankfort-on-Oder, a town of Prussia, on the Oder, 50 miles E.S.E. of Berlin, capital of the government district of Frankfurt, province of Brandenburg; a railway centre to Berlin, Breslau, Cüstrin, Posen, &c. There are Evangelical, Reformed, and Catholic churches; and among the schools are a higher grade girls', with a seminary for female teachers, and 9 Evangelical schools. A new stone bridge, 855 feet long, spanning the Oder, connects the town with the suburb of Damm. There is a monument of the Franco-German war (1882), and one to Prince Frederick Charles (1888). A workshop of the Lower-Silesian and Brandenburg railway employs over 800 workmen. Trade has suffered from the decline of the three fairs and the neighbourhood of Berlin. Population (1890), 55,738; (1900), 61,572.

Frankland, Sir Edward (1825–1899), English chemist, was born at Churchtown, near Lancaster, on 18th January 1825. After attending the grammar-school at Lancaster he studied chemistry, first in London and then in the laboratories of Liebig at Giessen and Bunsen at Marburg. From an early age he engaged in original research with great success, proving himself an experimentalist of exceptional brilliancy. Analytical problems, such as the isolation of certain organic radicals, attracted his attention to begin with, but he soon turned to synthetical studies, and he was only about twenty-five years of age when an investigation, doubtless suggested by the work of his master, Bunsen, on cacodyl, yielded the interesting discovery of the organo-metallic compounds which are formed by the direct combination of a metal with a positive organic radical. The theoretical deductions which he drew from the consideration of these bodies were even more interesting and important than the bodies themselves. Perceiving a molecular isonomy between them and the inorganic compounds of the metals from which they may be formed, he saw their true molecular type in the oxygen, sulphur, or chlorine compounds of those metals, from which he held them to be derived by the substitution of an organic group for the oxygen, sulphur, &c. In this way they enabled him to overthrow the theory of conjugate compounds, and they further led him in 1852 to publish the conception that the atoms of each elementary substance have a definite saturation capacity, so that they have only room, so to speak, for the attachment of a certain limited number of the atoms of other elements. The theory of valency thus founded has dominated the whole subsequent development of chemical doctrine, and forms the groundwork upon which the fabric of modern structural chemistry reposes. In applied chemistry Frankland's great work was in connexion with water-supply. Appointed a member of the second Royal Commission on the Pollution of Rivers in 1868, he was provided by the Government with a completely-equipped laboratory, in which, for a period of six years, he carried on the inquiries necessary for the purposes of that body, and was thus the means of bringing to light an enormous amount of valuable information respecting the contamination of rivers by sewage, trade-refuse, &c., and the purification of water for domestic use. In 1865, when he succeeded Hofmann at the Royal College of Chemistry, he undertook the duty of making monthly reports to the Registrar-General on the character of the water supplied to London, and these he continued down to the end of his life. At one time he was an unsparing critic of its quality, but in later years he became strongly convinced of its general excellence and wholesomeness. His analyses were both chemical and bacteriological, and his dissatisfaction with the processes in vogue for the former at the time of his appointment caused him to spend two years in devising new and more accurate methods. In 1859 he passed a night on the very top of Mont Blanc in company with Tyndall, of whom he was for some years a colleague at the Royal Institution, where he succeeded Faraday as professor of chemistry in 1863. One of the purposes of the expedition was to discover whether the rate of combustion of a candle varies with the density of the atmosphere in which it is burnt, a question which was answered in the negative. Other observations made by Frankland at the time formed the starting-point of a series of experiments which yielded far-reaching results. He noticed that at the summit the candle gave a very poor light, and was thereby led to investigate the effect produced on luminous flames by varying the pressure of the atmosphere in which they are burning. He found that pressure increases luminosity, so that hydrogen, for example, the flame of which in normal circumstances gives no light, burns with a luminous flame under a pressure of ten or twenty atmospheres, and the inference he drew was that the presence of solid particles is not the only factor that determines the light-giving power of a flame. Further, he showed that the spectrum of a dense ignited gas resembles that of an incandescent liquid or solid, and he traced a gradual change in the spectrum of an incandescent gas under increasing pressure, the sharp lines observable when it is extremely attenuated broadening out to nebulous bands as the pressure rises, till they merge in the continuous spectrum as the gas approaches a density comparable with that of the liquid state. An application of these results to solar physics in conjunction with Sir Norman Lockyer led to the view that at least the external layers, or photosphere, of the sun cannot consist of matter in the liquid or solid forms, but must be composed of gases or vapours. Frankland and Lockyer were also the discoverers of helium. In 1868 they noticed in the solar spectrum a bright yellow line which did not correspond to any substance then known, and which they therefore attributed to a hypothetical element, helium; this some thirty years afterwards was actually proved by Professor W. Ramsay to exist on this earth. Sir Edward Frankland died on 9th August 1899, while on a holiday in Norway.

A memorial lecture delivered by Professor H. E. Armstrong before the London Chemical Society on 31st October 1901 contained many personal details of Frankland's life, together with a full discussion of his scientific work. (H. M. R.)

Franklin, a town of Norfolk county, Massachusetts, U.S.A., with an area of 29 square miles of rolling surface. The principal village, which bears the same name as the town, is on the New England Railway. Population of the town (1880), 4051; (1890), 4831; (1900), 5017, of whom 1250 were foreign-born.

Franklin, a city of Merrimack county, New Hampshire, U.S.A., on the Merrimack river and on the Boston and Maine Railroad. It contains numerous small villages in which many minor manufactures are carried on. These villages are Franklin, Franklin Falls, Maplewood, Webster Place, Shaw Corner, and Lake City. Population of the town (1880), 3265; (1890), 4085; (1900), 5846, of whom 1323 were foreign-born.

Franklin, capital of Venango county, Pennsylvania, U.S.A., on the Allegheny river, at an altitude of 988 feet. Four railways intersect here, the Allegheny Valley, the Erie, the Lake Shore and Michigan Southern, and the Western New York and Pennsylvania. The city is well sewered, and paved with brick. Franklin is in the oil region, and owes its origin and prosperity to that mineral. Among its manufacturing establishments, those for the refining of petroleum are prominent. Population (1880), 5010; (1890), 6221; (1900), 7317, of whom 489 were foreign-born, and 264 negroes.

Franks, Sir Augustus Wollaston (1826–1897), English antiquary, was born on 20th March 1826, and was educated at Eton and at Trinity College, Cambridge. From his boyhood he evinced a strong predilection for antiquarian pursuits, and in 1851 was appointed assistant in the Antiquities Department of the British Museum, a line of life in general but little affected by young men endowed like Franks with ample private means. Here, and as Director of the Society of Antiquaries, which appointment he received in 1858, he made himself the first authority in England upon mediæval antiquities of all descriptions, upon porcelain, glass, the manufactures of savage nations, and in general upon all Oriental curiosities and works of art later than the Classical period. In 1866 the British and mediæval antiquities, with the ethnographical collections, were formed into a distinct department under his superintendence; and the Christy collection of ethnography in Victoria Street, London, prior to its amalgamation with the British Museum collections, was also under his care. He became a Vice-President and ultimately President of the Society of Antiquaries, and in 1878 declined the Principal Librarianship of the Museum. He retired on his seventieth birthday, 1896, and died on 21st May 1897. The British Museum has had officers as distinguished in their respective departments as Sir A. W. Franks, though none more so; but it was unique good fortune that almost the only officer it has ever had in a position greatly to enrich its collections from his own stores should also have been a man of rare munificence. Sir A. W. Franks's ample fortune was largely devoted to the collection of ceramics and precious objects of mediæval art, most of which became the property of the nation, either by donation in his lifetime or by bequest at his death. Although chiefly a mediæval antiquary, Franks was also an authority on classical art, especially Roman remains in Britain: he was also greatly interested in book-marks and playing-cards, of both of which he formed important collections. He edited Kemble's *Horæ Ferales*, and wrote numerous memoirs on archæological subjects. Perhaps his most important work of this class is the catalogue of his own collection of porcelain, which he permitted to be for a long time exhibited at the Bethnal Green Museum in the east of London. (R. G.)

Franz, Robert (1815–1892), German composer, was born at Halle, 28th June 1815. One of the most gifted of German song writers, he suffered in early life, as many musicians have suffered, from the hostility of his parents to a musical career. He was twenty years old when, his father's animosity conquered, he was allowed to live in Dessau to study organ-playing under Schneider. The two years of dry study under that famous teacher were advantageous chiefly in making him uncommonly intimate with the works of Bach and Handel, his knowledge of which he showed in his editions of the *Matthäus Passion*, *Magnificat*, ten cantatas, and of the *Messiah* and *L'Allegro*, though some of these editions have long been a subject of controversy among musicians. In 1843 he published his first book of songs, which ultimately was followed by some fifty more books, containing in all about 250 songs. At Halle, Franz filled various public offices, including those of organist to the city, conductor of the Sing-akademie and of the Symphony concerts, and he was also a royal music-director, and master of the music at the university. The first book of songs was warmly praised by Schumann and Liszt, the latter of whom wrote a lengthy review of it in Schumann's paper, *Die Neue Zeitschrift*, which later was published separately. Deafness had begun to make itself apparent as early as 1841, and Franz suffered also from a nervous disorder, which in 1868 compelled him to resign his offices. His future was then provided for by Liszt, Dr Joachim, Frau Magnus, and others, who gave him the receipts of a concert tour, amounting to some 100,000 marks. Franz died on 24th October 1892. On his seventieth birthday he published his first and only pianoforte piece. It is easy to find here and there among his songs gems that are hardly less brilliant than the best of Schumann's. Certainly no musician was ever more thoughtful and more painstaking. In addition to songs he wrote a setting for double choir of the 117th Psalm, and a four-part Kyrie; he also edited Astorga's *Stabat Mater* and Durante's *Magnificat*, and published an "open letter" to Hanslick on his methods of editing. (R. H. L.)

Franzensbad, or KAISER-FRANZENSBAD, a well-known Bohemian watering-place in the government district of Eger. It possesses besides an international hospital for poor patients and four large bathing establishments, Roman Catholic, Protestant, and Russian Churches, a synagogue, and a theatre. The mineral springs, used internally as well as externally, are twelve in number—saline, alkaline, and ferruginous—and one contains a considerable proportion of lithia salts. The so-called "moor-" or mud-baths, prepared from the peat of the Franzensbad marsh, which is rich in mineral substances, are an important part of the cure. Franzensbad is frequently resorted to for an after cure by patients from Marienbad and Karlsbad. There are over 8000 visitors during the season, and a considerable trade is done in mineral waters, &c. In 1890 the population (mostly German) was 2370; in 1900, 2330.

Franzensfeste, or FRANZENSVESTE, a strong Austrian fortress in the government district of Brixen, Tirol, on the road from the latter town to the Brenner Pass, at the entrance of the Pusterthal. It is situated on the right bank of the Eisack, about 9 miles north of Brixen, at the mouth of the narrow defile known as the "Brixener Klause," which is the junction of the roads from Botzen, Innsbruck, and the Pusterthal. It thus commands the Brenner road and railway and the entrance to the Puster Valley, with the railway to Villach, Klagenfurt, and Marburg. The latter line passes through the fortifications, crossing the Eisack by an iron bridge, 218 yards in length, and resting upon six granite piers. This bridge, together with the old wooden structure, the Ladritsch Brücke, is covered by the guns of the fort. Franzensveste station, about a mile north of the fortifications, has about 300 inhabitants.

For the strategic value of this fortress, and generally of the Austrian fortifications in Tirol, see articles by Lieut.-Col. Herman Frobenius in the *Archiv für die Artillerie- und Ingenieur-Officiere des deutschen Reichsheeres*, June–September 1895. The Austrian Field-Marshal Franz von Kuhn in his *Gebirgskrieg* (second edition, Vienna, 1878) draws many of his illustrations from Tirol, which he considers of incalculable value to the monarchy, not only in a war against Italy, but also in one with Germany.

Franz Josef Land, an arctic archipelago lying to the east of Spitsbergen and the north of Novaya Zemlya, extending northwards from about 80° N. lat. Petermann has expressed the opinion that Baffin may have sighted the west of Franz Josef Land in 1614, but the first actual discovery is due to Julius Payer, a lieutenant in the Austrian army, who was associated with Weyprecht in the second polar expedition fitted out by Count Wilczek on the ship *Tegetthof* in 1872. On 13th August 1873, the *Tegetthof* being then beset, high land was seen to the north-west. Later in the season Payer led expeditions to Hochstetter and Wilczek islands, and after a second winter in the ice-bound ship, a difficult journey was made northwards through Austria Sound, which was reported to separate two large masses of land, Wilczek Land on the east from Zichy Land on the west, to Cape Fligely, in 82° 5′ N. lat., where Rawlinson Sound branched away to the north-east. Cape Fligely was the highest latitude attained by Payer, and remained the highest attained in the Old World till 1895. Payer reported that from Cape Fligely, land (Rudolf Land) stretched north-east to a cape (Cape Sherard Osborn), and mountain ranges were visible to the north, indicating lands beyond the 83rd parallel, to which the names King Oscar Land and Petermann Land were given. In 1879 De Bruyne sighted high land in the Franz Josef Land region, but otherwise it remained untouched until Leigh Smith, in the yacht *Eira*, explored the whole southern coast from 42° to 54° E. long. in 1881 and 1882, discovering many islands and sounds, and ascertaining that the coast of Alexandra Land, in the extreme west, trended to north-west and north. In the face of almost insuperable difficulties, including the loss of his ship, Leigh Smith made botanical and zoological collections of great value, although he failed to reach high latitudes. After Leigh Smith comes another pause, and no further mention is made of Franz Josef Land till 1894. In that year Mr Alfred Harmsworth fitted out an expedition in the ship *Windward* under the leadership of Mr F. G. Jackson, with the object of establishing a permanent base from which systematic exploration should be carried on for successive years, and, if practicable, a journey should be made to the Pole. Mr Jackson and his party landed at "Elmwood," near Cape Flora, at the western extremity of Northbrook Island, on 7th September. After a preliminary reconnaissance to the north, which afterwards turned out to be vitally important, the summer of 1895 was spent in exploring the coast to the north-west by a boating expedition. This expedition visited many of the points seen by Leigh Smith, and discovered land, which it has been suggested may be the Gillies Land reported by the Dutch captain Gillies in 1707. In 1896 the Jackson-Harmsworth expedition worked northwards through an archipelago for about 70 miles, and reached Cape Richthofen, a promontory 700 feet high, whence an expanse of open water was seen to the northward, which received the name of Queen Victoria Sea. To the west, on the opposite side of a wide opening which was called the British Channel, appeared glacier-covered land, and an island lay to the northward. The island was probably the King Oscar Land of Payer. To north and north-east was the land which had been visited in the reconnaissance of the previous year, but beyond it a water-sky appeared in the supposed position of Petermann Land. Thus Zichy Land itself was resolved into a group of islands, and the outlying land sighted by Payer was found to be islands also. Meanwhile Nansen, on his southward journey, had approached Franz Josef Land from the north-east, finding only sea at the north end of Wilczek Land, and seeing nothing of Payer's Rawlinson Sound, or of the north end of Austria Sound. Nansen wintered near Cape Norway, only a few miles from the spot reached by Jackson in 1895. The general results of the two explorers agree in the conclusion that Franz Josef Land consists of an archipelago of small islands, which extends westwards to a distance as yet undetermined, but is probably connected by a continuous chain with Spitsbergen. Nansen had of course finally proved that a deep oceanic basin lies to the north. The *Windward* revisited "Elmwood" in 1896 and brought Nansen home, the work of the Jackson-Harmsworth expedition being continued for another year. As the non-existence of land to the north had been proved, the attempt to penetrate northwards was abandoned, and the last season was devoted to a survey and scientific examination of the archipelago, especially to the west; this was carried out by Jackson, Armitage, Koettlitz, Fisher, and Bruce. Further light was thrown on the relations of Franz Josef Land and Spitsbergen during 1897 by the discoveries of Captain Robertson of Dundee, and Wyche's Land was circumnavigated by Mr Arnold Pike and Sir Savile Crossley. The latter voyage was repeated in the following year by a German expedition under Dr Th. Lerner and Captain Rüdiger. In August 1898 an expedition under Mr Wellman, an American, landed at Cape Tegetthof. Beginning a northward journey with sledges at the end of the following winter, Wellman met with an accident which compelled him to return, but not before some exploration had been accomplished, and the eastern extension of the archipelago fairly well defined. In June 1899, H.R.H. the Duke of Abruzzi started from Christiania in his yacht, the *Stella Polare*, to make the first attempt to force a ship into the newly-discovered ocean north of Franz Josef Land. The *Stella Polare* succeeded in making her way through the British Channel to Crown Prince Rudolf Land, and wintered in Teplitz Bay, in 81° 33′ N. lat. The ship was nearly wrecked in the autumn, and the party had to spend most of the winter on shore, the Duke of Abruzzi suffering severely from frost-bite. In March 1900 a sledge party of thirteen, under Captain Cagni, started northwards. They found no trace of Petermann Land, but with great difficulty crossed the ice to 86° 33′ N. lat., 20 miles beyond Nansen's farthest, and 240 miles from the Pole. The party, with the exception of three, returned to the ship after an absence of 104 days, and the *Stella Polare* returned to Tromsö in September 1900. (H. N. D.)

Fraser, James (1818–1885), English bishop, was born at Prestbury, in Gloucestershire, on the 18th of August 1818. His father was of Scottish descent; his mother's family lived at Bilston, in Staffordshire, which occasioned him to receive his school education at Bridgnorth and Shrewsbury. At Oxford he gained a first-class and an Oriel fellowship, and was for some time tutor of the college, but did not take orders until 1846. He was successively rector of the livings of Cholderton, in Wiltshire, and of Ufton Nervet, in Berkshire; but his rise in life was owing to Hamilton, bishop of Salisbury's recommendation of him as an assistant commissioner of education. His report on the educational condition of thirteen poor-law unions, made in May 1859, is described by Mr Thomas Hughes as "a superb, almost a unique piece of work." In 1865 he was entrusted with a commission to report on the state of education in the United States and Canada, and his able performance of his mission brought him an offer of the bishopric of Calcutta, which he declined, but in January 1870 he accepted the see of Manchester. The task before him was an arduous one, for although his predecessor, Dr Prince Lee, had consecrated no fewer than 130 churches, the enormous population was still greatly in advance of the ecclesiastical machinery. Fraser worked with the utmost energy, and did even more for the Church by the liberality and geniality which earned him the title of "the bishop of all denominations." He was prominent in secular as well as religious works, interesting himself in every movement that promoted health, morality, or education; and especially serviceable as the friendly, unofficious counsellor of all classes. He was frequently invoked as an arbitrator in trade disputes, and was seldom absent from any important public gathering of a non-political nature. His theology was that of a liberal High Churchman, but his sympathies were exceedingly broad. His death, which occurred unexpectedly on the 22nd of October 1885, evoked the most earnest demonstrations of sorrow from all classes of society. A biography of him was written by Thomas Hughes, author of *Tom Brown's School-Days*. (R. G.)

Fraserburg, a town of Cape Colony, on the northern slope of the Nieuwveld range, near the sources of the Zak river, which, when flooded, flows northwards to the left bank of the Orange below Upington. Fraserburg is a thriving agricultural centre, and possesses some importance as the chief depôt for the distribution of supplies amongst the stock-breeders of the extensive Nieuwveld plains between Carnarvon and Calvinia. Population about 2000.

Fraserburgh, a police burgh and seaport of Aberdeenshire, Scotland, 47¼ miles north by east of Aberdeen by rail. The harbour has been enlarged at a total cost, up to 1898, of £315,000. There were 15 vessels of 3741 tons registered at the port at the end of 1898, and in that year 397 vessels of 63,195 tons entered, and 388 vessels of 61,844 tons cleared. Fraserburgh is the head of a fishery district (for statistics of district, see ABERDEENSHIRE). The value of the fish (mostly herrings) landed in 1899 was £200,504. Besides 161 other boats, there are now 10 steam trawlers. It has a public hall and a hospital. The Baptist church was built in 1880, and St Peter's Episcopal in 1891. There is an endowed academy. Population (1881), 6583; (1901), 8998.

Fraserville (formerly RIVIÈRE DU LOUP EN BAS), a town, railway station, and watering-place in Temiscouata county, Quebec, Canada, 107 miles (by water) north-east of Quebec, on the south shore of River St Lawrence, and at the mouth of the River du Loup. It contains a convent, boys' college, hospital, several mills, and a number of handsome villa residences. Population (1881), 2291; (1901), 4569.

Fraud, in its widest sense, is a term which has never been exhaustively defined by an English court of law, and for legal purposes probably cannot usefully be defined. But as denoting a cause of action for which damages can be recovered in civil proceedings it now has a clear and settled meaning. In actions in which damages are claimed for fraud, the difficulties and obscurities which commonly arise are due rather to the complexity of modern commerce and the ingenuity of modern swindlers than to any uncertainty or technicality in the modern law. To succeed in such an action, the person aggrieved must first prove a representation of fact, made either by words, by writing, or by conduct, which is in fact untrue. Mere concealment is not actionable unless it amounts not only to *suppressio veri*, but to *suggestio falsi*. An expression of opinion or of intention is not enough, unless it can be shown that the opinion was not really held, or that the intention was not really entertained, in which case it must be borne in mind, to use the phrase of Lord Bowen, that the state of a man's mind is as much a matter of fact as the state of his digestion. Next, it must be proved that the representation was made without any honest belief in its truth, that is, either with actual knowledge of its falsity or with a reckless disregard whether it is true or false. It was finally established, after much controversy, in the case of *Derry* v. *Peek* in 1889, that a merely negligent misstatement is not actionable, although the fact that a statement is made without reasonable grounds for believing it to be true may be strong evidence tending to show that it was made without honest belief in its truth. Further, the person aggrieved must prove that the offender made the representation with the intention that he should act on it, though not necessarily directly to him, and that he did in fact act in reliance on it. This principle excludes from the region of actionable fraud such "flourishing descriptions" as are common among auctioneers and house-agents, and also misrepresentations of a trifling and unimportant character. But the wrong-doer cannot escape the consequences of his own mis-statement by contending that the person who relied upon it ought not to have done so, and ought to have made further inquiries; by contending, in short, that by the exercise of more vigilance his own dishonesty might have been detected. Lastly, the complainant must prove that, as the direct consequence of the misrepresentation, he has suffered actual damage capable of pecuniary measurement.

As soon as the case of *Derry* v. *Peek* had established, as the general rule of law, that a merely negligent misstatement is not actionable, a statutory exception was made to the rule in the case of directors and promoters of companies who publish prospectuses and similar documents. By the Directors' Liability Act, 1890, such persons are liable for damage caused by untrue statements in such documents, unless they can prove that they had reasonable grounds for believing the statements to be true. It is also to be observed that, though damages cannot be recovered in an action for a misrepresentation made with an honest belief in its truth, still any person induced to enter into a contract by a misrepresentation, whether fraudulent or innocent, is entitled to avoid the contract and to obtain a declaration that it is not binding upon him. This is in accordance with the rule of equity, which since the Judicature Act prevails in all the courts. Whether the representation is fraudulent or innocent, the contract is not void, but voidable. The party misled must exercise his option to avoid the contract without delay, and before it has become impossible to restore the other party to the position in which he stood before the contract was made. If he is too late, he can only rely on his claim for damages, and in order to assert this claim it is necessary to prove that the misrepresentation was fraudulent. Fraud, in its wider sense of dishonest dealing, though not a distinct cause of action, is often material as preventing the acquisition of a right, for which good faith is a necessary condition. Also a combination or conspiracy by two or more persons to defraud gives rise to liabilities not at present very clearly or completely defined. (A. LL. D.)

Frederick Charles (1828–1885), Prussian prince, known as the "Red Prince" from the colour of his favourite Hussar uniform, was the eldest son of Prince Charles, brother of the Emperor William I. of Germany, his mother being a sister of the Empress Augusta. He was born in Berlin, 20th March 1828, and, like most princes of the House of Hohenzollern, was educated for the army. Chief amongst his various military tutors and governors was Major von Roon, afterwards Prussian minister for war, who attended him during the two years which he spent at the University of Bonn, 1846–48. In the latter year the prince entered the Foot Guards, and first saw active service under Marshal von Wrangel in the Schleswig–Holstein war. Shortly afterwards he attended his uncle, Prince William of Prussia, afterwards Emperor, in the campaign against the Free Companies of Baden. He was now a major of Hussars, having changed his branch of the service. He led a brilliant charge of about forty Hussars against the Polish legion at the battle of Wiesenthal, and received two wounds. Temporarily incapacitated for military duty, he devoted himself to the study of military works. The prince was appointed colonel of the First Dragoon Guards in 1852, and two years later was raised to the command of the First Guards Cavalry Brigade. In 1855 Frederick Charles visited Paris, where he closely studied the French military system, carefully noting its defects. He traced minutely the course of the Franco-Austrian war of 1859, and embodied his conclusions and strictures upon French tactics in a privately-published pamphlet. This pamphlet obtained a wider circulation than was intended, and gave rise to much indignation in France. Other military essays by the prince testified to his ability as a military critic. The prince became a general of cavalry, with the command of the Third Army Corps in 1861, and he commanded the Prussian corps forming the right wing of the allied army in 1864. It was he who had the credit of forcing the Danes to evacuate Schleswig, and also of leading the Prussians in the storming of the lines of Düppel. He acquired in this campaign the popular sobriquet of "Prinz Vorwärts." In the Austrian war of 1866 he commanded the First Army, numbering about 140,000 men. Entering Bohemia, he defeated the Austro-Saxon troops at Liebenau, Podol, and Gitschin. But his greatest generalship was displayed at the crowning battle of Königgrätz. The Austrians were commanded by the veteran Marshal Benedek, and the Prussians by their king, William I. Prince Frederick Charles halted at Kammeniz on 2nd July, and his troops commenced their march at midnight, the first shot being fired about 7·30 A.M. on 3rd July. It was alleged afterwards that the prince opened the engagement two hours sooner than commanded, in order that he might, if possible, win this decisive victory before the Crown Prince's army arrived. The attack became general at Königgrätz about ten o'clock, and a desperate struggle ensued, the result appearing uncertain until the Crown Prince and his force arrived at half-past twelve. When Chlum, which had been taken and lost seven times by the Prussians, was taken for the eighth time, the fate of the day was decided; and the retreat of the Austrians soon became a hasty and disastrous flight. The Austrians lost about 43,000, including 10,000 wounded and 13,000 unwounded prisoners; the Prussian loss was 10,000 men. When the war with France broke out in 1870, Prince Frederick Charles was appointed to the command of the Second Army. Again and again in the course of the campaign he gave evidence of his superior military abilities. He led his troops to victory in the great battles of Vionville and Gravelotte–St Privat, and compelled Marshal Bazaine to take refuge within the entrenchments of Metz. The prince then began a systematic blockade of the fortress, and after a siege of seventy days only, Bazaine surrendered with about 170,000 men. The prince was rewarded for this great feat by his elevation to the rank of field-marshal. From Metz the prince now hastened westwards to check the armies of D'Aurelle de Paladines and Chanzy in their attempts to raise the siege of Paris from the south. The series of battles which ensued, beginning with Beaune-la-Rolande, lasted almost uninterruptedly from the middle of November till the middle of January, when the French Army of the West was rendered impotent at the engagement of Le Mans. This was the prince's last action, for Paris capitulated immediately afterwards. After the Franco-German war Prince Frederick Charles was destined to see no further active service, the remainder of his life being spent in studying war, witnessing reviews, and farming his estates at Glienicke, near Potsdam. He made many efforts, some of which were successful, to reform and render more elastic the military system of the army. In appearance the prince was a model cavalry officer. He was strong and muscular in body, and active in his habits and pursuits. His private character was harsh and unamiable. In March 1879 his third daughter, Louise Margaret, was married to the Duke of Connaught. The prince died suddenly from apoplexy at his château of Glienicke on 15th June 1885.

(G. B. S.)

Frederick, capital of Frederick County, Maryland, U.S.A., in 39° 25′ N. and 77° 25′ W., in the broad and fertile valley of the Monocacy river, lying between the Catoctin Range and the Blue Ridge, at an altitude of 323 feet. It is on branches of the Baltimore and Ohio and the Pennsylvania railways. Population (1880), 8659; (1890), 8193; (1900), 9296, of whom 241 were foreign-born, and 1535 were negroes.

Frederick III. (1831–1888), King of Prussia and German Emperor, was born at Potsdam, 18th October 1831, being the eldest son of Prince William of Prussia, afterwards first German Emperor, and the Princess Augusta. He was carefully educated, and in 1849–50 studied at the University of Bonn. The next years were spent in military duties and in travels, in which he was accompanied by Moltke. In 1851 he visited England on the occasion of the Great Exhibition, and in 1855 became engaged to Victoria, Princess Royal of Great Britain, to whom he was married in London on 25th January 1858. On the death of his uncle in 1861 and the accession of his father, Prince Frederick William, as he was then always called, became Crown Prince of Prussia. His education, the influence of his mother, and perhaps still more that of his wife's father, the Prince Consort, had made him a strong Liberal, and he was much distressed at the course of events in Prussia after the appointment of Bismarck as Minister. He was urged by the Liberals to put himself into open opposition to the Government; this he refused to do, but he remonstrated privately with the King. In June 1863, however, he publicly dissociated himself from the Press Ordinances which had just been published. He ceased to attend meetings of the Council of State, and was much away from Berlin. The opposition of the Crown Prince to the Ministers was increased during the following year, for he was a warm friend of the Prince of Augustenburg, whose claims to Schleswig-Holstein Bismarck refused to support. During the war with Denmark he had his first military experience, being attached to the staff of Marshal von Wrangel; he performed valuable service in arranging the difficulties caused by the disputes between the Field-Marshal and the other officers, and was eventually given a control over him. After the war he continued to support the Prince of Augustenburg, and was strongly opposed to the war with Austria. During the campaign of 1866 he received the command of an army consisting of four army corps; he was assisted by General von Blumenthal, as Chief of the Staff, but took a very active part in directing the difficult operations by which his army fought its way through the mountains from Silesia to Bohemia, fighting four engagements in three days, and showed that he possessed genuine military capacity. In the decisive battle of Königgrätz the arrival of his army on the field of battle, after a march of nearly twenty miles, secured the victory. During the negotiations which ended the war he gave valuable assistance by persuading the King to accept Bismarck's policy as regards peace with Austria. From this time he was very anxious to see the King of Prussia unite the whole of Germany, with the title of Emperor, and was impatient of the caution with which Bismarck proceeded. In 1869 he paid a visit to Italy, and in the same year was present at the opening of the Suez Canal; on his way he visited the Holy Land.

He played a conspicuous part in the year 1870–71, being appointed to command the armies of the Southern States, General Blumenthal again being his Chief of the Staff; his troops won the victory of Wörth, took an important part in the battle of Sedan, and later in the siege of Paris. The popularity he won was of political service in preparing the way for the union of North and South Germany, and he was the foremost advocate of the Imperial idea at the Prussian Court. During the years that followed, little opportunity for political activity was open to him. He and the Crown Princess took a great interest in art and industry, especially in the Royal

Museums; and the excavations conducted at Olympia and Pergamon with such great results were chiefly due to him. The Crown Princess was a keen advocate of the higher education of women, and it was owing to her exertions that the Victoria Lyceum at Berlin (which was named after her) was founded. In 1878, when the Emperor was incapacitated by the shot of an assassin, the Prince acted for some months as Regent. His palace was the centre of all that was best in the literary and learned society of the capital. He publicly expressed his disapproval of the attacks on the Jews in 1878; and the coalition of Liberal parties founded in 1884 was popularly known as the "Crown Prince's party," but he scrupulously refrained from any act that might embarrass his father's Government. For many reasons the accession of the Prince was looked forward to with great hope by a large part of the nation. Unfortunately he was attacked by cancer in the throat; he spent the winter of 1887–88 at San Remo; in January 1888 the operation of tracheotomy had to be performed. On the death of his father, which took place on 9th March, he at once journeyed to Berlin; but his days were numbered, and he came to the throne only to die. In these circumstances his accession could not have the political importance which would otherwise have attached to it, though it was disfigured by a vicious outburst of party passion in which the names of the Emperor and the Empress were constantly misused. While the Liberals hoped the Emperor would use his power for some signal declaration of policy, the adherents of Bismarck did not scruple to make bitter attacks on the Empress. The Emperor's most important act was a severe reprimand addressed to Herr v. Putkamer, the reactionary Minister of the Interior, which caused his resignation; in the distribution of honours he chose many who belonged to classes and parties hitherto excluded from Court favour. A serious difference of opinion with the Chancellor regarding the proposal for a marriage between Prince Alexander of Battenberg and the Princess Victoria of Prussia was arranged by the intervention of Queen Victoria, who visited Berlin to see her dying son-in-law. He expired at Potsdam on 15th June 1888, after a reign of ninety-nine days.

After the Emperor's death Professor Geffcken, a personal friend, published in the *Deutsche Rundschau* extracts from the Diary of the Crown Prince containing passages which illustrated his differences with Bismarck during the war of 1870. The object was to injure Bismarck's reputation, and a very unseemly dispute ensued. Bismarck at first, in a letter addressed to the new Emperor, denied the authenticity of the extracts on the ground that they were unworthy of the Crown Prince. Geffcken was then arrested and imprisoned. He had undoubtedly showed that he was an injudicious friend, for the Diary proved that the Prince, in his enthusiasm for German unity, had allowed himself to consider projects which would have seriously compromised the relations of Prussia and Bavaria. The treatment of the Crown Prince's illness also gave rise to an acrimonious controversy. It arose from the fact that as early as May 1887 the German physicians recognized the presence of cancer in the throat, but Sir Morell Mackenzie, the English specialist who was also consulted, disputed the correctness of this diagnosis, and advised that the operation for removal of the larynx, which they had recommended, should not be undertaken. His advice was followed, and the differences between the medical men were made the occasion for a considerable display of national and political animosity.

The Empress VICTORIA, who, after the death of her husband, was known as the Empress Frederick, died on the 5th of August 1901 at the Castle of Friedrichskron, Cronberg, near Homburg v. d. H., where she spent her last years. Of the Emperor's children two, Prince Sigismund (1864–66) and Prince Waldemar (1869–79), died in childhood. He left two sons, William (*q.v.*), who succeeded him, and Henry, who adopted a naval career. Of his daughters, the Princess Charlotte was married to the Hereditary Prince of Meiningen; the Princess Victoria to Prince Adolf of Schaumburg-Lippe; the Princess Sophie to the Duke of Sparta, Crown Prince of Greece; and Princess Margaretha to Prince Friedrich Karl of Hesse.

AUTHORITIES.—M. VON POSCHINGER. *Kaiser Friedrich.* 3 vols. Berlin, 1898–1900. Adapted into English by SIDNEY WHITMAN. *Life of the Emperor Frederick.* (Harper), 1901. See also BISMARCK. *Reflections and Reminiscences.*—RENNELL RODD. *Frederick, Crown Prince and Emperor*, 1888.—GUSTAV FREYTAG. *Der Kronprinz und die deutsche Kaiserkrone*, 1889; English translation, 1890.—For his illness, the official publications, published both in English and German: *Die Krankheit Kaiser Friedrichs III.*, Berlin, 1888, and MORELL MACKENZIE, *The Fatal Illness of Frederick the Noble*, 1888.—Most of the copies of the *Deutsche Rundschau* containing the extracts from the Crown Prince's Diary were confiscated, but there is an English edition, published in 1889. (J. W. HE.)

Fredericksburg, a city of Virginia, U.S.A., in 38° 18′ N. and 77° 27′ W., on the Rappahannock river, at the head of navigation and tide. Though situated within the limits of Spottsylvania County, and containing the court house, it is independent of the county government. It is regularly built, on a succession of benches rising from the river. It is divided into two wards, Upper and Lower, and is on the Potomac, Fredericksburg, and Piedmont, and the Richmond, Fredericksburg, and Potomac railways. It was the scene of one of the severest battles of the Civil War. General Burnside, in command of the Union forces, attempted to storm the Confederate defences on the banks on which the city is built, but after repeated charges, in which his troops were decimated, he was forced to withdraw. Fredericksburg College had, in 1899, 12 instructors and 114 students. Population (1880), 5010; (1890), 4528; (1900), 5068.

Fredericton, the capital of New Brunswick, on the St John river, 84 miles from its mouth. Among recent improvements are the new parliament buildings, the post-office, the normal school, a neat and well-kept park, and the two bridges, passenger and railway, which unite the city with the towns of St Marys and Gibson on the east side of the river. In 1899–1900 exports were valued at $151,334, imports at $419,441. Population (1891), 6502; (1900), 7000.

Frederikshavn, a seaport of Denmark, county Hjörring, on the Cattegat, 25 miles south of the Skaw, and 50 miles by rail north-north-east from Aalborg. Originally it was a fishing station, known as FLADSTRAND, but it is now a harbour of refuge (1882–91) for the Cattegat. It is also a fishing centre, especially for plaice, and sends fishing boats to Iceland and to the oyster grounds of the North Sea. In 1899 the port was entered by 1311 vessels of 167,704 tons, and cleared by 1215 of 166,868 tons, the chief exports being fish, butter, cattle, and bacon; and the chief imports, coal and butter (this last in transport). Population (1880), 2891; (1900), 6338.

Fredrikshald, a seaport town of Norway, county Smaalenene, close to the Swedish frontier, 85 miles south-south-east of Christiania by rail. It is one of the principal ports of the kingdom for the export of timber. The total trade in 1897 was valued at £627,300 (£344,000 in 1887). Marble of very fine quality and grain is extensively quarried and exported for architectural ornamentation and for furniture-making. Wood-pulp is also exported. The industries embrace granite quarries, wood-pulp factories, and factories for sugar, tobacco, curtains, travelling-bags, boots, &c. Population (1875), 9792; (1900), 11,936.

Fredrikstad, a rapidly-growing seaport and manufacturing town of Norway, standing at the mouth of the Glommen, 59 miles by rail south by east of Christiania. The new town, on the right bank, is the centre of the timber export trade, this place being the principal port in Norway for the export of pit-props, planed boards, and other varieties of timber. In the closing years of the 19th century there was an extraordinary development in the making of red bricks, owing to the great expansion of Christiania, Gothenburg, and other towns. In 1899 the total output of bricks was 150 millions, as compared with 50 millions in 1896. Granite is hewn to a great extent and exported. Besides the large number of saw and planing mills, there are shipbuilding yards, engine and boiler works, cotton and woollen mills, and factories for acetic acid and naphtha. The total trade of the port was valued at £996,000 in 1897. The harbour, which can be entered by vessels drawing 14 ft., is kept open in winter by an ice-breaker. In 1899 the port owned a mercantile fleet of 176 vessels of 54,150 tons. In the vicinity is the much-frequented seaside resort of Hankö. Population (1875), 9616; (1900), 14,573.

Free Church Federation.—In the *Methodist Times* of 20th February 1890 Dr Guinness Rogers suggested that there should be a Nonconformist Church Congress as well as an Anglican Church Congress. The first was held in Manchester on 7th November 1892. In the following year it was resolved that the basis of representation should be neither personal (as in the Anglican Church Congress) nor denominational, but territorial. England and Wales have since been completely covered with a network of Local Councils, each of which elects its due proportion of representatives to the National gathering. This territorial arrangement eliminated all sectarian distinctions, and also the possibility of committing the different Churches as such to any particular policy. The representatives of the Local Councils attend not as Denominationalists, but as Evangelical Free Churchmen. The name of the organization was changed from Congress to National Council as soon as the Assembly ceased to be a fortuitous concourse of atoms, and consisted of duly appointed representatives from the Local Councils of every part of England. The Local Councils consist of representatives of the Congregational and Baptist Churches, the Methodist Churches, the Presbyterian Church of England, the Free Episcopal Churches, the Society of Friends, and such other Evangelical Churches as the National Council may at any time admit. The constitution states the following as the objects of the National Council: (*a*) To facilitate fraternal intercourse and co-operation among the Evangelical Free Churches; (*b*) to assist in the organization of Local Councils; (*c*) to encourage devotional fellowship and mutual counsel concerning the spiritual life and religious activities of the Churches; (*d*) to advocate the New Testament doctrine of the Church, and to defend the rights of the associated Churches; (*e*) to promote the application of the law of Christ in every relation of human life.

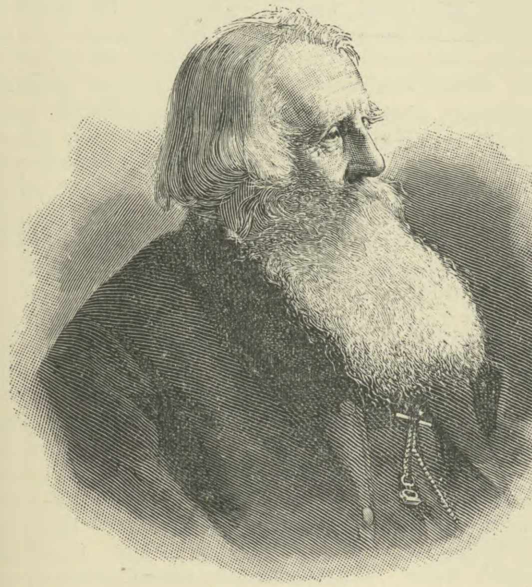
A striking feature of this movement is the adoption of the parochial system for the purpose of local work. Each of the associated Churches is requested to look after a parish, not of course with any attempt to exclude other Churches, but as having a special responsibility for those in that area who are not already connected with some existing Church. In the great cities, especially in London and in the counties, Local Councils are formed into Federations, which are intermediate between them and the National Council. The Local Councils do what is possible to prevent overlapping and excessive competition between the Churches. Large circulating libraries are already established for the benefit of ministers in villages and country districts. A considerable literature has sprung into existence, consisting of numerous periodicals, hymn-books for special occasions, and works of different kinds explaining the history and ideals of the Evangelical Free Churches. These can be obtained from the organizing secretary at the Memorial Hall, Farringdon Street, London, E.C. The primary object of the whole organization is to reach the masses of the people who are not yet attached to any Church. The Churches represented in the National Council have 9005 separated or ordained ministers, 50,729 local preachers, 388,160 Sunday-school teachers, 3,350,224 Sunday scholars, 1,911,924 communicants, and sitting accommodation in their sanctuaries for 7,993,708.

The most remarkable manifestation of this unprecedented reunion is the fact that a committee of the associated Churches has already prepared and published a Catechism expressing the positive and fundamental agreement of all the Evangelical Free Churches on the essential doctrines of Christianity. An account of the origin of this Catechism, together with the names of the theologians of all Churches who took part in its preparation, will be found in the prefatory note to the Catechism. A fuller history of its origin and its striking features was published in the *Contemporary Review* of January 1899. The Catechism represents substantially the creed of not less than 80,000,000 Protestants. It has been widely circulated throughout Great Britain, in British colonies, and the United States of America. It has also been translated into Welsh, French, and Italian. This movement has spread to all parts of Australia, New Zealand, South Africa, Jamaica, the United States of America, and India. It is perhaps necessary to add that it differs essentially from the Evangelical Alliance, inasmuch as its unit is not an individual, private Christian, but a definitely organized and visible Church. The essential doctrine of the movement is a particular doctrine of churchmanship which, as explained in the Catechism, regards the Lord Jesus Christ as the sole and Divine Head of every branch of the Holy Catholic Church throughout the world. For this reason those who do not accept the deity of Christ are necessarily excluded from the National Council and its local constituent councils. (H. P. H.)

Freeland, a borough of Luzerne county, Pennsylvania, U.S.A., in the anthracite coal region, on the Lehigh Valley Railway. It is a supply- and shipping-point for the coal mines in the neighbourhood. Population (1890), 1730; (1900), 5254, of whom 1339 were foreign-born.

Freeman, Edward Augustus (1823–1892), English historian, was born at Harborne, Staffordshire, on 2nd August 1823. He lost both his parents in infancy, was brought up by a grandmother, and was educated at private schools and by a private tutor. He was a studious and precocious boy, more interested in religious matters, history, and foreign politics than in boyish things. He obtained a scholarship at Trinity College, Oxford, and a second class in the degree examination, and was elected fellow of his college (1845). While at Oxford he was much influenced by the High Church movement, and thought seriously of taking orders, but abandoned the idea. He married the daughter of his former tutor, the Rev. R. Gutch, in 1847, and entered on a life of study. Ecclesiastical architecture attracted him strongly. He visited many churches and began a practice, which he pursued throughout his life, of making drawings of buildings on the spot and afterwards tracing them over in ink. His first book, save for his share in a volume of English verse, was *A History of Architecture* (1849). Though he had not then seen any buildings outside England, it contains a good sketch of the development of the art. It is full of youthful enthusiasm and is written in florid language. After some changes of residence he bought a house called Somerleaze, near Wells, Somerset, and settled there in 1860. His life was one of strenuous literary work. He wrote many books, and countless articles for reviews, newspapers, and other publications, and was a constant contributor to the *Saturday Review* until 1878, when he ceased to write for it for political reasons. His *Saturday*

Review articles corrected many errors and raised the level of historical knowledge among the educated classes, but as a reviewer he was apt to forget that a book may have blemishes and yet be praiseworthy. For some years he was an active county magistrate. He was deeply interested in politics, was a follower of Mr Gladstone, and approved the Home Rule Bill of 1886, but objected to the later proposal to retain the Irish members at Westminster. To be returned to Parliament was one of his few ambitions, and in 1868 he unsuccessfully contested Mid-Somerset. Foreign rather than domestic politics had the first place with him. Historical and religious sentiment combined with his detestation of all that was tyrannical to inspire him with hatred of the Turk and sympathy with the smaller and subject nationalities of Eastern Europe. He took a prominent part in the agitation which followed "the Bulgarian atrocities"; his speeches were intemperate, and he was accused of uttering the words "Perish India!" at a public meeting in 1876. This, however, was a misrepresentation of his



EDWARD AUGUSTUS FREEMAN.
(*From a photo. by Elliott and Fry.*)

words. He was made a knight commander of the order of the Saviour by the king of Greece, and also received an order from the prince of Montenegro.

Freeman advanced the study of history in England in two special directions, by insistence on the unity of history, and by teaching the importance and right use of original authorities. History is not, he urges, to be divided "by a middle wall of partition" into ancient and modern, nor broken into fragments as though the history of each nation stood apart. It is more than a collection of narratives; it is a science, "the science of man in his political character." The historical student, then, cannot afford to be indifferent to any part of the record of man's political being; but as his abilities for study are limited, he will, while reckoning all history to be within his range, have his own special range within which he will master every detail (*Rede Lecture*). Freeman's range included Greek, Roman, and the earlier part of English history, together with some portions of foreign mediæval history, and he had a scholarly though general knowledge of the rest of the history of the European world. He regarded the abiding life of Rome as "the central truth of European history," the bond of its unity, and he undertook his *History of Sicily* (1891–94) partly because it illustrated this unity. Further, he urges that all historical study is valueless which does not take in a knowledge of original authorities, and he teaches both by example and precept what authorities should be thus described, and how they are to be weighed and used. He did not use manuscript authorities, simply because he had no need to do so. All the authorities which he needed were already in print, and his books would not have been better if he had disinterred a few more facts from unprinted sources.

His reputation as a historian will chiefly rest on his *History of the Norman Conquest* (1867–76), his longest completed book. In common with his works generally, it is distinguished by exhaustiveness of treatment and research, critical ability, a remarkable degree of accuracy, and a certain insight into the past which he gained from his practical experience of men and institutions. He is almost exclusively a political historian. His saying that "history is past politics and politics are present history" is significant of this limitation of his work, which left on one side subjects of the deepest interest in a nation's life. In dealing with constitutional matters he sometimes attaches too much weight to words and formal aspects. This gives certain of his arguments an air of pedantry, and seems to lead him to find evidences of continuity in institutions which in reality and spirit were different from what they once had been. As a rule his estimates of character are remarkably able. It is true that he is sometimes swayed by prejudice, but this is the common lot of great historians; they cannot altogether avoid sharing in the feelings of the past, for they live in it, and Freeman did so to an extraordinary degree. Yet if he judges too favourably the leaders of the national party in England on the eve of the Norman Conquest, that is a small matter to set against the insight which he exhibits in writing of Aratus, Sulla, Nicias, William the Conqueror, Thomas of Canterbury, Frederick the Second, and many more. In width of view, thoroughness of investigation, and honesty of purpose he is unsurpassed by any historian. He never conceals or wilfully misrepresents anything, and he reckoned no labour too great which might help him to draw a truthful picture of the past. When a place had any important connexion with his work he invariably visited it. He travelled much, always to gain knowledge, and generally to complete his historical equipment. His collected articles and essays on places of historical interest are perhaps the most pleasing of his writings, but they deal exclusively with historical associations and architectural features. The quantity of work which he turned out is enormous, for the fifteen large volumes which contain his *Norman Conquest*, his unfinished *History of Sicily*, his *William Rufus* (1882), and his *Essays* (1872–79), and the crowd of his smaller books, are matched in amount by his uncollected contributions to periodicals. In respect of matter his historical work is uniformly excellent. In respect of form and style the case is different. Though his sentences themselves are not wordy, he is extremely diffuse in treatment, habitually repeating an idea in successive sentences of much the same import. While this habit was doubtless aggravated by the amount of his journalistic work, it seems originally to have sprung from what may be called a professorial spirit, which occasionally appears in the tone of his remarks. He was anxious to make sure that his readers would understand his exact meaning, and to guard them against all possible misconceptions. His lengthy explanations are the more grievous because he insists on the same points in several of his books. His prolixity was increased by his unwillingness, when writing without prescribed limits, to leave out any detail, however unimportant. His passion for details not only swelled his volumes to a portentous size, but was fatal to artistic construction. The length of his books has hindered their usefulness. They were written for the public at large, but few save professed students, who can admire and value his exhaustiveness, will read the many hundreds of pages which he devotes to a short period of history. In some of his smaller books, however, he shows great powers of condensation and arrangement, and writes tersely enough. His style is correct, lucid, and virile, but generally nothing more, and his endeavour to use as far as possible only words of Teutonic origin limited his vocabulary and makes his sentences rather monotonous. While Froude often strayed away from his authorities, Freeman kept his authorities always before his eyes, and his narrative is sometimes little more than a translation of their words. Accordingly, while it has nothing of Froude's carelessness and inaccuracy, it has nothing of his charm of style. Yet now and again he rises to the level of some heroic event, and parts of his chapter on the "Campaign of Hastings" and of his record of the wars of Syracuse and Athens, his reflexions on the visit of Basil the Second to the church of the Virgin on the Acropolis, and some other passages in his books, are fine pieces of eloquent writing.

The high quality of Freeman's work was acknowledged by all competent judges. He was made D.C.L. of Oxford and LL.D. of Cambridge *honoris causâ*, and when he visited the United States on a lecturing tour was warmly received at various places of learning. He served on the royal commission on ecclesiastical courts appointed in 1881. In 1884 he was appointed regius professor of modern history at Oxford. His lectures were thinly attended, for he did not care to adapt them to the requirements of the university examinations, and he was not perhaps well fitted to teach young men. But he exercised a wholesome influence over the more earnest students of history among the resident graduates. From 1886 he was forced by ill-health to spend much of his time abroad, and he died of small-pox at Alicante on 16th March 1892, while on a tour in Spain. Freeman had a strongly marked personality. Though impatient in temper and occasionally rude, he was tender-hearted and generous. His rudeness to strangers was partly caused by shyness and partly by a childlike inability to conceal his feelings. Eminently truthful, he could not understand that some verbal insincerities are necessary to social life. He had a peculiar faculty for friendship and his friends always found him sympathetic and affectionate. In their society he would talk well and showed a keen sense of humour. He considered it his duty to expose careless and ignorant writers and certainly enjoyed doing so; but, merciless as his attacks were, they were not the outcome of personal spite. He worked hard and methodically, often had several pieces of work in hand, and kept a daily record of the time which he devoted to each of them. His tastes were curiously limited. No art interested him except architecture, which he studied throughout his life; and he cared little for literature which was not either historical or political. In later life he ceased to hold the theological opinions of his youth, but remained a devout churchman.

AUTHORITIES.—STEPHENS. *Life and Letters of E. A. Freeman.* London, 1895.—HARRISON. *Tennyson, Ruskin, Mill, and other Literary Estimates.* London, 1899.—BRYCE. "E. A. Freeman," *Eng. Hist. Rev.*, July 1892. (W. HU.)

Freeport, capital of Stephenson county, Illinois, U.S.A., on the Pecatonica river, at an altitude of 760 feet. It has a level site, and its plan is fairly regular. Three railways, the Chicago and North-Western, the Chicago, Milwaukee, and St Paul, and the Illinois Central intersect here. Population (1880), 8516; (1890), 10,189; (1900), 13,258, of whom 2264 were foreign-born.

Free Ports, strictly speaking, are localities where no customs duties are levied, and where no customs supervision exists. In these ports (subject to payment for specific services rendered, wharfage, storage, &c., and to the observance of local police and sanitary regulations) ships load and unload, cargoes are deposited and handled, industries are exercised, manufactures are carried on, goods are bought and sold, without any action on the part of fiscal authorities. Ports are likewise designated "free" where a space or zone exists within which commercial operations are conducted without payment of import or export duty, and without active interference on the part of customs authorities. The French and German designations for these two descriptions of ports are—for the former "La ville franche," "Freihafen"; for the latter "Le port franc," "Freibezirk" or "Freilager." The English phrase free port applies to both.[1] The leading conditions under which free ports in Europe derived their origin were as follows:—(1) When public order became re-established during the Middle Ages, trading centres were gradually formed. Marts for the exchange and purchase of goods arose in different localities. Many Italian settlements, constituting free zones, were established in the Levant. The Hanseatic towns arose in the 12th century. Great fairs became recognized—the Leipzig charter was granted in 1268. These localities were free as regards customs duties, although dues of the nature of octroi charges were often levied. (2) Until the 19th century European states were numerous, and often of small size. Accordingly uniform customs tariffs of wide application did not exist. Uniform rates of duty were fixed in England by the Subsidy Act of 1660. In France, before the Revolution (besides the free ports) Alsace and the Lorraine Bishoprics were in trade matters treated as foreign countries. The unification of the German customs tariff began in 1834 with the Steuerverein and the Zollverein. The Spanish fiscal system did not include the Basque provinces until about 1850. The uniform Italian tariff dates from 1861. Thus until very recent times on the Continent free ports were compatible with the fiscal policy and practice of different countries. (3) Along the Mediterranean coast, up to the 19th century, convenient shelter was needed from corsairs. In other Continental countries the prevalent colonial and mercantile policy sought to create trans-oceanic trade. Free ports were advantageous from all these points of view.

In following the history of these harbours in Europe, it is to be observed that in Great Britain free ports have never existed. In 1552 it was contemplated to place Hull and Southampton on this footing but the design was abandoned. Subsequently the bonding and not the free port system was adopted in the United Kingdom.

Austria-Hungary.—Fiume and Trieste were respectively free ports during the periods 1722–1893 and 1719–1893.

Belgium.—The Emperor Joseph II. during his visit to the Austrian Netherlands in June 1781 endeavoured to create a direct trade between that country and India. Ostend was made a free port, and large bonding facilities were afforded at Bruges, Brussels, Ghent, and Louvain. In 1796, however, the revolutionary government abolished the Ostend privileges.

Denmark.—In November 1894 an area of about 150 acres at Copenhagen was opened as a free port, and great facilities are afforded for shipping and commercial operations in order that the Baltic trade may centre there.

France.—Marseilles was a free port in the Middle Ages, and so was Dunkirk when it formed part of Flanders. In 1669 these privileges were confirmed, and extended to Bayonne. In 1784 there was a fresh confirmation, and Lorient and St Jean de Luz were included in the *ordonnance.* The National Assembly in 1790 maintained this policy, and created free ports in the French West Indies. In 1795, however, all such privileges were abolished, but large bonding facilities were allowed at Marseilles to favour the Levant trade.

[1] In China at the present time (1902) certain ports are designated "free and open." This phrase means that the ports in question are (1) open to foreign trade, and (2) that vessels engaged in over-sea voyages may freely resort there. Exemption from payment of customs duties is not implied, which is a matter distinct from the permission granted under treaty engagements to foreign vessels to carry cargoes to and from the "treaty ports."

The government of Louis XVIII. in 1814 restored, and in 1817 again revoked, the free port privileges of Marseilles. There are now no free ports in France or in French possessions; the bonding system is in force.

Germany.—Bremen, Hamburg, and Lübeck were reconstituted free towns and ports under the treaties of 1814–15. Certain minor ports, and several landing stages on the Rhine and the Neckar, were also designated free. As the Zollverein policy became accepted throughout Germany, previous privileges were gradually lessened, and since 1888 only Hamburg remains a free port. There an area of about 2200 acres is exempt from customs duties and control, and is largely used for shipping and commercial purposes. Brake, Bremen, Bremerhaven, Cuxhaven, Geestemünde, and Lübeck are now "Freibezirke," and in 1899 free areas were opened under similar conditions at Neufahrwasser (the entrance to Danzig) and at Stettin. Heligoland is outside the Zollverein—practically a foreign country.

In *Italy* free ports were numerous and important, and possessed privileges which varied at different dates. They were—Ancona, during the period 1696–1868; Brindisi, 1845–62; Leghorn (in the 17th and 18th centuries a very important Mediterranean harbour), 1675–1867; Messina, 1695–1879; Senigallia, 1821–68, during the month of the local fair. Venice possessed warehouses, equivalent to bonded stores, for German and Turkish trade during the Republic, and was a free port 1851–73. Genoa was a free port in the time of the Republic and under the French Empire, and was continued as such by the treaties of 1814–15. The free port was, however, changed into a "deposito franco" by a law passed in 1865 and only storing privileges now remain.

Rumania.—Braila, Galatz, and Kustenji were free ports (for a period of about forty years) up to 1883, when bonded warehouses were established by the Rumanian Government.

Russia.—Archangel was a free port, at least for English goods, from 1553 to 1648. During this period English products were admitted into Russia *viâ* Archangel without any customs payment for internal consumption, and also in transit to Persia. The Tsar Alexis revoked this grant on the execution of Charles I. Free ports were opened in 1895 at Kola, in Russian Lapland, and in 1899 at Dalny, adjoining Port Arthur.

The number of free ports outside Europe has also lessened. The administrative policy of European countries has been gradually adopted in other parts of the world, and customs duties have become almost universal, conjoined with bonding and transhipment facilities. In British colonies and possessions, under an Act of Parliament passed in 1766, and repealed in 1867, two ports in Dominica and four in Jamaica were free. Malacca, Penang, and Singapore had been free ports since 1824, and Hong Kong since 1842. Zanzibar was a free port during 1892–99. Aden, Gibraltar, St Helena, and St Thomas (West Indies) are sometimes designated free ports. A few duties are, however, levied, which are really octroi rather than customs charges. These places are mainly stations for coaling and awaiting orders.

Some harbours in the Netherlands East Indies were free ports between 1829–99; but these privileges were withdrawn by laws passed in 1898–99, in order to establish uniformity of customs administration. Harbours where custom houses are not maintained will be practically closed to foreign trade, though the governor-general may in special circumstances vary the application of the new regulations.

Macao has been a free port since 1845. Portugal has no other harbour of this character.

The American Republics have adopted the bonding system. In 1896 a free wharf was opened at New Orleans in imitation of the recent European plan. Livingstone (Guatemala) was a free port during the period 1882–88.

The privileges enjoyed under the old free port system benefited the towns and districts where they existed; and their abolition has been, locally, injurious. These places were, however, "foreign" to their own country, and their inland intercourse was restricted by the duties levied on their products, and by the precautions adopted to prevent evasion of these charges. With fiscal usages involving preferential and deferential treatment of goods and places, the drawbacks thus arising did not attract serious attention. Under the limited means of communication within and beyond the country, in former times, these conveniences were not much felt. But when finance departments became more completely organized, the free port system fell out of favour with fiscal authorities: it afforded opportunities for smuggling, and impeded uniformity of action and practice. It became, in fact, out of harmony with the administrative and financial policy of later times. Bonding and entrepôt facilities, on a scale commensurate with local needs, now satisfy trade requirements. In countries where high customs duties are levied, and where fiscal regulations are minute and rigid, if an extension of foreign trade is desired, and the competition which it involves is a national aim, special facilities must be granted for this purpose. In these circumstances a free zone sufficiently large to admit of commercial operations and transhipments on a scale which will fulfil these conditions (watched but not interfered with by the customs) becomes indispensable. The German Government have, as we have seen, maintained a free zone of this nature at Hamburg. And when the free port at Copenhagen was opened, counter measures were adopted at Danzig and Stettin. An agitation has arisen in France to provide at certain ports free zones similar to those at Copenhagen and Hamburg, and to open free ports in French possessions. Resolutions to this effect were brought before the Chamber of Deputies in March 1899, and were referred to the Commission de Commerce et de l'Industrie: the ultimate action of the Legislature and Government is doubtful. Colonial free ports, such as Hong Kong and Singapore, do not interfere with the uniformity of the home customs and excise policy. These two harbours in particular have become great shipping resorts and distributing centres. The policy which led to their establishment as free ports has certainly promoted British commercial interests. (C. M. K*.)

Freetown. See SIERRA LEONE.

Freiberg, a town of Germany, 2 miles west of the Freiberger Mulde, 19 miles by rail south-west of the town and in the circle of Dresden, kingdom of Saxony. There are 5 Protestant churches and 1 Catholic church. The library of the Academy of Mines has now upwards of 36,000 volumes, besides MSS. and maps; and, in addition to a gymnasium and a *real* school, there are a commercial, a mining, a tanning, and an agricultural school. Population (1890), 28,955; (1900), 30,176.

Freiburg IN THE BREISGAU, a town and archiepiscopal see of Germany, grand-duchy of Baden, at the west foot of the Black Forest, 38 miles by rail north-north-east from Basel. A characteristic feature of the town is its numerous fountains. Another conspicuous ornament is the monument (1876) which commemorates the 14th (German) Army Corps and General von Werder for the part they took in the war of 1870–71. In 1900 the university was attended by 1766 students, and had 119 professors. The town possesses further the church of St Martin's (13th century, restored in 1880–81), a synagogue (1871), a museum, the corn market (1876), a theological seminary, a technical, an agricultural, and a commercial school. Population (1885), 42,596; (1900), 61,513.

Freiburg, or FRIBOURG, one of the Swiss cantons, with an area of 644 square miles, of which 78 square miles may be regarded as "unproductive." Of the rest, 113 square miles are covered by forests, and rather over $\frac{3}{4}$ square mile by vineyards. There are 281 communes in the canton, distributed over seven districts. The district of Sarine in 1900 numbered 33,052 inhabitants, that of the Singine or Sense had 18,800, that of the Gruyère had 22,936, that of the Lake had 15,440, that of the Glâne had 14,298, that of the Broye (capital, Estavayer or Stäffis) had 14,780, and that of the Veveyse had 8413. Besides the railway westwards from Freiburg to Estavayer past Payerne, there is another running northwards from Freiburg to Morat (Murten), while steamers ply on the Lake of Morat. One of the most interesting and most curious points relating to the canton is that the linguistic frontier between French and German not merely passes through it from north to south, but actually passes through its capital, Freiburg. In 1888 the population of the canton was 119,155, of whom 100,067 were Roman Catholics, 18,925 were Protestants, and 125 Jews. In 1900 the total population was 127,719, of whom 87,541 were French-speaking folk, while 38,759 spoke German. The cantonal constitution of 1857 still prevails, having been modified in only a very few minor respects since that date. It is remarkable as containing none of the modern devices (referendum, initiative, proportional representation), save the right of "initiative" of 6000 citizens to demand a revision of the cantonal constitution. In 1897 the state revenue of the canton was 3,544,222 francs (a rise of 12½ per cent. since 1885), and the state expenditure 3,475,083 francs (also a rise of 12½ per cent. since 1885), but in 1898 there was a deficit of 5910 francs. In 1897 the public debt was 38,803,500 francs, the largest cantonal debt in Switzerland, save in the case of Bern.

See Daguet. *Histoire de la Ville et Seigneurie de Fribourg* (to 1481), 1889.—Dellion. *Dictionnaire historique-statistique des paroisses Catholiques du Canton de F.*, 6 vols. Fribourg, 1884–88. —Heyck. *Geschichte d. Herzoge von Zähringen.* Freiburg i/B. 1891.—Kuenlin. *Der Kant. Freiburg.* St Gallen and Bern, 1834.—Zimmerli. *Die Deutsch-Französische Sprachgrenze in d. Schweiz*, vol. ii. 1895. (W. A. B. C.)

Freiburg, or Fribourg, capital of the above canton, on the railway between Bern (20 miles distant) and Lausanne (41 miles distant). Since 1663 the bishop of Lausanne has resided in Freiburg. The cantonal museum contains many antiquities, and also the paintings and statuary left to the town in 1879 by "Marcello," the artistic *nom de guerre* of the Duchess Adela Colonna, a member of the Fribourg family of d'Affry. In 1889 a Romanist University was founded in Freiburg; during the winter of 1899–1900 it was attended by 373 students. The span of M. Chaley's bridge is 808 feet, and two more wire cables (with 2238 strands) were added in 1880–81. It is 167 feet in height, but the Gotteron bridge is 246 feet high. The Grandfey viaduct is 249 feet high. In 1900 the population was 15,773.

Freienwalde, a town of Prussia, on the Oder, 28 miles north-east of Berlin; capital of the circle of Ober-Barnim, government district of Potsdam, province of Brandenburg; on the Frankfurt–Angermünde railway. Medicinal springs in the neighbourhood make it a favourite summer watering-place for the people of Berlin. A new tower commands a fine view of the Oderbruch. There are water-glass and brick works. Population (1890), 7259; (1900), 7989.

Freising, a town of Bavaria, Germany, district Upper Bavaria, on the Isar, 16 miles by rail north-north-east of Munich. The former Benedictine abbey (725–1803) of Weihenstephan is the seat of a royal model farm and brewery, with agricultural, horticultural, and brewing school, and an agricultural museum. Population (1885), 9125; (1900), 10,090.

Fremantle, town and chief port of West Australia, at the mouth of the Swan river, 12 miles south-west from Perth, with which it is connected by rail and cargo steamers. There are a town hall, handsome Episcopal church, and various other public buildings, and a recreation ground. The harbour is not naturally a good one, but improvements have been effected, including the construction of two moles. Fremantle is the western terminus of the Eastern Railway. The mean temperature for the year is 63·2° F.; for January, 73·4°; for July, 55·0°. Population (1881), 3641; (1900) (with suburbs), 20,359.

Frémont, John Charles (1813–1890), American explorer and politician, was born in Savannah, Ga., 21st January 1813. His father, a native of France, died when he was yet a boy, and his mother, a Virginian, removed to Charleston, S.C. He had a taste for mathematics, but was otherwise far from being a hard-working student; he was even expelled from Charleston College. Subsequently, however, he was given a degree, and passed an examination for a professorship in the United States navy; but he declined this appointment to give his attention to civil engineering in connexion with railways. In the spring of 1838 he became assistant to the French explorer Nicollet, whom the War Department employed to make a map of the country extending from the upper waters of the Missouri river to the British boundary line. Frémont showed great talent as an explorer in the five important expeditions he made in the north-west. The object of the first expedition was to obtain accurate knowledge as to the character of the territories of Nebraska and Wyoming, and especially of South Pass, the opening through the mountains on the way to Oregon (1842). The purpose of the second expedition (1843–44) was to explore the possible lines of communication between Missouri, Nebraska, Wyoming, Utah, Idaho, and Oregon, and find a way by land from the lower Columbia river to the Bay of San Francisco. The third expedition, begun in 1845, was designed to explore the great basin and the coast regions of California and Oregon, but it was changed by events connected with the Mexican war into a military and political conquest. From Oregon Frémont went to the Mexican province of California, and collected under his standard the scattered settlers who sided with the Americans in opposition to the Mexicans in the war then in progress. In less than thirty days he won the territory from the Mexicans, and, on 4th July 1846, was chosen its governor. A few months later Mexican authority was withdrawn, and California thenceforth belonged to the United States. In 1848, Frémont undertook at his own expense to discover a passage to California *viâ* the headwaters of the Rio Grande, along a route subsequently followed by the Southern Pacific railway. His fifth and last expedition, begun in 1853, was for the purpose of finding the best route for a national railway from the Mississippi valley to the Pacific Ocean. When, in 1850, California was admitted as a state, Frémont became one of her first two senators. But as he drew the short term he had only three weeks of service in the United States Senate, and he failed to obtain re-election on account of his anti-slavery opinions. In 1856, the newly-formed Republican party was in search of a popular anti-slavery man as candidate for the Presidency, and Frémont, then only forty-three years old, was nominated by both the Republicans and the National Americans. It was still too soon, however, for an anti-slavery policy to win the confidence of a majority of the voters, and he was defeated by Buchanan. Frémont was in Europe when the Civil War began. He purchased for the Federal Government a large supply of arms from France, and was appointed major-general in the regular army, with headquarters in St Louis. His military training had not been sufficient to fit him for so high a command. He declared martial law, arrested secessionists and muzzled the opposition press; but as he lacked system and executive ability his affairs soon became badly involved and he was subjected to damaging criticism. In August 1861, he announced his intention to emancipate the slaves of all Missourians in rebellion against the United States; but as this announcement was in advance of public opinion, President Lincoln decided to annul it. In November 1861 Frémont was removed on account of the alleged extravagance and inefficiency of his management of military affairs. In compliance with popular sympathy he was placed in command of the mountain district south of the Ohio river, but his operations against "Stonewall" Jackson were not sufficiently successful to inspire confidence. In June 1862, his corps was incorporated in the Army of Virginia, and he asked to be relieved from service under its commander, General Pope. Thenceforth he held no command. Frémont's picturesque career and his anti-slavery ideas made him a favourite of the Republicans, who were discontented with Lincoln's administration, and, in May 1864, he was nominated as their candidate for the Presidency, but he withdrew, lest his opposition to Lincoln might result in the election of a Democrat. After the war he was interested in the plan for a trans-continental railway between Norfolk, Va., and San Francisco, which proved to be a very unsuccessful financial enterprise. From 1878 to 1881 he was governor of the territory of Arizona. In his last years Congress authorized the President to appoint him major-general and placed him on the retired list. He died in New York on the 13th of July 1890. A volume of his memoirs, covering only the earlier part of his life, was published in 1886.

Fremont, capital of Dodge county, Nebraska, U.S.A., in 41° 26′ N. and 96° 30′ W., on the north bank of the Platte river, at an altitude of 1200 feet. It is on three railways, the Union Pacific (main line), the Fremont, Elkhorn, and Missouri Valley, and the Sioux City and Pacific. It is regularly laid out, has a good water supply and sewerage, and has stock-yards, packing-houses, and some manufactures. Population (1880), 3013; (1890), 6747; (1900), 7241, of whom 1303 were foreign-born.

Fremont, capital of Sandusky county, Ohio, U.S.A., on the Sandusky river, at an altitude of 630 feet. It is on three important railways, the Lake Shore and Michigan Southern, the Lake Erie and Western, and the Wheeling and Lake Erie. Both petroleum and natural gas are obtained in the neighbourhood. Population (1880), 8446; (1890), 7141; (1900), 8439, of whom 1074 were foreign-born, and 137 negroes.

French Congo.—The French colony in Equatorial Africa described by the name of French Congo has a coast-line along the Atlantic extending from 1° N. lat. to 5° S. lat., and stretching inland up to the 10th northern parallel, where it joins on to the French sphere of influence around Lake Chad. As defined by various conventions (see *History*), the limits of this possession are as follows:—Inland from the Muni estuary, which is the northern extremity on the coast, the boundary marches with that of the Spanish settlements, first east to about 11° 30′ E. long., and then north to the frontier of the German colony of Cameroon, in 2° N. lat., with which it runs east to the 16th meridian, and then north as far as the French Congo extends. Inland from the Lueme estuary, which is the southern limit on the coast, the boundary coincides first with that of the disconnected Portuguese territory of Kabinda, and then with that of the Congo Free State, running north-east and east along the Congo, the Ubangi, and the Mbomu. Near the parallel of 5° N. lat., to the south of the Sultanate of Tambura, the boundary turns northwards, and thence skirts the territories of Bahr el Ghazal and Fertit to the 10th parallel.

Physical Features.—The principal variations in the coast-line are Cape St John, the Bay of Corisco, the estuary of the Gaboon, Cape Lopez, the mouths of the Ogowe, the Bay of Mayumba, the roadstead of Loango, and the Pointe Noire. The coast region is low and marshy. Behind there is a ridge which rises from 3000 to 4500 feet, called the Crystal Mountains, then a plateau with an elevation varying from 1500 to 2800 feet, cleft with deep river-valleys, the walls of which are friable, almost vertical, and in some places 760 feet high. The coast rivers flowing into the Atlantic cross four terraces. On the higher portion of the plateau their course is over bare sand; on the second terrace, from 1200 to 2000 feet high, it is over wide grassy tracts; then, for 100 miles, the course passes through virgin forest, and, lastly, crosses the shore region, which is about 10 miles broad. The river-courses of French Equatorial Africa thus, in some respects, resemble those of Scandinavia. With rare exceptions, they are not navigable. On the north, the Rio Campo, 80 miles long, is unimportant. The San Benito or Eyo, visited by Crampel in 1889, probably descends from Cameroon. The Muni, which runs to the south of Cape St John, is under 40 miles in length. The Gaboon is rather a bay than an estuary; it is about 10 miles wide and receives the Como and the Rembo. The Ogowe rises near 2° 40′ S. lat., half-way between the coast and the Congo; first flowing in a north-westerly direction, forming numerous rapids and receiving the Passa, which waters Franceville, and the Nkoni, it then bends westwards, receives on the north the Ivindo, waters Lopé and N'Jolé near its confluence with the Okano, and thence, after being increased by the Ngunie, flows southwards. After issuing from the mountains it becomes wider for several miles, being fed by the lagoons Anengé and Zonengué, and divides into several arms round Cape Lopez. It is navigable from its mouth to N'Jolé, a distance of 235 miles. Its whole length is at least 750 miles. Other rivers are the Nyanga, 120 miles long, and the Kwilu. The latter, 320 miles in length, is formed by the Kiasi and the Luété; it has a very winding course, flowing by turns from north to south, from east to west, from south to north-west, and from north to south-west. It is encumbered with rocks and eddies, and is navigable only over 38 miles, and for five months in the year. 450 miles of the Congo are comprised within the boundary-line. The most important French post on the river is Brazzaville, situated at the lower end of the reach called Stanley Pool. The Ubangi receives from French territory the Ibenga and the Kemo.

Fauna and Flora.—The fauna includes the gorilla, the chimpanzee, the elephant, the hippopotamus, the alligator, and numerous serpents. There are few domestic animals, except fowls. As to the flora, it is remarkable for its splendour and variety. The forests contain bamboo, ebony, sandal-wood, baobab, caoutchouc, the castor plant, earth-nuts, &c.

Climate.—The climate is everywhere very warm, and dangerous for Europeans. On the coast four seasons are distinguished: the dry season (15th May to 15th September), the rainy season (15th September to 15th January), then a second dry season (15th January to 1st March), and a second rainy season (1st March to 1st May). The rainfall at Libreville is about 8 feet.

History of Occupation.—France acquired the estuary of the Gaboon in 1841–44, by agreement with native chiefs, to serve as a re-victualling station for vessels appointed to watch the coast. In 1849 Libreville was founded by a convoy of slaves taken from a slave-ship. In 1862 Cape Lopez was ceded to France, and the colony extended along the coast, nominally to the length of 200 miles. In the meantime the exploration of the interior had been begun. Du Chaillu penetrated (1856–65) to the south of the Ogowe; Walker, an Englishman, explored the Ngunie, an affluent of the Ogowe, in 1866. In 1872–1875 Marche and Compiègne examined the same river as far as the mouth of the Ivindo. In 1875 de Brazza began his travels, ascending in 1876–78 the Ogowe for more than 400 miles, and thence striking across to the Congo, which Stanley had just revealed. In a second journey (1879–82) he founded Brazzaville and explored the Kwilu, at the same time carrying on negotiations with the King of the Batéké. Loango was occupied in 1883. In the same year de Brazza set out at the head of the West African Expedition, and in the course of two years acquired new territories for France. The convention of February 1885 determined the frontier of the Congo Free State (then the International Association); boundary agreements were made with Germany (December 1885) and Portugal (May 1886); the zones of the north and south were delimited; and an arrangement with the Congo Free State in 1887 settled difficulties relating to the Ubangi, France abandoning the preferential rights which she had received in 1884. By creating the posts of Bangi (1890), Wesso, and Abira (1891), France extended her influence along the Ubangi and the Sanga. But at the same time the Belgians passed the parallel of 4° N. lat.—which, after the compromise of 1887, France had regarded as the southern boundary of her possessions—and, occupying the Sultanate of Bangasso, pushed on as far as 9° N. lat. The dispute which thus arose was only settled in 1894 after the Anglo-Congolese Convention of May 12 of that year, against which both the German and the French Governments protested. By a compromise of August 14, the boundary was definitely drawn and, in accordance with this pact, which put the frontier back to about 4° N. lat., France from 1895 to 1897 took possession of the Upper Ubangi, with Bangasso, Rafai, and Semio. Then began the French encroachment on the Bahr el Ghazal; the Marchand Expedition, despatched to the support of M. Liotard, the Lieutenant-Governor of the Upper Ubangi, reached Tambura in July 1897, and Fashoda in July 1898. A dispute with Great Britain arose, and it was decided that the expedition should evacuate Fashoda. The convention of 21st March 1899 finally terminated the dispute. Thus, after the Franco-Spanish Treaty of June 1900, settling the limits of the Spanish territory on the coast, the boundaries of the French Congo on all its frontiers were determined.

The important places are Libreville, with 3000 inhabitants; Bangi, on the Ubangi; Brazzaville, on the Congo, which, with the advent of the *concessionaires* (see below), has made rapid strides forward; Buensa; Franceville, near the Ogowe; Loango, a port much frequented; and N'Jolé, on the Ogowe.

Area and Population.—The area has been estimated at about 550,000 square miles. The population can be even less accurately determined, no kind of census whatever being yet possible. Perhaps 8,000,000 is the nearest approach to the right number. The natives belong either to a negro race (Loanga Batéké, Bubargi) or to a race crossed with red blood (Paheeni). The French Congo is now administered by a governor-general, assisted by a council composed of three official and three civilian members. He bears the title of *Commissaire-Général*, and has under his orders a lieutenant-governor for the Congo Proper, and another for the Upper Ubangi. A Government Commissioner is appointed for the Shari region. The seat of government is at Libreville. There is a tribunal of first instance, a paymaster-general, a vicar-apostolic, and a commandant for the naval station. It was only in 1889 that it became necessary for even the chief officials for the administration of justice to be legal magistrates. The budget for 1901 balanced at £225,000. In the estimated receipts France figured for £83,000, indirect contributions for £55,000, and returns from the concessions for £23,500. Of the estimated expenditure £55,000 was for administration, £66,000 for the occupation of the Shari.

For the exploitation of the colony the system has been adopted of farming out large areas to different companies. The terms of land tenure, &c., are mainly regulated by decrees of March 1899. Concessionaires are bound to pay rent, to provide security, and to contribute to the customs stations. Up to 1st September 1899, 37 concessions had been made, and it was estimated that 35 of these covered an area of nearly 240,000 square miles, the grants varying from 425 square miles to 54,000 square miles.

The natives cultivate manioc, which is their principal food. Rubber and ivory are as yet the only outstanding sources of wealth. In 1898, out of a total value of exports of £227,800, the former stood for £91,000 and the latter for £61,500. Other considerable exports are timber and palm-tree products. Warnings have been heard that the supply of ivory is likely to run out if the present abusive manner of collecting it be persisted in. On the other hand, the cultivation of the coffee and cacao plants is spreading; on 1st January 1899 there were 300,000 of the former and 200,000 of the latter. The cultivation of vanilla is also receiving considerable attention, and the rearing of zebras may yield good results. France obtained only £60,000 of the exports. Great Britain was the best customer, taking two-thirds of the rubber and more ivory than either France or Germany, which has the next largest share in the trade. The imports in 1898 were valued at £193,750, of which France only sent £51,300. Textiles figured in the total for £76,000. No other import approached this figure; the chief were hardware, intoxicants, and arms. In 1899 a committee was revived at Libreville by decree to watch over and advise upon all points connected with the economic development of the colony. The improvement of the country has already begun, and the plantations on the coast, as well as the factories on the Sanga and the Ubangi, are becoming profitable; but satisfactory results will only be attained when transport is facilitated, and the produce of the interior, including ivory, gold, copper, and iron, can be easily conveyed to the coast. It should be observed that no imports are chargeable on foreign merchandise conveyed inland, either in the basins of the Congo and Kwilu, in virtue of the Berlin Act of 1885, or in that of the Shari, in virtue of the Anglo-French Convention of 1899. Though internal communications are not organized, the utilization of the valleys of the Ogowe and the Kwilu has for several years been under consideration, and a survey for a railway between the Gaboon and the Sanga was made in 1899. In the meantime, produce from Brazzaville can be sent by the Belgian railway, which passes round the falls of the Congo and rejoins the river at Matadi, where it is navigable. A telegraph line from Loango to Brazzaville is being constructed. There is telegraphic communication with Europe by a British submarine cable, and steamship communication between Libreville and Marseilles, Bordeaux, Liverpool, and Hamburg. The port of Libreville should be improved and made accessible to the largest vessels.

Authorities.—Barret. *Sénégambie, Région Gabonnaise, &c.* Paris, 1888.—Henrique. *Les Colonies Françaises.* Paris, 1890.—Kruger. *Le Congo.* Paris, 1890.—Dutreuil de Rhyns. *Le Congo.* Paris, 1885.—De Chavanne. *La Mission de Brazza.* Paris, 1886.—Keltie. *The Partition of Africa.* London, 1896.—Lee. *French Colonies.* Foreign Office Report, 1900.—*L'Année Coloniale.* Paris, 1900.

(P. L.)

Frere, Sir Henry Bartle Edward (1815–1884), British administrator, born at Clydach, in Brecknockshire, on 29th March 1815, was the son of Edward Frere, a member of an old east county family, and a nephew of John Hookham Frere, of *Anti-Jacobin* and *Aristophanes* fame. After leaving Haileybury, Bartle Frere was appointed a writer in the Bombay Civil Service in 1834, and went out to India by the then unfamiliar overland route. Having passed his examination in the native languages, he was appointed assistant collector at Poona in 1835. There he did valuable work in checking the extortion of the native officials, gained the confidence both of the people and of his superiors, and was in 1842 chosen as private secretary to Sir George Arthur, governor of Bombay. Two years later he became political resident at the court of the Rajah of Sattara, where he did much to benefit the country by the development of its communications. On the Rajah's death in 1848 he administered the province both before and after its formal annexation in 1849. In 1850 he was appointed chief commissioner of Sind, and took ample advantage of the opportunities afforded him of developing the province. He pensioned off the dispossessed amirs, improved the harbour at Karáchi, where he also established municipal buildings, a museum, and barracks, instituted fairs, multiplied roads, canals, and schools. Returning to India in 1857 after a well-earned rest, Frere was greeted at Karáchi with news of the mutiny. His rule had been so successful that he felt he could answer for the internal peace of his province. He therefore sent his only European regiment to Mooltan, thus securing that strong fortress against the rebels, and sent further detachments to aid Sir John Lawrence in the Punjab. The 178 British soldiers who remained in Sind proved sufficient to extinguish such insignificant outbreaks as occurred. His services were fully recognized by the Indian authorities, and he received the thanks of both houses of Parliament, and was made K.C.B. He became a member of the Viceroy's council in 1859, and was especially serviceable in financial matters. In 1862 he was appointed governor of Bombay, where he effected great improvements, such as the demolition of the old ramparts, and the erection of handsome public offices upon a portion of the space, the inauguration of the university buildings, and the improvement of the harbour. He established the Deccan College at Poona, as well as a college for instructing natives in civil engineering. The prosperity—due to the American civil war—which rendered these developments possible brought in its train a speculative mania, which led eventually to the disastrous failure of the Bombay Bank (1866), an affair in which, from neglecting to exercise such means of control as he possessed, Frere incurred severe and not wholly undeserved censure. In 1867 he returned to England, was made G.C.S.I., and received honorary degrees from Oxford and Cambridge; he was also appointed a member of the Indian Council. In 1872 he was sent by the Foreign Office to Zanzibar to negotiate a treaty with the sultan, Sayyid Burghash, for the suppression of the slave traffic. In 1875 he accompanied the Prince of Wales to Egypt and India. The tour was beyond expectation successful, and to Frere, from Queen Victoria downwards, came acknowledgments of the service he had rendered in piloting the expedition. He was asked by Lord Beaconsfield to choose between being made a baronet or G.C.B. He chose the former, but the Queen bestowed both honours upon him. But the greatest service that Frere undertook on behalf of his country was to be attempted not in Asia, but in Africa. Sir Bartle landed at Cape Town as High Commissioner of South Africa on 31st March 1877. He had been chosen by Lord Carnarvon in the previous October as the statesman most capable of carrying his scheme of confederation into effect, and within two years it was hoped that he would be the first governor of the South African Dominion. He went out in harmony with the aims and enthusiasm of his chief, "hoping to crown by one great constructive effort the work of a bright and noble life."

Discord or a policy of blind drifting seemed to be the alternatives presented to Frere upon his arrival. He chose the former as the less dangerous, and the first year of his sway was marked by a Kaffir war on the one hand and by a rupture with the Cape (Molteno – Merriman) ministry on the other. The Transkei Kaffirs were subjugated early in 1878 by General Thesiger and a small force of regular and colonial troops. The constitutional difficulty was solved by Frere dismissing his obstructive cabinet and entrusting the formation of a ministry to Mr Gordon Sprigg. Frere emerged successfully from a year of crisis, but the advantage was more than counterbalanced by the resignation of Lord Carnarvon early in 1878, at a time when Frere required the steadiest and most unflinching support. He had reached the conclusion that there was a widespread insurgent spirit pervading the natives, which it was necessary to put down, and that it should be suppressed speedily and once for all by the direct action of the imperial power—not merely scotched by setting Boer against Zulu or Kaffir against Fingo. He became aware that this insurgent spirit had its focus and strength in the celibate military organization of Cetywayo and in the prestige which impunity for the outrages he had committed had gained for the Zulu king in the native mind. That organization and that evil prestige must be put an end to, if possible by moral pressure, but otherwise by force. Frere reiterated these views to the Colonial Office, where they found a general acceptance. When, however, in view of a series of outrages upon the Natal border (not so much serious in themselves as indicating a feeling of contempt and defiance), Frere undertook the responsibility of forwarding an ultimatum to the Zulu chief in November 1878, the Home Government abruptly discovered that a native war in South Africa was inopportune, and raised difficulties about reinforcements. Having entrusted into Lord Chelmsford's hands the enforcement of the British demands, Frere's immediate responsibility ceased. On 10th January 1879 the British troops crossed the Tugela, and fourteen days later the disaster of Isandhlwana was reported; and Frere, attacked and censured in the House of Commons, was but feebly defended by the Government. Lord Beaconsfield, it appears, supported Frere; the majority of the cabinet were inclined to recall him. The result was the unsatisfactory compromise by which he was censured and begged to stay on. Frere wrote an elaborate justification of his conduct, which was adversely commented on by the Colonial Secretary (Sir M. Hicks-Beach), who "did not see why Frere should take notice of attacks; and as to the war, all African wars had been unpopular." Frere's rejoinder was that no other sufficient answer had been made to his critics, and that he wished to place one on record. "Few may now agree with my view as to the necessity of the suppression of the Zulu rebellion. Few, I fear, in this generation. But unless my countrymen are much changed, they will some day do me justice. I shall not leave a name to be permanently dishonoured." The Government had some excuse for irritation, but the disaster at Isandhlwana ought to have been visited upon the military authorities and not upon Frere.

The Zulu trouble and the disaffection that was brewing in the Transvaal reacted upon each other in the most disastrous manner. Frere had borne no part in the actual annexation of the Transvaal, which was announced by Sir Theophilus Shepstone a few days after the High Commissioner's arrival at Cape Town. The delay of Shepstone to give the country a constitution gave a pretext to the malcontent Boers, a rapidly increasing minority, while the reverse at Isandhlwana had lowered British prestige. Owing to the Kaffir and Zulu wars Sir Bartle had hitherto been unable to give his undivided attention to the state of things in the Transvaal. Much had been effected since the annexation by Shepstone and his successor, Owen Lanyon: debts paid, credit restored, the Zulu trouble rolled away. At the same time the grievances of the Boers were genuine. An autocratic régime had been set up, while no signs were forthcoming of the free constitution promised by Shepstone. In April 1879 Sir Bartle was at last able to visit the Transvaal, and the conviction was forced upon him that the government had been unsatisfactory in many ways. The country was very unsettled. A large camp, numbering 4000 disaffected Boers, had been formed near Pretoria, and they were terrorizing the country. Frere visited them unarmed and practically alone. Even yet all might have been well, for he won the Boers' respect and liking. On the condition that the Boers dispersed, Frere undertook to represent their complaints to the British Government, and to urge the fulfilment of the promises that had been made to them. They parted with mutual good feeling, and the Boers did eventually disperse—on the very day upon which Frere received the telegram announcing the Government's censure. He returned to Cape Town, and his journey back was in the nature of a triumph. But bad news awaited him at Government House. On 1st June 1879 the Prince Imperial had met his death in Zululand, and a few hours later Frere heard that the High Commissionership, with the care of affairs in the Transvaal and Zululand, had been transferred from him to Sir Garnet Wolseley. When Mr Gladstone's ministry came into office in the spring of 1880, Lord Kimberley had no intention of recalling Frere. In June, however, a section of the Liberal party memorialized Mr Gladstone to remove him, and the Prime Minister weakly complied (1st August 1880). Upon his return Frere replied to the charges relating to his conduct respecting Afghanistan as well as South Africa, previously preferred in Mr Gladstone's Midlothian speeches, and was preparing a fuller vindication when he died at Wimbledon from the effect of a severe chill, 29th May 1884. He was buried in St Paul's, and in 1888 a statue of Frere upon the Thames Embankment was unveiled by the prince of Wales. His *Life and Correspondence*, by John Martineau, was published in 1895. Frere himself edited the works of his uncle, Hookham Frere, and the popular story-book, *Old Deccan Days*, written by his daughter, Mary Frere. He was three times president of the Royal Asiatic Society. (T. SE.)

Frère-Orban, Hubert Joseph Walther (1812–1896), Belgian statesman, was born at Liège on 24th April 1812. His family name was Frère, to which on his marriage he added his wife's name of Orban. After studying law in Paris, he practised as a barrister at Liège, took a prominent part in the Liberal movement, and in June 1847 was returned to the Chamber as member for Liège. In August of the same year he was appointed Minister of Public Works in the Rogier Cabinet, and from 1848 to 1852 was Minister of Finance. He founded the Banque Nationale and the Caisse d'Épargne, abolished the newspaper tax, reduced the postage, and modified the customs duties as a preliminary to a decided free-trade policy. The Liberalism of the Cabinet, in which Frère-Orban exercised an influence hardly inferior to that of Rogier, was, however, distasteful to Napoleon III. Frère-Orban, to facilitate the negotiations for a new commercial treaty, conceded to France a law of copyright, which proved highly unpopular in Belgium, and he resigned office, soon followed by the rest of the Cabinet. His work *La Mainmorte et la charité* (1854–57), published under the pseudonym of Jean van Damme, contributed greatly to restore his party to power in 1857, when he again became Minister of Finance. He now embodied his free-trade principles in commercial treaties with England and France, and abolished the *octroi* duties and the tolls on the national roads. He resigned in 1861 on the gold question, but soon resumed office, and in 1868 succeeded Rogier as Prime Minister. In 1869 he defeated the attempt of France to gain control of the Luxembourg railways, but, despite this service to his country, fell from power at the elections of 1870. He returned to office in 1878 as President of the Council and Foreign Minister. He provoked the bitter opposition of the Clerical party by his law of 1879 establishing secular primary education, and in 1880 went so far as to break off diplomatic relations with the Vatican. He next found himself at variance with the Radicals, whose leader, Janson, moved the introduction of universal suffrage. Frère-Orban, while rejecting the proposal, conceded an extension of the franchise (1883); but the hostility of the Radicals, and the discontent caused by a financial crisis, overthrew the Government at the elections of 1884. Frère-Orban continued to take an active part in politics as leader of the Liberal opposition till 1894, when he failed to secure re-election. He died at Brussels on 2nd January 1896. Besides the work above mentioned, he published *La Question monétaire* (1874); *La Question monétaire en Belgique* in 1889; *Échange de vues entre MM. Frère-Orban et E. de Laveleye* (1890); and *La Révision constitutionnelle en Belgique et ses conséquences* (1894). He was also the author of numerous pamphlets, among which may be mentioned his last work, *La Situation présente* (1895). (E. SY.)

Freshwater, a seaside resort and railway station, in the Isle of Wight parliamentary division of Hampshire, England, 9½ miles west of Newport. The parish contains Farringford House, for some time the home of Lord Tennyson the poet, to whom there is a memorial tablet in All Saints' church. Area of parish, 4836 acres. Population about 3000.

Fresno, capital of Fresno county, California, U.S.A., in the San Joaquin Valley, at an altitude of 290 feet. It is surrounded by a rich farming region, which produces especially grain and fruit. One of the most extensive irrigation systems of the West is in operation in the neighbouring country. The city has a regular plan and an excellent water supply and sewerage. It is on the Southern Pacific and the Atchison, Topeka, and Santa Fé railways. Population (1880), 1112; (1890), 10,818; (1900), 12,470, of whom 3299 were foreign-born, and 1573 were coloured, including 291 negroes.

Freycinet, Charles Louis de Saulces de (1828——), French statesman, was born at Foix on 14th November 1828. He was educated at the Ecole Polytechnique, and entered the Government service as a mining engineer. In 1858 he was appointed traffic manager to the Compagnie de chemins de fer du Midi, a post in which he gave proof of his remarkable talent for organization, and in 1862 returned to the engineering service (in which he attained in 1886 the rank of Inspector-General). He was sent on a number of special scientific missions, among which may be mentioned one to England, on which he wrote a notable *Mémoire sur le travail des femmes et des enfants dans les manufactures de l'Angleterre* (1867). On the establishment of the Third Republic in September 1870, he offered his services to Gambetta, was appointed Prefect of the Department of Tarn-et-Garonne, and in October became chief of the military cabinet. It was mainly his powers of organization that enabled Gambetta to raise army after army to oppose the invading Germans. He showed himself a strategist of no mean order; but the policy of dictating operations to the generals in the field was not attended with happy results. The friction between him and General Aurelle de Paladines resulted in the loss of the advantage temporarily gained at Orleans, and he was responsible for the campaign in the east, which ended in the destruction of Bourbaki's army. In 1871 he published a defence of his administration under the title of *La Guerre en province pendant le siège de Paris.* He entered the Senate in 1876 as a follower of Gambetta, and in December 1877 became Minister of Public Works in the Dufaure Cabinet. He carried a great scheme for the gradual acquisition of the railways by the State and the construction of new lines at a cost of three milliards, and for the development of the canal system at a further cost of one milliard. He retained his post in the Ministry of M. Waddington, whom he succeeded in December 1879 as President of the Council and Minister for Foreign Affairs. He passed an amnesty for the Communists, but in attempting to steer a middle course on the question of the religious Associations, lost the support of Gambetta, and resigned in September 1880. In January 1882 he again became President of the Council and Minister for Foreign Affairs. His refusal to join England in the bombardment of Alexandria was the death-knell of French influence in Egypt. He attempted to compromise by occupying the Isthmus of Suez, but the vote of credit was rejected in the Chamber by 417 votes to 75, and the Ministry resigned. He returned to office in April 1885 as Foreign Minister in the Brisson Cabinet, and retained that post when, in January 1886, he succeeded to the Premiership. He came into power with an ambitious programme of internal reform; but except that he settled the question of the exiled Pretenders, his successes were won chiefly in the sphere of colonial extension. In spite of his unrivalled skill as a parliamentary tactician, he failed to keep his party together, and was defeated on 3rd December 1886. In the following year, after two unsuccessful attempts to construct new Ministries, he stood for the Presidency of the Republic; but the Radicals, to whom his opportunism was distasteful, turned the scale against him by transferring their votes to M. Sadi Carnot. In April 1888 he became Minister of War in the Floquet Cabinet—the first civilian since 1848 to hold that office. His services to France in this capacity were the crowning achievement of his life, and he enjoyed the conspicuous honour of holding his office without a break for five years through as many successive administrations—those of Floquet and Tirard, his own fourth ministry (March 1890–February 1892), and the Loubet and Ribot ministries. To him were due the introduction of the three-years' service and the establishment of a general staff, a supreme council of war, and the army commands. His Premiership was marked by heated debates on the clerical question, and it was a hostile vote on his Bill against the religious Associations that caused the fall of his Cabinet. He failed to clear himself entirely of complicity in the Panama scandals, and in January 1893 resigned the Ministry of War. In November 1898 he once more became Minister of War in the Dupuy Cabinet, but resigned office on 6th May 1899. He has published, besides the works already mentioned, *Traité de mécanique rationelle* (1858); *De l'Analyse infinitésimale* (1860, revised ed. 1881); *Des Pentes économiques en chemin de fer* (1861); *Emploi des eaux d'égout en agriculture* (1869); *Principes de l'assainissement des villes* and *Traité d'assainissement industriel* (1870); *Essai sur la philosophie des sciences* (1896); besides some remarkable "Pensées" contributed to the *Contemporain* under the pseudonym of "Alceste." In 1890 he was elected to the French Academy in succession to Émile Augier.

Freytag, Gustav (1816–1895), German novelist, was born at Kreuzburg, in Silesia, 13th July 1816. He was educated at the universities of Breslau and Berlin, and, settling in the former city, gave lessons in the university as a private tutor, but devoted his principal attention to writing for the stage, without, however, attaining any very prominent position until in after years (1854) he produced his comedy, *Die Journalisten.* In 1847 he migrated to Berlin, and in the following year of revolution founded at Dresden, in conjunction with Julian Schmidt, *Die Grenzboten*, a monthly periodical which immediately took rank as the exponent of sane and strenuous Liberalism in politics, and was equally distinguished by the general soundness of its criticism. Freytag helped to conduct it until 1861, and again from 1867 till 1870, when for a short time he edited the new periodical, *Im Neuen Reich.* His literary fame was made universal by the publication in 1855 of his novel, *Soll und Haben* (*Debit and Credit*), which was translated into almost all the languages of Europe. It is certainly the best German novel of its day, impressive by its sturdy but unexaggerated realism, and in many parts highly humorous. Its main purpose is the recommendation of the German middle class as the soundest element in the country, but it also has a more directly patriotic intention in the contrast which it draws between the homely virtues of the Teuton and the shiftlessness of the Pole and the rapacity of the Jew. As a Silesian, Freytag had no great love for his Slavonic neighbours, and being a native of a province which owed everything to Prussia, he was naturally an earnest champion of Prussian hegemony over Germany. His powerful advocacy of this idea in his *Grenzboten* gained him the friendship of the Duke of Saxe-Coburg-Gotha, who took him with him in the French campaign of 1870. Before this he had published (1864) another novel, *Die Verlorne Handschrift* (*The Lost Manuscript*), founded on a supposed discovery of the lost history of Tacitus, and dealing in some measure with the inner life of the University of Leipzig. It obtained considerable success, but was less celebrated than *Debit and Credit.* Between 1859 and 1867 he published in five volumes *Bilder aus der deutschen Vergangenheit* (*Pictures from the German Past*), a most valuable work, full of delightful and instructive collections of essays illustrating the history and manners of old Germany. In 1872 he began a work with a similar patriotic purpose, *Die Ahnen* (*The Ancestors*), designed to unfold German history in a series of romances. These continued to appear until 1880, but were not very successful. The author's aversion from the Slavonic race is again noticeable. In 1887 Freytag published his *Autobiography*, more distinguished by elegance of style than by copiousness of information, and died, full of years and honours, at Wiesbaden, 30th April 1895. Among his other works of importance may be noticed his essays, chiefly reprinted from the *Grenzboten*, an esteemed work on the technique of the drama, and an excellent biography of the Baden statesman Karl Mathy. Freytag had all the qualities most characteristic of a German of the practical type, and his great success in literature and life was largely owing to the fidelity with which he represented his nation. (R. G.)

Friedek, a town in Austrian Silesia, on the Ostrawitza, a tributary of the Oder. It has a château of the late Archduke Albrecht of Austria, who was the proprietor of the two large smelting works in the vicinity; and there is a very old parish church. It has also a considerable textile industry. Friedek, with the Moravian town of Mistek, on the opposite side of the river, forms the station Friedek-Mistek, on the Kaiser Ferdinands Nordbahn.

Population (1890), 7374; (1900), 9023, estimated to be two-thirds Czech, one-third German and Polish.

Friedrichroda, a favourite summer resort in the grand-duchy of Coburg-Gotha, Germany, at the north foot of the Thuringian Forest, 13 miles by rail south-west from Gotha. It is surrounded by fir-clad hills and possesses numerous handsome villa residences. There are a *kurhaus*, a sanatorium, and the ducal hunting castle of Reinhardsbrunn, built out of the ruins of a Benedictine monastery (1089–1525) in 1827–35. The people bleach linen on a very extensive scale and manufacture toys. Population (1900), 4397.

Friedrichshafen, a town, lake-port, summer resort, and bathing-place of Würtemberg, Germany, on the east shore of the Lake of Constance. It consists of the former imperial town of Buchhorn (dating from 837) and the monastery and village of Hofen (dating from 1050), united in 1824–30. The principal building is the royal castle (summer residence), to which is attached the Evangelical parish church. A hydropathic, whey cure, baths, &c., attract visitors in summer. There are also here the natural history and antiquarian collections of the Lake Constance Association. Population (1900), 4627.

Friendly Societies.—*United Kingdom.*—The Friendly Societies Act, 1875, and the several Acts amending it, are still, in effect, the law by which these societies are regulated, though in form they have been replaced by two consolidating Acts, viz., the Friendly Societies Act, 1896, and the Collecting Societies and Industrial Assurance Companies Act, 1896. All that is necessary in the present article, therefore, is to state the purport of the amendments made since 1876, and to trace to the present time the results of the working of the Act of 1875. That Act, in continuation of an enactment which first appeared in a statute passed in 1829, required every registered society to make quinquennial returns of the sickness and mortality experienced by its members. By the year 1880 ten periods of five years had been completed, and at the end of each of them a number of returns had been received. Some of these had been tabulated by actuaries, the latest tabulation being of those for the five years ending 1855. There remained untabulated five complete sets of returns for the five subsequent quinquennial periods. It was resolved that these should be tabulated once for all, and it was considered that they would afford sufficient material for the construction of tables of sickness and mortality that might be adopted for the future as standard tables for friendly societies; and that it would be inexpedient to impose any longer on the societies the burden of making such returns. This requirement of the Act was accordingly repealed in 1882. The result of the tabulation appeared in 1896, in a blue book of 1367 folio pages, containing tables based upon the experience of nearly four and a half million years of life. These tables show generally, as compared with previous observations, an increased liability to sickness. With regard to the procedure of the registrars some amendments of the law have been made. An appeal to the Chief Registrar in the case of the refusal of an assistant registrar to register a society or an amendment of rules, and in the case of suspension or cancelling of registry, is interposed before appeal is to be made to the High Court. The grounds upon which registry under a particular name may be refused are extended to include the opinion of the registrar, that the name is likely to deceive the members or the public as to the nature of the society, and not merely as to its identity. Authority is given to the Chief Registrar to direct the expense of an inspection or special meeting to be defrayed by the members or officers, or former members or officers, of a society, if he does not think they should be defrayed either by the applicants or out of the society's funds. He is also empowered, with the approval of the Treasury, to exempt any friendly society from the provisions of the Collecting Societies Act if he considers it to be one to which those provisions ought not to apply. Every society registered after 1895, to which these provisions do apply, is to use the words "Collecting Society" as the last words of its name.

The law as to the membership of infants has been altered twice. The Act of 1875 allowed existing societies to continue any rule or practice of admitting children as members that was in force at its passing, and prohibited membership under sixteen years of age in any other case, except the case of a juvenile society composed wholly of members under that age. The Treasury made special regulations for the registry of such juvenile societies. In 1887 the maximum age of their members was extended to twenty-one. In 1895 it was enacted that no society should have any members under one year of age, whether authorized by an existing rule or not; and that every society should be entitled to make a rule admitting members at any age over one year. The Treasury, upon this enactment coming into operation, rescinded its regulations for the registry of juvenile societies; and though it is still the practice to submit for registry societies wholly composed of persons under twenty-one, these societies in no way differ from other societies, except in the circumstance that they are obliged to seek officers and a committee of management from outside, as no member of the committee of any society can be under twenty-one years of age. In order to promote the discontinuance of this anomalous proceeding of creating societies under the Friendly Societies Act, which, by the conditions of their existence, are unable to be self-governing, the Act provides an easy method of amalgamating juvenile societies and ordinary societies or branches, or of distributing the members and the funds of a juvenile society among a number of branches. The liability of schoolboys and young working lads to sickness is small, and these societies frequently accumulate funds, which, as their membership is temporary, remain unclaimed and are sometimes misapplied.

The affiliated orders have strengthened their position; most of the lodges existing before 1875 have converted themselves into registered branches. The requirement that for that purpose a vote of three-fourths should be necessary was altered in 1895 to a bare majority vote. The provisions as to settlement of disputes were extended in 1885 to every description of dispute between branches and the central body, and in 1895 it was provided that the forty days after which a member may apply to the court to settle a dispute where the society fails to do so, shall not begin to run until application has been made in succession to all the tribunals created by the order for the purpose. In 1887 it was enacted that no body which had been a registered branch should be registered as a separate society except upon production of a certificate from the order that it had seceded or been expelled; and in 1895 it was further enacted that no such body should, after secession or expulsion, use any name or number implying that it is still a branch of the order. The orders generally, especially the greater ones, have carefully supervised the valuations of their branches, and have urged and, as far as circumstances have rendered it practicable, have enforced upon the branches measures for diminishing the deficiencies which the valuations have disclosed. They have organized plans by which branches disposed to make an effort to help themselves in this matter may be assisted out of a central fund.

The establishment of the National Conference of Friendly

Societies by the orders and a few other societies has been of great service in obtaining some of these improvements in the law, and in enabling the societies strongly to represent to the Government and the Legislature any grievance entertained by them. A complaint that membership of a shop club was made by certain employers a condition of employment, and that the rules of the club required the members to withdraw from other societies, led to the appointment of a departmental committee, who recommended that such a condition of employment should be made illegal, except in certain cases, and that in every case it should be illegal to make the withdrawal from a society a condition of employment.

The practice among societies of combining together to obtain medical attendance and medicine for their members by the formation of medical associations has increased. In 1895 trade unions were enabled to join in such associations, and it was provided that a contributing society or union should not withdraw from an association except upon three months' notice. The working of these associations has been viewed with dissatisfaction by members of the medical profession, and it has been suggested that a board of conciliation should be formed consisting of representatives of the Conference of Friendly Societies and of an equal number of medical men. One of the most important organic reforms introduced by the Act of 1875 was the requirement from every society of a valuation of its assets and liabilities once in every five years. No comparison of the aggregates of the valuations that have been completed since the passing of the Act could be made, or if made, would be of any service, inasmuch as the elements on which they depend are extremely variable; but a consideration of the successive valuations of individual societies strongly confirms the conclusion that "nothing is more elastic than the contract made by a friendly society with its members; no error more easy of remedy if found out in time than one existing in the original terms of such a contract."

The following figures are derived from returns of registered societies and branches of registered societies to 31st December 1899:—

	Number of Members.	Amount of Funds.
		£
7,090 Ordinary Friendly Societies	2,807,823	13,747,273
19,340 Branches of Registered Orders	2,409,438	19,004,596
45 Collecting Friendly Societies	5,922,615	5,207,686
86 Medical Societies	298,691	70,027
70 Benevolent Societies	18,363	286,141
632 Working Men's Clubs	175,469	209,041
465 Specially Authorized Societies	114,307	956,256
55 Cattle Insurance Societies	3,424	6,599
27,783 Societies and Branches	11,750,130	39,487,619

(E. W. B.)

United States.—Under the title of Fraternal Societies are included in the United States what are known in England as friendly societies, having some basis of mutual help to members, mutual insurance associations, and benefit associations of all kinds. There are various classes and a great variety of forms of fraternal associations. It is therefore difficult to give a concrete historical statement of their origin and growth; but, dealing with those having benefit features for the payment of certain amounts in case of sickness, accident, or death, it is found that their history in the United States is practically within the last half of the 19th century. The more important of the older organizations are the Improved Order of Red Men, founded in 1771 and re-organized in 1834; Ancient Order of Foresters, 1836; Ancient Order of Hibernians of America, 1836; United Ancient Order of Druids, 1839; Independent Order of Rechabites, 1842; Independent Order of B'nai B'rith, founded in 1843; Order of the United American Mechanics, 1845; Independent Order of Free Sons of Israel, 1849; Junior Order of United American Mechanics, 1853. A very large proportion, probably more than one-half, of the societies which have secret organizations pay benefits in case of sickness, accident, disability, and funeral expenses in case of death. This class of societies grew out of the English friendly societies, and have Masonic characteristics. The Freemasons and other secret societies, while not all having benefit features in their distinctive organizations, have auxiliary societies with such features. There is also a class of secret societies, based largely on Masonic usages, that have for their principal object the payment of benefits in some form. These are the Odd-Fellows, the Knights of Pythias, the Knights of Honour, the Royal Arcanum, and some others. Many trade unions have now adopted benefit features, especially the Typographical Union, while many subordinate unions and great publishing houses have mutual relief associations purely of a local character, and some of the more important newspapers have such mutual relief or benefit societies. The New York trade unions, taken as a whole, have paid out large sums of money in benefits where members have been out of work, or are sick, or are on strike, or have died. The total paid in a recent year for all these benefits was over $500,000.

Membership.

It is impossible to give the membership of all the fraternal associations in the United States; but according to the latest lists, including Odd-Fellows, Freemasons, purely benefit associations, and all the class of the larger fraternal organizations, the membership is nearly 5,500,000. Among the more important, so far as membership is concerned, are the Knights of Pythias, with a membership of nearly 500,000; the Odd-Fellows, with nearly 1,000,000; the Modern Woodmen of America, with nearly 450,000; the Ancient Order of United Workmen, with nearly 400,000; Improved Order of Red Men, with about 215,000; Royal Arcanum, with over 190,000; Knights of the Maccabees, with about 190,000; Junior Order of United American Mechanics, with nearly 184,000; Foresters of America, with 155,000; Independent Order of Foresters, with 150,000, &c. These and other organizations pay out a vast amount of money every year in the various forms of benefits. At the present time the sum is probably over $40,000,000, while the aggregate paid out by them since their organization would reach very nearly $500,000,000.

Assessment Insurance.

Since about the year 1870 a new form of benefit organization has come into existence. This is a life insurance based on the assessment plan, assessments being levied whenever a member dies; or, as more recently, regular assessments being made in advance of death, as post-mortem assessments have proved a fallacious method of securing the means of paying death benefits. The importance of this class of insurance is shown by a comparative statement. On the 1st January 1899 the number of policies in force under regular level premium companies was 11,218,330, the amount of insurance carried by them being $6,825,037,770. The assessment companies and orders, including industrial insurance, had a membership the year before of 4,039,062, while the amount of insurance in force under them was $7,799,428,000. There are about 200 mutual benefit insurance companies or associations in the United States conducted on the "lodge system"; that is to say, they have regular meetings for social purposes and for general improvement, and in their work there is found the mysticism, forms, and ceremonies which belong to secret societies generally. These elements have proved a very strong force in keeping this class of associations fairly intact. The "work" of the lodges in the initiation of members and their passing through various degrees is attractive to many people, and in small places, remote from the amusements of the city, these lodges constitute a resort where members can give play to their various talents. In most of them the features of the Masonic ritual are prominent. The amount of insurance which a single member can carry in such associations is small. In the Knights of Honour, one of the first of this class, policies ranging from $500 to $2000 are granted. In the Royal Arcanum the maximum is $3000. This form of insurance may be called co-operative, and has many elements which make the organizations practising it stronger than the ordinary assessment insurance companies having no stated meetings of members. These co-operative insurance societies are organized on the federal plan—as the Knights of Honour, for instance—having local assemblies, where the lodge room element is in force; state organizations, to which the local bodies send delegates, and the national organization, which conducts all the insurance business through its executive officers. The local societies pay a certain given amount towards the support of the state and national offices, and while originally they paid death assessments, as called for, they now pay regular monthly assessments, in order to avoid the weakness of the post-mortem assessment. The difficulty which these organizations have in conducting the insurance business is in keeping the average age of membership at a low point, for with an increase in the average the assessments increase, and many such organizations have had great trouble to convince younger members that their assessments should be increased to make up for the heavy losses among the older members. The experience of these purely insurance associations has not been sufficient yet to demonstrate their absolute soundness or desirability, but they have enabled a large number of persons of limited means to carry insurance at a very low rate. They have not materially interfered with regular level premium insurance enterprises, for they have stimulated the people to understand the benefits of insurance, and have really been an educational force in this direction.

A modern method of benefit association is found in the railway relief departments of some of the large railway corporations.

Railway Relief Departments.

These departments are organized upon a different plan from the benefit features of labour organizations and secret societies, providing the members not only with payments on account of death, but also with assistance of definite amounts in case of sickness or accident, the railway companies contributing to the funds, partly from philanthropic and partly from financial motives. The principal railway companies in the United States which have established these relief departments are the Pennsylvania, the Philadelphia and Reading, the Baltimore and Ohio, the Chicago, Burlington and Quincy, and the Plant System. The membership of these railway relief departments includes over one-eighth of all the railway employés in the United States, and on the various lines the number enrolled in them varies from 55 to 65 per cent. The Baltimore and Ohio, which organized its department in 1880, paid out a very large amount of money, up to 30th June 1896 the sum being nearly $5,000,000. The Pennsylvania line has paid out a like sum. In one fiscal year this railway paid out nearly $800,000, 18·27 per cent. being paid by the company; the Pennsylvania lines west distributed over $300,000, nearly 18 per cent. being paid by the company. The Baltimore and Ohio paid over $434,000, of which nearly 16 per cent. was paid by the company. The balance of the payments was made by the members of the associations through a mutual insurance plan. These data indicate the volume of business of railway relief associations. The relief department benefits the employés, the railways, and the public, because it is based upon the sound principle that the "interests and welfare of labour, capital, and society are common and harmonious, and can be promoted more by co-operation of effort than by antagonism and strife."

The railway employés support one-twentieth of the entire population, and most of their associations maintain organizations to provide their members with relief and insurance. The Brotherhood of Locomotive Engineers, the Order of Railway Conductors of America, the Brotherhood of Locomotive Firemen, the Brotherhood of Railway Trainmen, the Brotherhood of Railway Trackmen, the Switchmen's Union, the Brotherhood of Railway Carmen, and the Order of Railway Telegraphers, all have relief and benefit features. The oldest and largest of these is the International Brotherhood of Locomotive Engineers, founded at Detroit in August 1863. Like other labour organizations of the higher class of workmen, the objects of the brotherhoods of railway employés are partly social and partly educational, but in addition to these great purposes they seek to protect their members through relief and benefit features. Of course the relief departments of the railway companies are competitors of the relief and insurance features of the railway employés' Orders, but both methods of providing assistance have proved successful and beneficial.

AUTHORITIES.—For a history of the various organizations, see ALBERT C. STEVENS, *The Cyclopædia of Fraternities*, New York, 1899; *Facts for Fraternalists*, published by the *Fraternal Monitor*, Rochester, N.Y.; for annual statements, "The *World* Almanac," "Railway Relief Departments," "Brotherhood Relief and Insurance of Railway Employés," "Mutual Relief and Benefit Associations in the Printing Trade," "Benefit Features of American Trade Unions." *Bulletins* Nos. 8, 17, 19, and 22 of the U.S. Department of Labour. (C. D. W.)

Frisian Islands, the chain which stretches from the Zuider Zee eastwards and northwards as far as Jutland, fringing the coasts of Holland, Hanover (East Friesland), Oldenburg, Schleswig, and Holstein. The term is, strictly speaking, ethnographical. The chain is divided into three groups:—(1) the West Frisian, (2) the East Frisian, and (3) the North Frisian. The first group embraces Texel or Tessel (44,050 acres; 6000 pop.), Vlieland (12,220 acres; 700 pop.), Terschelling (25,765 acres; 3750 pop.), Ameland (14,360 acres; 2250 pop.), Schiermonnikoog (12,100 acres; 900 pop.), Boschplaat, and Rottum or Rottummeroog (640 acres; 400 pop.). With the exception of Wangeroog, which belongs to the grand-duchy of Oldenburg, the East Frisian islands belong to Prussia (*i.e.*, Hanover). They comprise Borkum ($2\frac{1}{2}$ miles by 5; 1350 pop.), Memmert; Juist ($2\frac{1}{4}$ sq. miles; 200 pop.), Norderney ($5\frac{1}{2}$ sq. miles; 3500 pop.), Baltrum (120 pop.), Langeoog (8 miles by 1; 250 pop.), Spiekeroog (4 sq. miles; 250 pop.), and Wangeroog (4 miles by $\frac{1}{2}$ mile; 100 pop.). All these islands are visited for sea-bathing in summer. Norderney, which inspired Heine's *Nordseebilder*, and Borkum are visited annually, the one by 24,000 and the other by 14,000 persons, and have been in repute since the beginning of the 19th century. In the beginning of the 18th century Wangeroog was eight times its present area. Borkum and Juist are two surviving fragments of the original island of Borkum (380 sq. miles), which was rent asunder by the sea in 1170. The North Frisian group embraces the islands of Nordstrand ($17\frac{1}{4}$ sq. miles; 2300 pop.), Pellworm ($16\frac{1}{4}$ sq. miles; 2000 pop.), Amrum ($10\frac{1}{2}$ sq. miles; 670 pop.), Föhr (32 sq. miles; 4500 pop.), Sylt (38 sq. miles; 4000 pop.), Röm (16 sq. miles; 1150 pop.), Fanö (21 sq. miles; 3000 pop.), and Heligoland ($\frac{1}{4}$ sq. mile; 2300 pop.). Except Fanö, all these belong to Prussia (province Schleswig-Holstein). Sylt (Westerland) is one of the most fashionable seaside resorts of Germany. Heligoland was anciently the holy island of the Frisian race. In the North Frisian group there is also a number of smaller islands called *halligen*, and rising generally only a few feet above the level of the sea, and crowned each by a single house standing on an artificial mound and surrounded by a dyke or embankment.[1]

The chain of the Frisian Islands, which lies 3 to 20 miles from the existing coastline, marks the outer fringe of the former continental coastline, and is separated from the firm land of the existing continent by shallows, known as *wadden* or *watten*,[2] answering to the *maria vadosa* of the Romans. Notwithstanding the artificial protection which is afforded these islands by earthen embankments, backed by stones and timber, and matted together with long tenacious grass, they are slowly but surely crumbling away under the persistent attacks of storm and flood. But the efforts of man are from time to time stimulated afresh. For instance, in 1873 a strong causeway was built from Ameland to Holwerd on the mainland with the view of promoting the warping of the *wadden*. In 1896 the Prussian Government voted £66,000 for the protection of the North Frisian *halligen*. About the year 1250 the area of the North Frisian islands was estimated at 1065 sq. miles; by 1850 this had diminished to only 105 sq. miles. The island of Nordstrand has been exceptionally severely visited by storms and inundations, having suffered terribly in 1300, in 1436, and in 1634. But since the 16th century the low-lying sea-

---

[1] See Dr EUGEN TRAEGER, *Die Halligen der Nordsee* (Stuttgart, 1892); also *Globus*, vol. lxxviii. (1900), No. 15.

[2] An entire world lies buried underneath the sands and clays of the *watten*; see C. P. HANSEN, *Chronik der friesischen Uthlande*, p. 103, footnote (Altona, 1856).

"Coming of Age in the Olden Time." By W. P. Frith, R.A.

marshes of the continent adjacent to the *wadden* and *watten* have been intermittently but effectually enclosed and drained. For instance, some 66,600 acres have been thus reclaimed to the north of the Ij in Holland; between 1545 and 1877 some 64,850 acres were reclaimed around the Dollart; and in Dithmarsch accretions were made amounting to 14,600 acres between 1579 and 1873. The view that the Dollart and similar indentations of this coast were formed by violent cataclysms is now abandoned by the modern school of Dutch and continental geographers in favour of the theory that their formation has been gradual, and has resulted more from the permanent subsidence of the coast, assisted more or less by sea-floods and the neglect of the embankments. The lands occupied by the Frisians originally extended across what is now the northern part of the Zuider Zee into the present province of North Holland, the eastern peninsula of which is indeed called West Friesland. The inhabitants of these islands support themselves by seafaring (they make excellent sailors), pilotage, grazing of cattle and sheep, fishing, and a little agriculture. Dr D. F. Buitenrust Hettema is editing a *Fryske Bybleteek* (Utrecht, 1895, &c.), a series of reprints of Middle Frisian literary works of the 16th, 17th, and 18th centuries.

See STARING, *De Bodem van Nederland* (1856).—BLINK, *Nederland en zijne Bewoners* (1892).—P. J. W. TEDING VAN BERKHOUT, *De Landaanwinning op de Friesche Wadden* (1869).—J. de VRIES and T. FOCKEN, *Ostfriesland* (1881).—C. P. HANSEN, *Das Schleswig'sche Wattenmeer* (Glogau, 1865).—R. HANSEN, in *Globus* (1896) and (1898), and in *Petermann's Mitteilungen* (1893).—P. AXELSEN, in *Deut. Rundschau für Geog. u. Statistik* (1898).—CHRISTIAN JENSEN, *Vom Dünenstrand der Nordsee und vom Wattenmeer*, Schleswig (1901), which has a good bibliography. (J. T. BE.)

Frith, William Powell (1819——), English painter, was born at Aldfield, in Yorkshire, on 9th January 1819. His parents moved in 1826 to Harrogate, where his father became landlord of the Dragon Inn, and it was then that the boy began his general education at a school at Knaresborough. Later he went for about two years to a school at St Margaret's, near Dover, where he was placed specially under the direction of the drawing-master, as a step towards his preparation for the profession which his father had decided on as the one that he wished him to adopt. In 1835 he was entered as a student in the well-known art school kept by Henry Sass in Bloomsbury, from which he passed after two years to the Royal Academy schools. His first independent experience was gained in 1839, when he went about for some months in Lincolnshire executing several commissions for portraits; but he soon began to attempt compositions, and in 1840 his first picture, "Malvolio, cross-gartered before the Countess Olivia," appeared at the Royal Academy. During the next few years he produced several notable paintings, among them "Squire Thornhill relating his town adventures to the Vicar's family," and "The Village Pastor," which established his reputation as one of the most promising of the younger men of that time. This last work was exhibited in 1845, and in the autumn of that year he was elected an Associate of the Royal Academy. His promotion to the rank of Academician followed in 1853, when he was chosen to fill the vacancy caused by Turner's death. The chief pictures painted by him during his tenure of Associateship were: "An English Merry-making in the Olden Time," "Old Woman accused of Witchcraft," "The Coming of Age," "Sancho and Don Quixote," "Hogarth before the Governor of Calais," and the "Scene from Goldsmith's 'Good-natured Man,'" which was commissioned in 1850 by Mr Sheepshanks, and bequeathed by him to the South Kensington Museum. Then came a succession of large compositions, which gained for the artist an extraordinary popularity. "Life at the Seaside," better known as "Ramsgate Sands," was exhibited in 1854, and was bought by Queen Victoria; "The Derby Day," in 1858; "Claude Duval," in 1860; "The Railway Station," in 1862; "The Marriage of the Prince of Wales," painted for Queen Victoria, in 1865; "The Last Sunday of Charles II," in 1867; "The Salon d'Or," in 1871; "The Road to Ruin," a series, in 1878; a similar series, "The Race for Wealth," shown at a gallery in King Street, St James's, in 1880; "The Private View," in 1883; and "John Knox at Holyrood," in 1886. The artist has also painted a considerable number of portraits of well-known people. In 1889 he became an Honorary Retired Academician. His "Derby Day" is now in the National Gallery of British Art. In his youth, in common with the men by whom he was surrounded, he had leanings towards romance, and he scored many successes as a painter of imaginative subjects. In these he proved himself to be possessed of exceptional qualities as a colourist and manipulator, qualities that promised to earn for him a secure place among the best executants of the British School. But in his middle period he chose a fresh direction. Fascinated by the welcome which the public gave to his first attempts to illustrate the life of his own times, he undertook a considerable series of large canvases, in which he commented on the manners and morals of society as he found it. He became a pictorial preacher, a painter who moralized about the everyday incidents of modern existence; and he sacrificed some of his technical variety. There remained, however, in all his later work a remarkable sense of characterization, and an appreciation of dramatic effect more than ordinarily acute.

See W. P. FRITH, R.A. *My Autobiography and Reminiscences.* London, 1887.—*Further Reminiscences.* London, 1889.

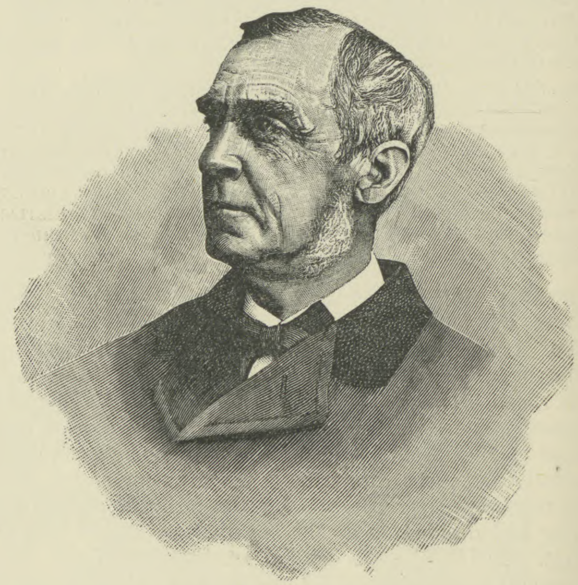
Frohschammer, Jakob (1821–1893), German theologian and philosopher, was born at Illkofen, near Ratisbon, on 6th January 1821. Destined by his parents for the Roman Catholic priesthood, he studied theology at Munich, but felt an ever-growing attraction to philosophy. Nevertheless, after much hesitation, he took what he himself calls the most mistaken step of his life, and in 1847 entered the priesthood. His keenly logical intellect, and his impatience of authority where it clashed with his own convictions, quite unfitted him for that unquestioning obedience to his superiors which the Church demanded. It was only after open defiance of the bishop of Ratisbon that he obtained permission to continue his studies at Munich. He at first devoted himself more especially to the study of the history of dogma, and in 1850 published his *Beiträge zur Kirchengeschichte*, which was placed on the Index Expurgatorius. But he felt that his real vocation was philosophy, and after holding for a short time an extraordinary professorship of theology, he became professor of philosophy in 1855. This appointment he owed chiefly to his work, *Ueber den Ursprung der menschlichen Seelen* (1854), in which he maintained that the human soul was not implanted by a special creative act in each case, but was the result of a secondary creative act on the part of the parents: that soul as well as body, therefore, was subject to the laws of heredity. This was supplemented in 1855 by the controversial *Menschenseele und Physiologie*. Undeterred by the offence which these works gave to his ecclesiastical superiors, he published in 1858 the *Einleitung in die Philosophie und Grundriss der Metaphysik*, in which he assailed the doctrine of Thomas Aquinas, that philosophy was the handmaid of theology. In 1861 appeared *Ueber die Aufgabe der Naturphilosophie und ihr Verhältniss zur Naturwissenschaft*, which was, he declared, directed against the purely mechanical conception of the universe, and affirmed the necessity of a creative Power. In the same year he published *Ueber die Freiheit der Wissenschaft*, in which he maintained the independence of science, whose goal was truth, against authority, and reproached the excessive respect for the latter in the Roman Church with the insignificant part played by the German Catholics in literature and philosophy. He was denounced by the pope himself in an apostolic brief of

11th December 1862, and students of theology were forbidden to attend his lectures. Public opinion was now keenly excited; he received an ovation from the Munich students, and the king, to whom he owed his appointment, remained staunch to him. A conference of Catholic *savants* was held in 1863 under the presidency of Döllinger, and decided that authority must be supreme in the Church. When, however, Döllinger and his school in their turn started the Old Catholic movement, Frohschammer refused to associate himself with their cause, holding that they did not go far enough, and that their declaration of 1863 had cut the ground from under their feet. Meanwhile he had, in 1862, founded the *Athenäum* as the organ of Liberal Catholicism. For this he wrote the first adequate account in German of the Darwinian theory of natural selection, and drew a warm letter of appreciation from Darwin himself. Excommunicated in 1871, he replied with three articles, which were reproduced in thousands as pamphlets in the chief European languages—*Der Fels Petri in Rom* (1873), *Der Primat Petri und des Papstes* (1875), and *Das Christenthum Christi und das Christenthum des Papstes* (1876). His later years were occupied with a series of philosophical works, of which the most important were *Die Phantasie als Grundprincip des Weltprocesses* (1877), *Ueber die Genesis der Menschheit und deren geistige Entwicklung in Religion, Sittlichkeit und Sprache* (1883), and *Ueber die Organisation und Cultur der menschlichen Gesellschaft* (1885). His system is based on the unifying principle of imagination ("Phantasie"), which he extends to the objective creative force of Nature, as well as to the subjective mental phenomena to which the term is usually confined. He died at Bad Kreuth in the Bavarian Highlands on 14th June 1893.

Frohschammer's works, in addition to those already mentioned, include: *Beleuchtung der Encyklika* (anonymous, 1865); *Das Christenthum und die moderne Naturwissenschaft* (1868); *Das Recht der eigenen Ueberzeugung, Die politische Bedeutung der Unfehlbarkeit des Papstes und der Kirche*, and *Zur Würdigung der Unfehlbarkeit des Papstes und der Kirche* (1869); *Die Unfehlbarkeit des Papstes* (addressed to the archbishop of Munich—Freising, 1871), *Ueber die religiösen und kirchenpolitischen Fragen der Gegenwart. Gesammelte Abhandlungen* (1875); *Die wahre Bedeutung des Kulturkampfes* (1878); *Monaden und Weltphantasie* and *Ueber die Bedeutung der Einbildungskraft in der Philosophie Kant's und Spinoza's* (1879); *Ueber die Principien der Aristotelischen Philosophie und die Bedeutung der Phantasie in derselben* (1881); *Die Philosophie als Idealwissenschaft und System* (1884); *Die Philosophie des Thomas von Aquino kritisch gewürdigt* (1889); *Ueber das Mysterium Magnum des Daseins* (1891); *System der Philosophie im Umriss* (1892 *et seq.*); *Briefe von und über J. Frohschammer herausgegeben von B. Münz* (1897); *J. Frohschammer's philosophisches System im Grundriss, nach Frohschammer's Vorlesungen herausgegeben von A. Attensperger* (1899). In 1888 he published a brief autobiography. For his philosophy consult F. Friedrich and B. Münz. (H. Sy.)

Frome (or Frome Selwood), a market-town in the Frome parliamentary division (since 1885) of Somersetshire, England, 11 miles south of Bath by rail. There are in all five parish or district churches, a Roman Catholic church, and various Nonconformist chapels. A recreation ground was provided in 1888. Public offices and a Church of England home for boys have been erected; there is a cottage hospital. Area of urban district, 731 acres; population (1881), 9377; (1891), 9613. Area of township, 7614 acres; population (1881), 11,304; (1901), 11,055. There is a parish of Frome.

Froude, James Anthony (1818–1894), English historian, son of R. H. Froude, archdeacon of Totnes, was born at Darlington, Devon, on 23rd April 1818. He was educated at Westminster and Oriel College, Oxford, then the centre of the ecclesiastical revival. He obtained a second class and the chancellor's English essay prize, and was elected a fellow of Exeter College (1842). Though not so conspicuous in the High Church movement at Oxford as his elder brother, Richard Hurrell Froude, he was one of its prominent adherents, and helped J. H. Newman, afterwards cardinal, in his *Lives of the English Saints*. He was ordained deacon in 1844. Soon afterwards his religious opinions began to change, he grew dissatisfied with the views of the High Church party, and came under the influence of Carlyle's teaching. Signs of this change first appeared publicly in his *Shadows of the Clouds*, a volume containing two stories of a religious sort, which he published in 1847 under the pseudonym of "Zeta," and his complete desertion of his party was declared



J. A. Froude.
(*From a photo. by Elliott and Fry.*)

a year later in his *Nemesis of Faith*, of which the earlier part seems to be autobiographical. He resigned his fellowship at Oxford, and mainly at least supported himself by writing, contributing largely to *Fraser's Magazine* and the *Westminster Review*. The excellence of his style was soon generally recognized. The first two volumes of his *History of England from the Fall of Wolsey to the Defeat of the Spanish Armada* appeared in 1856, and the work was completed in 1870. As a historian he is chiefly remarkable for literary excellence, for the art with which he represents his conception of the past. He condemns a scientific treatment of history and disregards its philosophy. He held that its office was simply to record human actions and that it should be written as a drama. Accordingly he gives prominence to the personal element in history. His presentations of character and motives, whether truthful or not, are undeniably fine; but his doctrine that there should be "no theorizing" about history tended to narrow his survey, and consequently he sometimes, as in his remarks on the foreign policy of Elizabeth, seems to misapprehend the tendencies of a period on which he is writing.

Froude was not a historical scholar and his work is often marred by prejudice and incorrect statements. He wrote with a purpose. The keynote of his *History* is contained in his assertion that the Reformation was "the root and source of the expansive force which has spread the Anglo-Saxon race over the globe." Hence he overpraises Henry VIII. and others who forwarded the movement, and speaks too harshly of some of its opponents. So too, in his *English in Ireland* (1871–74), which was written to show the futility of attempts to conciliate the Irish, he aggravates all that can be said against the Irish, and touches too lightly on atrocities on the part of the English. A strong anti-clerical prejudice is manifest in his historical work generally, and is doubtless the result of the change in his views on Church matters and his abandonment of the clerical profession. Carlyle's influence on him may be traced both in his admiration for strong rulers and strong government, which sometimes led him to write as though tyranny and brutality were excusable, and in his independent treatment of character. His rehabilitation of Henry VIII. was a useful protest against the idea that the king was a mere sanguinary profligate, but his representation of him as the self-denying minister of his people's will is erroneous, and is founded on the false theory that the preambles of the Acts of Henry's Parliaments represented the opinions of the educated laymen of England. As an advocate he occasionally forgets that sobriety of judgment and expression become a historian. He was not a judge of evidence, and seems to have been unwilling to admit the force of any argument or the authority of any statement which militated against his case. In his *Divorce of Catherine of Aragon* (1891) he made an unfortunate attempt to show that certain fresh evidence on the subject, brought forward by Dr Gairdner, Dr Friedmann, and others, was not inconsistent with the views which he had expressed in his *History* nearly forty years before. No attempt at thoroughness of investigation appears in any of his books. The manuscript treasures of Hatfield were opened to him, but he is said to have been content with a single day's examination of them; and though he visited Simancas, his work there must have been careless. His *Life of Cæsar* (1879), a glorification of Imperialism, betrays an imperfect acquaintance with the life and writings of Cicero; and of his two pleasant books of travel, *The English in the West Indies* (1888) shows that he made little effort to master his subject, and *Oceana* (1886), the record of a tour in Australia and New Zealand, among a multitude of other blunders, notes the prosperity of the working-classes in Adelaide at the date of his visit, when, in fact, owing to a failure in the wheat-crop, hundreds were then living on charity. He was constitutionally inaccurate, and seems to have been unable to represent the exact sense of a document which lay before him, or even to copy from it correctly. Historical scholars ridiculed his mistakes, and Freeman, the most violent of his critics, never let slip a chance of hitting at him in the *Saturday Review*. Froude's temperament was sensitive, and he suffered from these attacks, which were in truth far too savage in tone. The literary quarrel between him and Freeman excited general interest when it blazed out in a series of articles which Freeman wrote in the *Contemporary Review* (1878–79) on his *Short Study* of Thomas Becket.

Yet, notwithstanding its defects, Froude's *History* is a great achievement; it presents an important and powerful account of the Reformation period in England, and lays before us a picture of the past magnificently conceived, and painted in colours which will never lose their freshness and beauty. As with Froude's work generally, its literary merit is remarkable; it is a well-balanced and orderly narrative, coherent in design and symmetrical in execution. Though it is perhaps needlessly long, the thread of the story is never lost amid a crowd of details; every incident is made subordinate to the general idea, appears in its appropriate place, and contributes its share to the perfection of the whole. The excellence of its form is matched by the beauty of its style, for Froude was a master of English prose. The most notable characteristic of his style is its graceful simplicity; it is never affected or laboured; his sentences are short and easy, and follow one another naturally. He is always lucid. He was never in doubt as to his own meaning, and never at a loss for the most appropriate words in which to express it. Simple as his language is, it is dignified and worthy of its subject. Nowhere perhaps does his style appear to more advantage than in his four series of essays entitled *Short Studies on Great Subjects* (1867–82), for it is seen there unfettered by the obligations of narrative. Yet his narrative is admirably told. For the most part flowing easily along, it rises on fit occasions to splendour, picturesque beauty, or pathos. Few more brilliant pieces of historical writing exist than his description of the coronation procession of Anne Boleyn through the streets of London, few more full of picturesque power than that in which he relates how the spire of St Paul's was struck by lightning; and to have once read is to remember for ever the touching and stately words in which he compares the monks of the London Charterhouse preparing for death with the Spartans at Thermopylæ. Proofs of his power in the sustained narration of stirring events are abundant; his treatment of the Pilgrimage of Grace, of the sea fight at St Helens and the repulse of the French invasion, and of the murder of Rizzio, are among the most conspicuous examples of it. Nor is he less successful when recording pathetic events, for his stories of certain martyrdoms, and of the execution of Mary Queen of Scots, are told with exquisite feeling and in language of well-restrained emotion. And his characters are alive. We may not always agree with his portraiture, but the men and women whom he saw exist for us instinct with the life with which he endows them and animated by the motives which he attributes to them. His successes must be set against his failures. At the least he wrote a great history, one which can never be disregarded by future writers on his period, be their opinions what they may; which attracts and delights a multitude of readers, and is a splendid example of literary form and grace in historical composition.

The merits of his work met with full recognition. Each instalment of his *History*, in common with almost everything which he wrote, was widely read, and in spite of some adverse criticisms was received with eager applause. In 1868 he was elected Rector of St Andrews University, defeating Disraeli by a majority of fourteen. He was warmly welcomed in the United States, which he visited in 1872, giving lectures in various places. On the death of his adversary Freeman in 1892, he was appointed, on the recommendation of Lord Salisbury, to succeed him as regius professor of modern history at Oxford. Except to a few Oxford men, who considered that historical scholarship should have been held to be a necessary qualification for the office, his appointment gave general satisfaction. His lectures on Erasmus and other 16th-century subjects were largely attended. With some allowance for the purpose for which they were originally written, they present much the same characteristics as his earlier historical books. His health gave way in the summer of 1894, and he died on 20th October of that year, at the age of seventy-six. His long life was full of literary work. Besides his labours as an author, he was for fourteen years editor of *Fraser's Magazine*. He was one of Carlyle's literary executors, and brought some sharp criticism upon himself by publishing Carlyle's *Reminiscences* and the *Memorials of Jane Welsh Carlyle*, for they exhibited the domestic life and character of his old friend in an unpleasant light. Carlyle had given the manuscripts to him, telling him that he might publish them if he thought it well to do so, and at the close of his life agreed to their publication. Froude therefore declared that in giving them to the world he was carrying out his friend's wish by enabling him to make a posthumous confession of his faults. But Carlyle did not intend that they should be published without "fit editing," and said so in a passage which Froude omitted to print. Besides publishing these manuscripts, he wrote a *Life of Carlyle.* His earlier study of Irish history afforded him suggestions for a historical novel entitled *The Two Chiefs of Dunboy* (1889). In spite of one or two stirring scenes, it is a tedious book; it lacks the necessary elements of romance, and its personages are little more than machines for the enunciation of the author's opinions and sentiments. Though Froude had some intimate friends, he was generally reserved. When he cared to please, his manners and conversation were charming. Those who knew him well formed a high estimate of his ability in practical affairs. In 1874 Lord Carnarvon, then colonial secretary, sent him to South Africa on a mission of inquiry, and in 1875 to Cape Town as a member of a proposed conference; but his speeches there were rather injudicious, and his mission was a failure. He was twice married. His first wife, a daughter of Mr Pascoe Grenfell, died in 1860; his second, a daughter of Mr John Warre, M.P. for Taunton, died in 1886. (W. Hu.)

FRUIT AND FLOWER FARMING.

Imports of Fresh Fruit.

The quantities of apples, pears, plums, cherries, and grapes imported in the raw condition into the United Kingdom in each year, 1892 to 1901, are shown in Table I. Previous to 1892 apples only were separately enumerated. Up to 1899 inclusive the quantities were given in bushels, but in 1900 a change was made to hundredweights. This renders the quantities in that and subsequent years not directly comparable with those in earlier years, but the comparison of the values, which are also given in the table, continues to hold good. In some years the value of imported apples exceeds the aggregate value of the pears, plums, cherries, and grapes imported. The extreme values for apples shown in the table are £844,000 in 1893 and £1,582,000 in 1896. Grapes rank next to apples in point of value, and over the ten years the amount ranged between £394,000 in 1892 and £695,000 in 1901. On the average, the annual outlay on imported plums is slightly in excess of that on pears. The extremes shown are £166,000 in 1895 and £498,000 in 1897. In the case of pears, the smallest outlay tabulated is £167,000 in 1895, whilst the largest is £411,000 in 1894. The amounts expended upon imported cherries varied between £96,000 in 1895 and £308,000 in 1900. In 1900 apricots and peaches, imported raw, previously included with raw plums, were for the first time separately enumerated, the import into the United Kingdom for that year amounting to 13,689 cwt., valued at £25,846; in 1901 the quantity was 13,463 cwt., and the value £32,350. In 1900, also, currants, gooseberries, and strawberries, hitherto included in unenumerated raw fruit, were likewise for the first time separately returned. Of raw currants the import was 64,462 cwt., valued at £87,170; of raw gooseberries 26,045 cwt., valued at £14,626; and of raw strawberries 52,225 cwt., valued at £85,949. In 1901 the quantities and values were respectively—currants, 70,402 cwt., £75,308; gooseberries, 21,735 cwt., £11,420; strawberries, 38,604 cwt., £51,290. Up to 1899 the imports of tomatoes were included amongst unenumerated raw vegetables, so that the quantity was not separately ascertainable. For 1900 the import of tomatoes was 833,032 cwt., valued at £792,339, which is equivalent to a fraction under $2\frac{1}{2}$d. per lb. For 1901 the quantity was 793,991 cwt., and the value £734,051.

Table I.—Imports of raw apples, pears, plums, cherries, and grapes into the United Kingdom, 1892 to 1901. Quantities in thousands of bushels (thousands of cwt. in 1900 and 1901), values in thousands of pounds sterling.

Year.	Apples.	Pears.	Plums.	Cherries.	Grapes.
	Quantities.				
1892	4515	637	413	217	762
1893	3460	915	777	346	979
1894	4969	1310	777	311	833
1895	3292	407	401	196	865
1896	6177	483	560	219	883
1897	4200	1052	1044	312	994
1898	3459	492	922	402	1136
1899	3861	572	558	281	1158
1900	2129 [a]	477 [a]	423 [a]	243 [a]	593 [a]
1901	1830 [a]	349 [a]	264 [a]	213 [a]	680 [a]
	Values.				
1892	1354	297	200	135	394
1893	844	347	332	195	530
1894	1389	411	302	167	470
1895	960	167	166	96	487
1896	1582	207	242	106	443
1897	1187	378	498	178	495
1898	1108	222	435	231	550
1899	1186	266	294	154	588
1900	1225	367	393	308	595
1901	1183	296	244	214	695

[a] Thousands of cwt.

In 1900 the outlay of the United Kingdom upon imported raw fruits, such as can easily be produced at home, was £2,708,512, made up as follows:—

Apples . . .	£1,224,655	Currants . . .	£87,170
Grapes . . .	595,000	Strawberries . .	85,949
Pears . . .	366,871	Apricots and peaches	25,846
Cherries . .	308,395	Gooseberries . .	14,626

In addition, £289,752 was spent upon "unenumerated" raw fruit, and £602,130 on nuts other than almonds "used as fruit," which would include walnuts and filberts, both produced at home. It is certain, therefore, that the expenditure on imported fruits, such as are grown within the limits of the United Kingdom, exceeds three millions sterling per annum. The remainder of the outlay on imported fruit in 1900, amounting to £3,660,419, was made up of £2,120,789 for oranges, £420,857 for lemons, £548,956 for bananas, and £569,817 for almond-nuts; these cannot be grown on an industrial scale in the British Isles.

In 1901 the total expenditure on raw fruit imported into the United Kingdom was £7,623,500, the largest items being £2,119,726 for oranges, £1,182,798 for apples, £1,090,477 for almonds and other nuts used as fruit, £875,542 for bananas, and £694,942 for grapes.

Acreages of Orchards and Small Fruit Plantations.

The Board of Agriculture returns concerning the orchard areas of Great Britain show a continuous expansion year by year from 199,178 acres in 1888 to 234,660 acres in 1901, as will be learnt from Table II. There is, it is

Table II.—Extent of Orchards in Great Britain in each year, 1887 to 1901.

Year.	Acres.	Year.	Acres.	Year.	Acres.
1887	202,234	1892	208,950	1897	224,116
1888	199,178	1893	211,664	1898	226,059
1889	199,897	1894	214,187	1899	228,603
1890	202,305	1895	218,428	1900	232,129
1891	209,996	1896	221,254	1901	234,660

true, an exception in 1892, but the decline in that year is explained by the circumstance that since 1891 the agricultural returns have been collected only from holdings of more than one acre, whereas they were previously obtained from all holdings of a quarter of an acre or more. As there are many holdings of less than an acre in extent upon which fruit is grown, and as fruit is largely raised also in suburban and other gardens which do not come into the returns, it may be taken for granted that the actual extent of land devoted to fruit culture exceeds that which is indicated by the official figures. Table III. shows that

Table III.—Areas under Orchards in England, Wales, and Scotland, in each year, 1896 to 1901,—Acres.

Year.	England.	Wales.	Scotland.	Great Britain.
1896	215,642	3677	1935	221,254
1897	218,261	3707	2148	224,116
1898	220,220	3690	2149	226,059
1899	222,712	3666	2225	228,603
1900	226,164	3695	2270	232,129
1901	228,580	3767	2313	234 660

the expansion of the orchard area of Great Britain is mainly confined to England, for it is almost at a standstill in Wales, and only increases slowly in Scotland. The acreage officially returned as under orchards is that of arable or grass land which is also used for fruit trees of any kind. Conditions of soil and climate determine the irregular distribution of orchards in Great Britain. The dozen counties which possess the largest extent of orchard land all lie in the south or west of the island. According to the returns for 1901, they are the following :—

County.	Acres.	County	Acres.	County.	Acres.
Kent .	27,175	Worcester	21,414	Salop .	4758
Devon .	27,161	Gloucester	19,806	Dorset .	4459
Hereford	26,987	Cornwall .	5,252	Monmouth	4027
Somerset	24,929	Middlesex	4,974	Wilts .	3774

Leaving out of consideration the county of Kent, which grows a greater variety of fruit than any of the others, the counties of Devon, Hereford, Somerset, Worcester, and Gloucester have an aggregate orchard area of 120,297 acres. These five counties of the west and south-west of England—constituting in one continuous area what is essentially the cider country of Great Britain—embrace therefore rather more than half of the entire orchard area of the island. Eight English counties have less than 1000 acres each of orchards, namely, the small counties of Bedford, Huntingdon, and London, and the northern counties of Cumberland, Westmorland, Northumberland, Durham, and the East Riding of York. Rutland has less than 100 acres. The largest orchard areas in Wales are in the two counties adjoining Hereford—Brecon with 1185 acres, and Radnor with 723 acres; at the other extreme is Anglesey, with an orchard area of only 41 acres. Of the Scottish counties, Lanark takes the lead with 771 acres, Perth and Haddington following with 566 and 126 acres respectively. Ayr, according to the 1901 returns, is the only other county possessing 100 acres or more of orchards, whilst Kincardine, Orkney, Shetland, and Wigtown return no orchard area, and Banff, Bute, Kinross, Nairn, Peebles, and Sutherland return less than 10 acres each. It may be added that in 1901 Jersey returned 1027 acres of orchards; Guernsey, &c., 209 acres; and the Isle of Man 307 acres.

Outside the cider counties proper of England, the counties in which orchards for commercial fruit-growing have increased considerably in recent years include Berks, Buckingham, Cambridge, Essex, Lincoln, Middlesex, Monmouth, Norfolk, Oxford, Salop, Sussex, Warwick, and Wilts. Apples are the principal fruit grown in the western and south-western counties, pears also being fairly common. In parts of Gloucestershire, however, and in the Evesham and Pershore districts of Worcestershire, plum orchards predominate. Plums are likewise largely grown in Cambridgeshire and the neighbouring counties. Large quantities of apples, plums, damsons, cherries, and pears are grown for the market in Kent and Middlesex, whilst in many counties damsons are cultivated around fruit plantations to shelter the latter from the wind.

Of small fruit (currants, gooseberries, strawberries, raspberries, &c.) no return was made of the acreage previous to 1888, in which year it was given as 36,724 acres for Great Britain. In 1889 it rose to 41,933 acres. The areas in subsequent years are shown in Table IV. It

Table IV.—Areas of Small Fruit in Great Britain in each year, 1890 to 1901.

Year.	Acres.	Year.	Acres.	Year.	Acres.
1890	46,234	1894	68,415	1898	69,753
1891	58,704	1895	74,547	1899	71,526
1892	62,148	1896	76,245	1900	73,780
1893	65,487	1897	69,792	1901	74,999

will be observed that, owing to corrections made in the enumeration in 1897, a considerable reduction in the area is recorded for that year, and presumably the error then discovered existed in all the preceding returns. Despite this, however, the area of 74,999 acres in 1901 is double that of 1888, and there has undoubtedly been a considerable expansion, rather than a contraction, of small fruit plantations since 1896. The acreage of small fruit in Great Britain is about one-third that of the orchards. As may be seen in Table V., it is mainly confined to

Table V.—Areas under Small Fruit in England, Wales, and Scotland in 1898, 1899, 1900, and 1901,—Acres.

Year.	England.	Wales.	Scotland.	Great Britain.
1898	63,438	1044	5271	69,753
1899	64,867	1106	5553	71,526
1900	66,749	1109	5922	73,780
1901	67,828	1092	6079	74,999

England, though Scotland has a much larger acreage of small fruit than of orchards. Fully one-third of the area of small fruit in England belongs to Kent alone, that county having returned 22,778 acres in 1901. Middlesex ranks next with 4524 acres, followed by Worcestershire with 3851 acres, Cambridge with 3740 acres, Norfolk with 3342 acres, Hants with 2382 acres, and Essex with 1983 acres. The largest county area of small fruit in Wales is 622 acres in Denbighshire, and in Scotland 2174 acres in Lanarkshire, followed by 348 acres in Haddingtonshire. The only counties in Great Britain which make no return under the head of small fruit are Orkney, Shetland, and Sutherland. It is hardly necessary to say that considerable areas of small fruit, in kitchen gardens and elsewhere, find no place in the official returns, which, however, include small fruit grown between and under orchard trees.

Gooseberries are largely grown in most small fruit districts. Currants are less widely cultivated, but the red currant is more extensively grown than the black, the latter having suffered seriously from the ravages of the black currant mite. Kent is the great centre for raspberries and for strawberries, though, in addition, the latter fruit is largely grown in Middlesex, South Hants, Norfolk, and other counties.

There are no official returns as to the acreage devoted to orchard cultivation in Ireland. The figures relating to small fruit, moreover, extend back only to 1899, when the area under this head was returned as 4809 acres, which became 4359 acres in 1900 and 4877 acres in 1901. In most parts of the country there are districts favourable to the culture of small fruits, such as strawberries, raspberries, gooseberries, and currants, and of top fruits, such as apples, pears, plums, and damsons. The only localities largely identified (in 1900) with fruit culture as an industry were the Drogheda district and the Armagh district. In the former all the varieties named are grown except strawberries, the speciality being raspberries, which are marketed in Dublin, Belfast, and Liverpool. In the Armagh district, again, all the varieties named are grown, but in this case strawberries are the speciality, the markets utilized being Richhill, Belfast, and those in Scotland. In the Drogheda district the grower bears the cost of picking, packing, and shipping, but he cannot estimate his net returns until his fruit is on the market. Around Armagh the Scottish system prevails—that is, the fruit is sold while growing, the buyer being responsible for the picking and marketing.

Fruit-Growing in Kent.

As by far the largest fruit-growing county in England, Kent may appropriately be dealt with first. For centuries that county has been famous for its fruit, and appears to have been the centre for the distribution of trees and grafts throughout the country. The cultivation of fruit land upon farms in many parts of Kent has always been an important feature in its agriculture. The most recent description of this noteworthy characteristic of Kentish farming is contained in a comprehensive paper on the agriculture of Kent by Mr Charles Whitehead,[1] whose remarks, with various additions and modifications, are here reproduced :—

Where the conditions are favourable, especially in East and Mid Kent, there is a considerable acreage of fruit land attached to each farm, planted with cherry, apple, pear, plum, and damson trees, and with bush fruits, or soft fruits as they are sometimes called, including gooseberries, currants, raspberries, either with or without standard trees, and strawberries, and filberts and cob-nuts in Mid Kent. This acreage has largely increased, and will no doubt continue to increase, as, on the whole, fruit-growing has been profitable, and has materially benefited those fortunate enough to have fruit land on their farms. There are also cultivators who grow nothing but fruit. These are principally in the district of East Kent, between Rochester and Canterbury, and in the district of Mid Kent near London, and they manage their fruit land, as a rule, better than farmers, as they give their undivided attention to it and have more technical knowledge. But there has been great improvement of late in the management of fruit land, especially of cherry and apple orchards, the grass of which is fed off by animals having corn or cake, or the land is well manured. Apple trees are grease-banded and sprayed systematically by advanced fruit-growers, to prevent or check the attacks of destructive insects. Far more attention is being paid to the selection of varieties of apples and pears having colour, size, flavour, keeping qualities, and other attributes to meet the tastes of the public, and to compete with the beautiful fruit that comes from the United States and Canada.

Of the various kinds of apples at present grown in Kent mention should be made of Mr Gladstone, Beauty of Bath, Devonshire Quarrenden, Lady Sudely, Yellow Ingestre, and Worcester Pearmain. These are dessert apples coming to pick in August and September, and not stored. For storing, King of the Pippins, Cox's Orange Pippin (the best dessert apple in existence), Cox's Pomona, Duchess, Favourite, Gascoyne's Scarlet Seedling, Court Pendu Plat, Baumann's Red Reinette, Allington Pippin, Duke of Devonshire, and Blenheim Orange. Among kitchen apples for selling straight from the trees the most usually planted are Lord Grosvenor, Lord Suffield, Keswick Codlin, Early Julian, Eclinville Seedling, Pott's Seedling, Early Rivers, Grenadier, Golden Spire, Stirling Castle, and Domino. For storing, the cooking sorts favoured now are Stone's or Loddington, Warner's King, Wellington, Lord Derby, Queen Caroline, Tower of Glamis, Winter Queening, Lucombe's Seedling, Bismarck, Bramley's Seedling, Golden Noble, and Lane's Prince Albert. Almost all these will flourish equally as standards, pyramids, and bushes. Among pears are Hessle, Clapp's Favourite, William's Bon Chrétien, Beurré de Capiaumont, Fertility, Beurré Riche, Chissel, Beurré Clairgeau, Louise Bonne of Jersey, Doyenne du Comice, and Vicar of Winkfield. Among plums, Rivers's Early Prolific, Czar, Belgian Purple, Black Diamond, Kentish Bush Plum, Pond's Seedling, Magnum Bonum, and Victoria are mainly cultivated. The damson known as Farleigh Prolific, or Crittenden's, is most extensively grown throughout the county, and usually yields large crops, which make good prices. As a case in point, purchasers were offering to contract for quantities of this damson at £20 per ton in May of 1899, as the prospects of the yield were unsatisfactory. On the other hand, in one year recently, when the crop was abnormally abundant, some of the fruit barely paid the expenses of sending to market. The varieties of cherries most frequently grown are Governor Wood, Knight's Early Black, Frogmore Blackheart, Black Eagle, Waterloo, Amberheart, Bigarreau, Napoleon Bigarreau, and Turk. A variety of cherry known as the Kentish cherry, of a light red colour and fine subacid flavour, is much grown in Kent for drying and cooking purposes. Another cherry, similar in colour and quality, which comes rather late, known as the Flemish, is also extensively cultivated, as well as the very dark red large Morella, used for making cherry brandy. These three varieties are grown extensively as pyramids, and the last-named also on walls and sides of buildings. Sometimes the cherry crop is sold by auction to dealers, who pick, pack, and consign the fruit to market. Large prices are often made, as much as £80 per acre being not uncommon. The crop on a large cherry orchard in Mid Kent has been sold for more than £100 per acre.

Where old standard trees have been long neglected and have become overgrown by mosses and lichens, the attempts made to improve them seldom succeed. The introduction of bush fruit trees dwarfed by grafting on the Paradise stock has been of much advantage to fruit cultivators, as they come into bearing in two or three years, and are more easily cultivated, pruned, sprayed, and picked than standards. Many plantations of these bush trees have been formed in Kent of apples, pears, and plums. Half standards and pyramids have also been planted of these fruits, as well as of cherries. Fruit bushes of gooseberries and currants, and of raspberry canes, have been planted to a great extent in many parts of the East and Mid divisions of Kent, but not much in the Weald, where apples are principally grown. Sometimes fruit bushes are put in alternate rows with bush trees of apple, pear, plum, and damson, or other standards, or they are planted by themselves. The distances apart for planting are generally for cherry and apple trees on grass 30 feet by 30 feet; for standard apples and pear trees from 20 feet to 24 feet upon arable land, with bush fruit, as gooseberries and currants, under them. These are set 6 feet by 6 feet apart, and 5 feet by 2 feet for raspberries, and strawberries 2 feet 6 inches to 3 feet by 1 foot 6 inches to 1 foot 3 inches apart. On some fruit farms bush or dwarf trees—apples, pears, plums—are planted alone, at distances varying from 8 feet to 10 feet apart, giving from 485 to 680 bush trees per acre, nothing being grown between them except perhaps strawberries or vegetables during the first two or three years. It is believed that this is the best way of ensuring fruit of high quality and colour. Another arrangement consists in putting standard apple or pear trees 30 feet apart (48 trees per acre), and setting bush trees of apples or pears 15 feet apart between them; these latter come quickly into bearing, and are removed when the standards are fully grown. Occasionally gooseberry or currant bushes, or raspberry canes or strawberry plants, are set between the bush trees, and taken away directly they interfere with the growth of these. Half standard apple or plum trees are set triangularly 15 feet apart, and strawberry plants at a distance of 1½ foot from plant to plant and 2½ feet from row to row. Or currant or gooseberry bushes are set between the half standards, and strawberry plants between these.

These systems involve high farming. The manures used are London manure, where hops are not grown, and bone meal, superphosphate, rags, shoddy, wool-waste, fish refuse, nitrate of soda, kainit, and sulphate of ammonia. Where hops are grown the London manure is wanted for them. Fruit plantations are always dug by hand with the Kent spud. Fruit land is never ploughed, as in the United States and Canada. The soil is levelled down with the "Canterbury" hoe, and then the plantations are kept free from weeds with the ordinary or "plate" hoe. The best fruit farmers spray fruit trees regularly in the early spring, and continue until the blossoms come out, with quassia and soft soap and paraffin emulsions, and a very few with Paris green only, where there is no under fruit, in order to prevent and check the constant attacks of the various caterpillars and other insect pests. This is a costly and laborious process, but it pays well, as a rule. The fallacy that fruit trees on grass land require no manure, and that the grass may be allowed to grow up to their trunks without any harm, is exploding, and many fruit farmers are well

[1] *Jour. Roy. Agric. Soc.*, 1899.

manuring their grass orchards and removing the grass for some distance round the stems, particularly where the trees are young.

Strawberries are produced in enormous quantities in the northern part of the Mid Kent district round the Crays, and from thence to Orpington; also near Sandwich, and to some extent near Maidstone. Raspberry canes have been extensively put in during the last few years, and in some seasons yield good profits. There is a very great and growing demand for all soft fruits for jam-making, and prices are fairly good, taking an average of years, notwithstanding the heavy importations from France, Belgium, Holland, Spain, and Italy. The extraordinary increase in the national demand for jam and other fruit preserves has been of great benefit to Kent fruit producers. The cheapness of duty-free sugar, as compared with sugar paying duty in the United States and other large fruit-producing countries, afforded one of the very few advantages possessed by British cultivators, but the re-imposition of the sugar duty in the United Kingdom in 1901 has modified the position in this respect. Jam factories were established in several parts of Kent about 1889 or 1890, but most of them collapsed either from want of capital or from bad management. There are still a few remaining, principally in connexion with large fruit farms. One of these is at Swanley, whose energetic owners farm nearly 2000 acres of fruit land in Kent. The fruit grown by them that will not make satisfactory prices in a fresh raw state is made into jam, or if time presses it is first made into pulp, and kept until the opportunity comes for making it into jam. In this factory there are fifteen steam-jacketed vats in one row, and six others for candied peel. A season's output on a recent occasion comprised about 3500 tons of jam, 850 tons of candied peel, and 750 gross (108,000 bottles) of bottled fruit. A great deal of the fruit preserved is purchased, whilst much of that grown on the farms is sold. A strigging machine is employed, which does as much work as fifty women in taking currants off their strigs or stalks. Black currant pulp is stored in casks till winter, when there is time to convert it into jam. Strawberries cannot be pulped to advantage, but it is otherwise with raspberries, the pulp of which is largely made. Apricots for jam are obtained chiefly from France and Spain. There is another flourishing factory near Sittingbourne worked on the same lines. It is very advantageous to fruit farmers to have jam factories in connexion with their farms, or to have them near, as they can thoroughly grade their fruit, and send only the best to market, thus ensuring a high reputation for its quality. Carriage is saved, which is a serious charge, though railway rates from Kent to the great manufacturing towns and to Scotland are very much less proportionally than those to London, and consequently Kent growers send increasing quantities to these distant markets, where prices are better, not being so directly interfered with by imported fruit, which generally finds its way to London.

Kentish fruit-growers are becoming more particular in picking, grading, packing, and storing fruit, as well as in marketing it. A larger quantity of fruit is now carefully stored, and sent to selected markets as it ripens, or when there is an ascertained demand, as it is found that if it is consigned to market direct from the trees there must frequently be forced sales and competition with foreign fruit that is fully matured and in good order. It was customary formerly for Kentish growers to consign all their fruit to the London markets; now a good deal of it is sent to Manchester, Birmingham, Liverpool, Sheffield, Newcastle, and other large cities. Some is sent even to Edinburgh. Many large growers send no fruit to London now. It is by no means uncommon for growers to sell their fruit crops on the trees or bushes by auction or private treaty, or to contract to supply a stipulated quantity of specified fruit, say of currants, raspberries, or strawberries, to jam manufacturers. There is a considerable quantity of fruit, such as grapes, peaches, nectarines, grown under glass, and this kind of culture tends to increase.

Filberts and cob-nuts are a special product of Kent, in the neighbourhood of Maidstone principally, and upon the Ragstone soils, certain conditions of soil and situation being essential for their profitable production. A part of the filbert and cob-nut crop is picked green in September, as they do well for dessert, though their kernels are not large or firm, and it pays to sell them green, as they weigh more heavily. One grower in Mid Kent has 100 acres of nuts, and has grown 100 tons in a good year. The average price of late years has been about 5d. per lb, which would make the gross return of the 100 acres amount to £4660. Kentish filberts have long been proverbial for their excellence. Cobs are larger and look better for dessert, though their flavour is not so fine. They are better croppers, and are now usually planted. This cultivation is not much extending, as it is very long before the trees come into full bearing. The London market is supplied entirely with these nuts from Kent, and there is some demand in America for them. Filbert and cob trees are most closely pruned. All the year's growth is cut away except the very finest young wood, which the trained eye of the tree-cutter sees at a glance is blossom-bearing. The trees are kept from 5½ to 7 feet high upon stems from 1½ to 2 feet high, and are trained so as to form a cup of from 7 to 8 feet in diameter.

There seems no reason to expect any decrease in the acreage of fruit land in Kent, and if the improvement in the selection of varieties and in the general management continues it will yet pay. A hundred years ago every one was grubbing fruit land in order that hops might be planted, and for this many acres of splendid cherry orchards were sacrificed. Now the disposition is to grub hop plants and substitute cherry trees.

Fruit-Growing in other Districts.

The large fruit plantations in the vicinity of the metropolis are to be found mostly in the valley of the Thames above London, around such centres as Richmond, Hounslow, Cranford, and Southall. All varieties of orchard trees and small fruit are grown in these districts, the nearness of which to the metropolitan fruit market at Covent Garden is of course an advantage. Some of the orchards are old, and are not managed on modern principles. They contain, moreover, varieties of fruit many of which are out of date and would not be employed in establishing new plantations. In the better-managed grounds the antiquated varieties have been removed, and their places taken by newer and more approved types. In addition to apples, pears, plums, damsons, cherries, and quinces as top fruit, currants, gooseberries, and raspberries are grown as bottom fruit. Strawberries are extensively grown in some of the localities, and occasionally outdoor tomatoes are ripened and marketed.

Fruit is extensively grown in Cambridgeshire and adjacent counties in the east of England. A leading centre is Cottenham, where the Lower Greensand crops out and furnishes one of the best of soils for fruit-culture. In Cottenham about a thousand acres are devoted to fruit, and nearly the same acreage to asparagus, which is, however, giving place to fruit. Plums and gooseberries are the most largely grown, apples, currants, and raspberries following. Of varieties of plums the Victoria is first in favour, and then Rivers's Early Prolific, Tsar, and Gisborne. London is the chief market, as it receives about half the fruit sent away, whilst a considerable quantity goes to Manchester, and some is sent to a neighbouring jam factory at Histon, where also a moderate acreage of fruit is grown. Another fruit-growing centre in Cambridgeshire is at Willingham, where—besides plums, gooseberries, and raspberries—outdoor tomatoes are a feature. Greengages are largely grown near Cambridge. Wisbech is the centre of an extensive fruit district, situated partly in Cambridgeshire and partly in Norfolk. Gooseberries, strawberries, and raspberries are largely grown, and as many as 80 tons of the first-named fruit have been sent away from Wisbech station in a single day. In the fruit-growing localities of Huntingdonshire plums and gooseberries are the most extensively grown, but apples, pears, greengages, cherries, currants, strawberries, and raspberries are also cultivated. As illustrating variations in price, it may be mentioned that about the year 1880 the lowest price for gooseberries was £10 per ton, whereas it has since been down to £4. Huntingdonshire fruit is sent chiefly to Yorkshire, Scotland, and South Wales, but railway freights are high.

Essex affords a good example of successful fruit-farming at Tiptree Heath, near Kelvedon, where under one management about 260 acres out of a total of 360 are under fruit. The soil, a stiff loam, grows strawberries to perfection, and 165 acres are allotted to this fruit. The other principal crops are 43 acres of raspberries and 30 acres of black currants, besides which there are small areas of red currants, gooseberries, plums, damsons, greengages, cherries, apples, quinces, and blackberries. The variety of strawberry known as the Small

Scarlet is a speciality here, and it occupies 55 acres, as it makes the best of jam. The Paxton, Royal Sovereign, and Noble varieties are also grown. Strawberries stand for six or seven years on this farm, and begin to yield well when two years old. A jam factory is worked in conjunction with the fruit farm. Pulp is not made except when there is a glut of fruit. Perishable fruit intended for whole-fruit preserves is never held over after it is gathered. The picking of strawberries begins at 4 A.M., and the first lot is made into jam by 6 A.M.

Hampshire, like Cambridgeshire and Norfolk, is one of the few counties in which the area of small fruit exceeds that of orchards, the former in 1901 being returned at 2382 acres, and the latter at 2078 acres. Compared with a dozen years previously, the acreage of small fruit has trebled. This is largely due to the extension of strawberry culture in the Southampton district, where the industry is in the hands of many small growers, few of whom cultivate more than 20 acres each. Sarisbury and Botley are the leading parishes in which the business is carried on. Most of the strawberry holdings are from half an acre to 5 acres in extent, a few are from 5 to 10 acres, fewer still from 10 to 20 acres, and only half-a-dozen over that limit. Runners from one-year plants are used for planting, being found more fruitful than those from older plants. Peat moss manure from London stables is much used, but artificial manures are also employed with good results. Shortly after flowering the plants are bedded down with straw at the rate of about 25 cwt. per acre. Picking begins some ten days earlier than in Kent, at a date between 1st June and 15th June. The first week's gathering is sent mostly to London, but subsequently the greater part of the fruit goes to the Midlands and to Scotland and Ireland.

In recent years fruit-growing has much increased in South Worcestershire, in the vicinity of Evesham and Pershore. Hand-lights are freely used in the market gardens of this district for the protection of cucumbers and vegetable marrows, besides which tomatoes are extensively grown out of doors. The egg plum and the Worcester damson are the chief fruit crops, apples and cherries ranking next, pears being grown to only a moderate extent. In a prolific season a single tree of the Damascene or Worcester damson will yield from 400 to 500 ℔ of fruit. There is a tendency to grow plum trees in the bush shape, as they are less liable than standards to injury from wind. The manures used include soot, fish guano, blood manure, and phosphates—basic slag amongst the last named. In the Pershore district, where there is a jam factory, plums are the chief tree fruit, whilst most of the orchard apples and pears are grown for cider and perry. Gooseberries are a feature, as are also red and black currants and a few white, but raspberries and strawberries are little grown, and cherries much less than formerly. The soil, a strong or medium loam of fair depth, resting on clay, is so well adapted to plums that trees live for fifty years. In order to check the ravages of the winter moth, plum and apple trees are grease-banded at the beginning of October and again at the end of March. The trees are also sprayed when necessary with insecticidal solutions. Pruning is done in the autumn. An approved distance apart at which to grow plum trees is 12 feet by 12 feet. In the Earl of Coventry's fruit plantation, 40 acres in extent, at Croome Court, plums and apples are planted alternately, the bottom fruit being black currants, which are less liable to injury from birds than are red currants or gooseberries. Details concerning the methods of cultivation of fruit and flowers in various parts of England, the varieties commonly grown, the expenditure involved, and allied matters, will be found in Mr W. E. Bear's papers in the *Journal of the Royal Agricultural Society* in 1898 and 1899.

The Woburn Experimental Fruit Farm.

The establishment in 1894 of the experimental fruit farm at Ridgmont, near Woburn, Beds, is likely to exercise a healthy influence upon the progress and development of fruit-farming in England. The farm was founded, and is carried on, by the public-spirited enterprise of the Duke of Bedford and Mr Spencer U. Pickering, the latter acting as director. The main object of the experimental station is "to ascertain facts relative to the culture of fruit, and to increase our knowledge of, and to improve our practice in, this industry." The farm is 20 acres in extent, and occupies a field which up to June 1894 had been used as arable land for the ordinary rotation of farm crops. The soil is a sandy loam 9 or 10 inches deep, resting on a bed of Oxford Clay. Although it contains a large proportion of sand, the land would generally be termed very heavy, and the water often used to stand on it in places for weeks together in a wet season. The tillage to which the ground was subjected for the purposes of the fruit farm much improved its character, and in dry weather it presents as good a tilth as could be desired. Chemical analyses of the soil from different parts of the field show such wide differences that it is admitted to be by no means an ideal one for experimental purposes. Without entering upon further details, it may be useful to give a summary of the chief results hitherto obtained.

Apples have been grown and treated in a variety of ways, but of the different methods of treatment careless planting, coupled with subsequent neglect, has given the most adverse results, the crop of fruit being not 5 per cent. of that from trees grown normally. Of the separate deleterious items constituting total neglect, by far the most effective was the growth of weeds on the surface; careless planting, absence of manure, and the omission of trenching all had comparatively little influence on the results. A set of trees that had been carelessly planted and neglected, but subsequently tended in the early part of 1896, were in the autumn of that year only 10 per cent. behind their normally-treated neighbours, thus demonstrating that the response to proper attention is prompt. The growth of grass around young apple trees produced a very striking effect, the injury being much greater than that due to weeds. It is possible, however, that in wet years the ill effects of both grass and weeds would be less than in dry seasons. Nevertheless, the grass-grown trees, after five years, were scarcely bigger than when planted, and the actual increase in weight which they showed during that time was about eighteen times smaller than in the case of similar trees in tilled ground. It is believed that one of the main causes of the ill effects is the large increase in the evaporation of water from the soil which is known to be produced by grass, the trees being thereby made to suffer from drought, with constant deprivation of other nourishment as well. That grass growing round young apple trees is deleterious was a circumstance known to many horticulturists, but the extent to which it interferes with the development of the trees had never before been realized. Thousands of pounds are annually thrown away in England through want of knowledge of this fact. Yet trees will flourish in grass under certain conditions, and there were signs that those on the farm were in 1900 beginning to get over the baneful influence of the grass. Whether the dominant factor is the age (or size) of the tree is being investigated by grassing over trees which have hitherto been in the open ground, and so far (1901), the results appear to indicate that the grass is as deleterious to the older trees as it was to the younger ones. Again, it appears to have been demonstrated that young apple trees, at all events in certain soils, require but little or no manure in the early stages of their existence, so that in this case also large sums must be annually wasted upon manurial dressings which produce no effects. The experiments have dealt with dwarf trees of Bramley, Cox, and Potts, six trees of each variety constituting one investigation. Some of the experiments were repeated with Stirling Castle, and others with standard trees of Bramley, Cox, and Lane's Prince Albert. All were planted in 1894–95, the dwarfs being then three years old and the standards four. In each experiment the "normal" treatment is altered in some one particular, this normal treatment consisting of planting the trees carefully in trenched ground, and subsequently keeping the surface clean; cutting back after planting, pruning moderately in autumn, and shortening the growths when it appeared necessary in summer; giving in autumn a dressing of mixed mineral manures, and in February one of nitrate of soda, this dressing being probably equivalent to one of 12 tons of dung per acre. In the experiments on branch treatment, the bad effects of omitting to cut the trees back on planting, or to prune them subsequently, is evident chiefly in the straggling and bad shape of the resulting trees, but such trees also are not so vigorous as they should be. The quantity of fruit borne, however, is in excess of the average. The check on the vigour and growth of a tree by cutting or injuring its roots is in marked contrast with the effects of a similar interference with the branches. Trees which had been root-pruned each year were in 1898 little more than half as big as the normal trees, whilst those root-pruned every second year were about two-thirds as big as the normal. The crops borne by these trees were nevertheless heavy in proportion to the size of the trees. Such frequent root-pruning is not, of course, a practice which should be adopted. It was found that trees which had been carefully lifted every other year and replanted at once experienced no ill effects from the operation; but in a case where the trees after being lifted had been left in a shed for three days before replanting—which would reproduce to a certain extent the conditions experienced when trees are sent out from a nursery—material injury was suffered, these trees after four years being 28 per cent. smaller than similar ones which had not been replanted. Sets of trees planted respectively in November, January, and March have, on the whole, shown nothing in favour of any of these different times for planting purposes. Some doubt is thrown on the accepted view that there is a tendency, at any rate with young apple and pear trees, to fruit in alternate seasons.

Strawberries of eighty-five different varieties have been experimented with, each variety being represented in 1900 by plants of five different ages, from one to five years. In 1896 and 1898 the crops of fruit were about twice as heavy as in 1897 and 1899, but it has not been found possible to correlate these variations with the meteorological records of the several seasons. Taking the average of all the varieties, the relative weights of crop per plant, when these are compared with the two-year-old plants in the same season, are, for the five ages of one to five years, 31, 100, 122, 121, and 134, apparently showing that the bearing power increases rapidly up to two years, less rapidly up to three years, after which age it remains practically constant. The relative average size of the berries shows a deterioration with the age of the plant. The comparative sizes from plants of one to five years old were 115, 100, 96, 91, and 82 respectively. If the money value of the crop is taken to be directly dependent on its total weight, and also on the size of the fruits, the relative values of the crop for the different ages would be 34, 100, 117, 111, and 110, so that, on the Ridgmont ground, strawberry plants could be profitably retained up to five years, and probably longer. As regards what may be termed the order of merit of different varieties of strawberries, it appears that even small differences in position and treatment cause large variations, not only in the features of the crop generally, but also in the relative behaviour of the different varieties. The relative cropping power of the varieties under apparently similar conditions may often be expressed by a number five or tenfold as great in one case as in the other. A comparison of the relative behaviour of the same varieties in different seasons is attended by similar variations. The varying sensitiveness of different varieties of strawberry plants to small and undefinable differences in circumstances is indeed one of the most important facts brought to light in the experiments. Manurial experiments upon strawberries, as well as upon raspberries, gooseberries, black, red, and white currants, are not sufficiently advanced to permit the establishment of conclusions of practical value.

The Flower-Growing Industry.

During the last two or three decades of the 19th century a very marked increase in flower production occurred in England. Notably was this the case in the neighbourhood of London, where, within a radius of 15 or 20 miles, the fruit crops, which had largely taken the place of garden vegetables, were themselves ousted in turn to satisfy the increasing demand for land for flower cultivation. No flower has entered more largely into the development of the industry than the narcissus or daffodil, of which there are now some 600 varieties, fully one-fourth of these being worth cultivating. On some flower farms a dozen or more acres are devoted to narcissi alone, the production of bulbs for sale as well as of flowers for market being the object of the growers.

In the London district the country in the Thames valley, west of the metropolis, is as largely occupied by flower farms as it is by fruit farms—in fact, the cultivation of flowers is commonly associated with that of fruit. In the vicinity of Richmond narcissi are extensively grown, as they also are more to the west in the Long Ditton district, and likewise around Twickenham. Roses come more into evidence in the neighbourhood of Hounslow, Cranford, and Ealing, and in some gardens daffodils and roses occupy alternate rows. South of London is the Mitcham country, long noted for its production of lavender. The incessant growth of the lavender plant upon the same land, however, has led to the decline of this industry, which has been largely transferred to districts in the counties of Bedford, Essex, and Hertford. At Mitcham, nevertheless, mixed flowers are very largely grown for the supply of the metropolis, and one farm alone has nearly 100 acres under flowers and glass-houses. Chrysanthemums, asters, Iceland poppies, gaillardias, pansies, calceolarias, geraniums, and other plants are cultivated in immense quantities. At Swanley and Eynsford, in Kent, flowers are extensively cultivated in association with fruit and vegetables. Narcissi, chrysanthemums, violets, carnations, campanulas, roses, pansies, irises, sweet peas, and many other flowers are here raised, and disposed of in the form both of cut flowers and of plants.

The Scilly Isles are important as providing the main source of supply of flowers to the English markets in the early months of the year. This trade arose almost by accident, for it was about the year 1870 that a box of narcissi sent to Covent Garden Market, London, realized £1; and the knowledge of this fact getting abroad, the farmers of the isles began collecting wild bulbs from the fields in order to cultivate them and increase their stocks. Some ten years, however, elapsed before the industry promised to become remunerative. In 1885 a Bulb and Flower Association was established to promote the industrial growth of flowers. The exports of flowers in that year reached 65 tons, and they steadily increased until 1893, when they amounted to 450 tons. A slight decline followed, but in 1896 the quantity exported was no less than 514 tons. This would represent upwards of $3\frac{1}{2}$ million bunches of flowers, chiefly narcissi and anemones. Rather more than 500 acres are devoted to flower-growing in the isles, by far the greater part of this area being assigned to narcissi, whilst anemones, gladioli, marguerites, arum lilies, Spanish irises, pinks, and wallflowers are cultivated on a much smaller scale. The great advantage enjoyed by the Scilly flower-growers is earliness of production, due to climatic causes; the soil, moreover, is well suited to flower culture, and there is an abundance of sunshine. The long journey to London is somewhat of a drawback, in regard to both time and freight, but the earliness of the flowers more than compensates for this. Open-air narcissi are usually ready at the beginning of January, and the supply is maintained in different varieties up to the middle or end of May. The narcissus bulbs are usually planted in October, 4 inches by 3 inches apart for the smaller sorts and 6 inches by 4 to 6 inches for the larger. A compost of farmyard manure, seaweed, earth, and road scrapings is the usual dressing, but nitrate of soda, guano, and bones are also occasionally employed. A better plan, perhaps, is to manure heavily the previous crop, frequently potatoes, no direct manuring then being needed for the bulbs, these not being left in the ground more than two or three years. The expenses of cultivation are heavy, the cost of bulbs alone—of which it requires nearly a quarter of a million of the smaller varieties, or half as many of the largest, to plant an acre—being considerable. The polyanthus varieties of narcissus are likely to continue the most remunerative to the flower-growers of Scilly, as they flourish better in these isles than on the mainland.

In the district around the Wash, in the vicinity of such towns as Wisbech, Spalding, and Boston, the industrial culture of bulbs and flowers underwent great expansion in the period between 1880 and 1900. At Wisbech one concern alone has a farm of some 900 acres, devoted chiefly to flowers and fruit, the soil being a deep fine alluvium. Roses are grown here, one field containing upwards of 100,000 trees. Nearly 20 acres are devoted to narcissi, which are grown for the bulbs and also, together with tulips, for cut flowers. Carnations are cultivated both in the field and in pots. Cut flowers are sent out in large quantities, neatly and effectively packed, the parcel post being mainly employed as a means of distribution. In the neighbourhood of Spalding crocuses and snowdrops are less extensively grown than used to be the case. On one farm, however, upwards of 20 acres are devoted to narcissi alone, whilst gladioli, lilies, and irises are grown on a smaller scale. Around Boston narcissi are also extensively grown for the market, both bulbs and cut blooms being sold. The bulbs are planted 3 inches apart in rows, the latter being 9 inches apart, and are allowed to stand from two to four years.

The imports of fresh flowers into the United Kingdom were not separately shown prior to 1900. In that year, however, their value amounted to £200,585, and in 1901 to £225,011. From the monthly totals quoted in Table VI. it would appear that the trade sinks to its minimum dimensions in the four months July to October inclusive,

Table VI.—Values of Fresh Flowers imported into the United Kingdom in each month of 1900 and 1901

Month.	1900.	1901.
January	£27,991	£26,521
February	24,888	25,525
March	34,693	45,655
April	40,256	45,848
May	22,506	22,586
June	12,245	11,433
July	2,305	2,523
August	821	1,252
September	632	478
October	3,962	4,026
November	11,671	17,173
December	18,615	21,991
Total	£200,585	£225,011

and that after September the business continually expands—excepting in February, for the shortness of which month allowance must be made—up to April, subsequent to which contraction again sets in. About one-half of the trade belongs practically to the three months of February, March, and April.

Hothouse Culture of Fruit and Flowers.

The cultivation of fruit and flowers under glass has increased enormously since about the year 1880, especially in the neighbourhood of London, where large sums of money have been sunk in the erection and equipment of hothouses. In the parish of Cheshunt, Herts, alone there are upwards of 130 acres covered with glass, and between that place on the north and London on the south extensive areas of land are similarly utilized. At Erith, Swanley, and other places in Kent, as also at Worthing, in Sussex, glass-house culture has much extended. A careful estimate puts the area of industrial hothouses in England at about 1200 acres, representing a tenfold increase within the space of thirty years. The leading products are grapes, tomatoes, and cucumbers, the last-named two being true fruits from the botanist's point of view, though commercially included with vegetables. Peaches, nectarines, and strawberries are largely grown under glass, and, in private hothouses—from which the produce is used mainly for household consumption, and which are not taken into consideration here—pineapples, figs, and other fruit. Conservative estimates indicate the average annual yield of hothouse grapes to be about 12 tons per acre, and of tomatoes 20 tons. The greater part of the space in the hothouses is assigned to fruit, but whilst some houses are devoted exclusively to flowers, in others, where fruit is the main object, flowers are forced in considerable quantities in winter and early spring. The flowers grown under glass include tulips, hyacinths, primulas, cyclamens, spiræas, mignonettes, fuchsias, calceolarias, lilies, geraniums, roses, chrysanthemums, and many others. There is an increasing demand for foliage hothouse plants, such as ferns, palms, crotons, aspidistras, and solanums. Tomatoes are grown largely in vineries and in cucumber-houses, as also in houses exclusively occupied by them, in which case two and sometimes three crops can be gathered in the year. In the Channel Islands, where potatoes grown under glass are lifted in April and May, in order to secure the high prices of the early markets, tomato seedlings are planted out from boxes into the ground as quickly as the potatoes are removed, the tomato planter working only a few rows behind the potato digger. The trade in imported tomatoes is so considerable that home growers are well justified in their endeavours to meet the demand more fully with native produce, whether raised under glass or in the open. Tomatoes were not separately enumerated in the imports previous to 1900. It has already been stated that in 1900 the raw tomatoes imported amounted to 833,032 cwt., valued at £792,339, and in 1901 to 793,991 cwt., valued at £734,051. From the monthly quantities given in Table VII., it would appear that the imports are largest

TABLE VII.—Quantities of Tomatoes imported into the United Kingdom in each month of 1900 and 1901.

Month.	1900.	1901.
	Cwt.	Cwt.
January	27,496	37,768
February	38,420	36,310
March	46,888	49,576
April	44,746	57,007
May	47,199	33,590
June	123,032	100,738
July	160,303	186,535
August	115,152	132,786
September	91,468	75,412
October	66,061	37,490
November	36,906	20,924
December	35,361	25,855
Total	833,032	793,991
Value	£792,339	£734,051

in June, July, and August, about one-half of the year's total arriving during those three months. It is too early in June and July for home-grown outdoor tomatoes to enter into competition with the imported product, but home-grown hothouse tomatoes should be qualified to challenge this trade.

Prospects of the Fruit and Flower-Growing Industries.

As regards open-air fruit-growing, the outlook for new ventures is perhaps brighter than in the hothouse industry, not—as Mr Bear has pointed out—because the area of fruit land in England is too small, but because the level of efficiency, from the selection of varieties to the packing and marketing of the produce, is very much lower in the former than in the latter branch of enterprise. In other words, whereas the practice of the majority of hothouse nurserymen is so skilled, so up-to-date, and so entirely under high pressure that a new competitor, however well trained, will find it difficult to rise above mediocrity, the converse is true of open-air fruit-growers. Many, and an increasing proportion, of the latter are thoroughly efficient in all branches of their business, and are in possession of plantations of the best market varieties of fruit, well cultivated, pruned, and otherwise managed. But the extent of fruit plantations completely up to the mark in relation to varieties and treatment of trees and bushes, and in connexion with which the packing and marketing of the produce are equally satisfactory, is small in proportion to the total fruit area of the country. Information concerning the best treatment of fruit trees has spread widely in recent years, and old plantations, as a rule, suffer from the neglect or errors of the past, however skilful their present holders may be. Although the majority of professional market fruit-growers may be well up to the standard in skill, there are numerous contributors to the fruit supply who are either ignorant of the best methods of cultivation and marketing, or careless in their application. The bad condition of the great majority of farm orchards is notorious, and many landowners, farmers, and amateur gardeners who have planted fruit on a more or less extensive scale have mismanaged their undertakings. For these reasons new growers of open-air fruit for market have opportunities of succeeding by means of superiority to the majority of those with whom they will compete, provided that they possess the requisite knowledge, energy, and capital. It has been asserted on sound authority that there is no chance of success for fruit-growers except in districts favourable as regards soil, climate, and nearness to a railway or a good market; and, even under these conditions, only for men who have had experience in the industry and are prepared to devote their unremitting attention to it. Most important is it to a beginner that he should ascertain the varieties of fruit that flourish best in his particular district. Certain kinds seem to do well or fairly well in all parts of the country; others, whilst heavy croppers in some localities, are often unsatisfactory in others.

As has been intimated, there is probably in England less room for expansion of fruit culture under glass than in the open. The large increase of glass-houses in recent years appears to have brought the supply of hothouse produce, even at greatly reduced prices, at least up to the level of the demand; and as most nurserymen continue to extend their expanse of glass, the prospect for new competitors is not a bright one. Moreover, the vast scale upon which some of the growers conduct the hothouse industry puts small producers at a great disadvantage, not only because the extensive producers can grow grapes and other fruit more economically than small growers—with the possible exception of those who do all or nearly all their own work—but also, and still more, because the former have greater advantages in transporting and marketing their fruit. There has, in recent years, been a much greater fall in the prices of hothouse than of open-air fruit, especially under the existing system of distribution, which involves the payment by consumers of 50 to 100 per cent. more in prices than growers receive. The best openings for new nurseries are probably, not where they are now to be found in large groups, and especially not in the neighbourhood of London, but in suitable spots near the great centres of population in the Midlands and the North, or big towns elsewhere not already well supplied with nurseries. By such a selection of a locality the beginner may build up a retail trade in hothouse fruit, or at least a trade with local fruiterers and grocers, thus avoiding railway charges and salesmen's commissions to a great extent, though it may often be advantageous to send certain kinds of produce to a distant market. Above all, a man who has no knowledge of the hothouse industry should avoid embarking his capital in it, trusting himself in the hands of a foreman, as experience shows that such a venture usually leads to disaster. Some years of training in different nurseries are desirable for any young man who is desirous of becoming a grower of hothouse fruit.

There can be no doubt that flower-growing is greatly extending in England, and that competition among home growers is becoming more severe. Foreign supplies of flowers have increased, but not nearly as greatly in proportion as home supplies, and it seems clear that home growers have gained ground in relation to their foreign rivals, except with respect to flowers for the growth of which foreigners have extraordinary natural advantages. There seems some danger of the home culture of the narcissus being over-done, and the chrysanthemum appears to be produced in excess of the demand. Again, in the production of violets, the warm and sunny South of France has an advantage not possessed by England, whilst Holland, likewise for climatic reasons, maintains her hold upon the hyacinth and tulip trade. Whether the production of flowers as a whole is gaining ground upon the demand or not is a difficult question to answer. It is true that the prices of flowers have fallen generally; but production, at any rate under glass, has been cheapened, and if a fair profit can be obtained, the fall in prices, without which the existing consumption of flowers would be impossible, does not necessarily imply over-production. There is some difference of opinion among growers upon this point; but nearly all agree that profits are now so small that production on a large scale is necessary to provide a fair income. Industrial flower-growing affords such a wide scope for the exercise of superior skill, industry, and alertness, that it is not surprising to find some who are engaged in it doing remarkably well to all appearance, while others are struggling on and hardly paying their way. That a man with only a little capital, starting in a small way, has many disadvantages is certain; also that his chance of saving money and extending his business quickly is much smaller than it was. To the casual looker-on, who knows nothing of the drudgery of the industry, flower-growing seems a delightful method of getting a living. That it is an entrancing pursuit there is no doubt; but it is equally true that it is a very arduous one, requiring careful forethought, ceaseless attention, and abundant energy. Fortunately for those who might be tempted, without any knowledge of the industry, to embark capital in it, flower-growing, if at all comprehensive in scope, so obviously requires a varied and extensive technical knowledge, that any one can see that a thorough training is necessary to a man who intends to adopt it as a business, especially if hothouse flowers are to be produced.

The market for fruit, and more especially for flowers, is a fickle one, and there is nearly always some uncertainty as to the course of prices. The perishable nature of soft fruit and cut flowers renders the markets very sensitive to anything in the nature of a glut, the occurrence of which is usually attended with disastrous results to producers. Foreign competition, moreover, has constantly to be faced, and it is likely to increase rather than diminish. French growers have a great advantage over the open-air cultivators of England, for the climate enables them to get their produce into the markets early in the season, when the highest prices are obtainable. The geographical advantage which France enjoys in being so near to England is likely, however, to be considerably discounted by the increasing facilities for cold storage in transit, both by rail and sea. The development of such facilities will permit of the retail sale in England of luscious fruit as fresh and attractive as when it was gathered beneath the sunny skies of California. In the case of flowers, fashion is an element not to be ignored. Flowers much in request in one season may meet with very little demand in another, and it is difficult for the producer to anticipate the changes which caprice may dictate. Even for the same kind of flower the requirements are very uncertain, and the white chrysanthemum which is all the rage in one season may be discarded in favour of chrysanthemums of another colour in the next. The sale of fresh flowers for church decoration at Easter has reached enormous dimensions. The irregularity in the date of the festival, however, causes inconvenience to growers. If it falls very early the great bulk of suitable flowers may not be sufficiently forward for sale, whilst a late Easter may find the season too far advanced. The trade in cut flowers, therefore, is generally attended by uncertainty, and often by anxiety. (W. Fr.)

Fryxell, Anders (1795–1881), Swedish historian, was born at Hesselskog, Dalsland, Sweden, on the 7th of February 1795. He was educated at Upsala, took holy orders in 1820, was made a doctor of philosophy in 1821, and in 1823 began to publish the great work of his life, the *Stories from Swedish History.* He did not bring this labour to a close until, fifty-six years later, he published the forty-sixth and crowning volume of his vast enterprise. Fryxell, as a historian, appealed to every class by the picturesqueness of his style and the breadth of his research; he had the gift of awakening to an extraordinary degree the national sense in his readers. In 1824 he published his *Swedish Grammar*, which was long without a rival. In 1833 he received the title of professor, and in 1835 he was appointed to the incumbency of Sunne, in the diocese of Karlstad, where he resided for the remainder of his life. In 1840 he was elected to the Sweden Academy in succession to the poet Wallin (1779–1839). In 1847 Fryxell received from his bishop permission to withdraw from all the services of the Church, that he might devote himself without interruption to historical investigation. Among his numerous minor writings are prominent his *Characteristics of Sweden between 1592 and 1600* (1830), his *Origins of the Inaccuracy with which the History of Sweden in Catholic Times has been Treated* (1847), and his *Contributions to the Literary History of Sweden.* It is now beginning to be seen that the abundant labours of Fryxell were rather of a popular than of a scientific order, and although their influence during his lifetime was unbounded, it is only fair to later and exacter historians to admit that they threaten to become obsolete in more than one direction. On the 21st of March 1881 Anders Fryxell died at Stockholm, and in 1884 his daughter Eva Fryxell (born 1829) published from his MS. an interesting *History of My History*, which was really a literary autobiography and displays the persistency and tirelessness of his industry. (E. G.)

Fuente Ovejuna, a town of Spain, in the province of Cordoba, on a hill near the western limits of the province, in a well-irrigated district. Population about 10,000. Cattle are largely reared in the neighbourhood, which also contains argentiferous lead mines and stone quarries. The local industries are tanning, and the manufacture of soap, flour, and preserved meat. There is trade in wheat, wine, pod-fruit, and honey. The parish church is an old palace of the Knights of Calatrava. There are several other churches—one, the Assumption, with three fine naves and altars. Many ruins still stand on the hills around the town.

Fuenterrabia, an ancient town of Spain, on the French frontier, near the Bay of Biscay. It has begun to revive from the decay into which it had fallen, having become a summer resort for people from the interior of Spain. Hotels and villas have been built in the new part of the town that has sprung up outside the picturesque walled fortress, and there is quite a contrast between the part inside the heavy, half-ruined ramparts, with its narrow, steep streets and curious gable-roofed houses, its fine old church and castle, and its massive town hall, and the new suburbs and fishermen's quarter facing the estuary of the Bidassoa. Many local industries are thriving on the outskirts of the town; rope and net manufactures, flour mills, saw mills, mining railways, paper mills. The population, which is rapidly growing, is over 5000.

Fugue, an exacting and highly organized musical form. It originated in the abundant canonic imitations of early vocal writers, advanced with the growth of instrumental music (chiefly at the hands of famous organists) during the 17th century, and reached a perfection in the works of Bach (1685–1750) which no subsequent writer has surpassed. Fugue is written for two or more parts, and may be vocal or instrumental. Its chief characteristic lies in the equal interest of all its voices. In other great forms—*symphony*, *sonata*, and notably *song*—one voice is usually important while others are subservient, but in fugue all are equally important; and since average listeners only attend with ease to one prominent part, commonly called the tune, fugue is associated with erudition and mental effort, and often dissociated from emotional power, which, however, it can possess to a stupendous degree. Fugue is akin to Canon (see MUSIC, *Ency. Brit.*, vol. xvii. p. 82); Albrechtsberger—Beethoven's master, and an authority—even defines canon as "a kind of fugue." But fugue, inferior in its first loose forms, gradually gained upon the older form in artifice and restraint, and far surpassed it in freedom, magnitude, and expressiveness.

The chief parts of a fugue are:—*Exposition*, which begins with the entry of the subject and ends when all the voices have stated it; *Counter-exposition* (optional), in which the subject is sometimes restated, somewhat differently, but without further modulation; *Episode*, of which several are possible in one fugue, and in which (under a rather misleading name) fragments of the subject or subsidiary subjects are developed to afford both contrast and illumination; *Stretto*, in which interest is heightened by such rapid recurrences of the subject that the successive statements overlap; *Stretto maestrale*, a rare and difficult stretto, in which all voices, entering closely, still preserve the subject unaltered; and *Pedal*, in which the dominant or other note is persistently held through intricate melodic or harmonic devices. (For origin, see Faburden in MUSIC, vol. xvii. p. 81). Such a note, acting as guide to the mind, justifies the greatest complexities while it establishes key; hence its place of importance near the end of a fugue. Other devices common to both fugue and canon are:—*Augmentation*, the doubling in duration of every note in the subject; *diminution*, the reverse process; *inversion*, in which the direction—up or down—of each interval in the subject is reversed. These devices together give endless, even bewildering, varieties of treatment.

The first statement of the theme is technically the *subject;* the second is called *answer*, and is either an exact or modified transposition of the subject into the dominant key. Strict rules (to preserve a perfect tonic and dominant balance) govern this point, and a fugue is styled *real* or *tonal* accordingly. The melody which accompanies the answer is called *counter-subject;* theoretically important, it is sometimes ignored; and a real secondary or companion subject appears later to usurp its place. When the counter-subject is actually sounded with the subject itself, and acquires equal importance, the fugue is called a *double fugue*, or *fugue with two subjects.* In a most effective variety of double fugue, two subjects receive separate expositions, to be ultimately combined.

The historic connexion of fugue with the development of harmonic resource is shown with striking clearness in the greatest collection of fugues, known as Bach's "Forty-eight" (*Wohltemperirte Klavier*). These were written to establish equal right of existence for all keys. This fact and the one-fold nature of fugue form caused Bach, with his unerring instinct and great power, to organize and widen the key kingdom of each degree of the scale. He did this so well that his successors, in developing the superior forms of sonata and symphony, found their key heritage too rich; and only in recent times have composers risen, and that with difficulty, to the intellectual height of the simpler form, perfected nearly two centuries ago. (H. W. D.)

Fukui, a town in the province of Echizen, Nippon, Japan, near the west coast, some miles north by east of Wakasa Bay. It lies in a volcanic district much exposed to earthquakes, and suffered severely during the disturbances of 1891–92, when a chasm over 40 miles long was opened across the Neo valley from Fukui to Katabira. But Fukui has since revived, and is now in a flourishing condition, with several local industries, and a population which increased from 37,000 in 1884 to 42,000 in 1898.

Fukuoka, a town on the north-west coast of the island of Kiushiu, Japan, about 60 miles north by east of Nagasaki. With Hakata, on the opposite side of a small coast stream, it forms a large centre of population, with an increasing export trade and several local industries. Of these the most important is silk-weaving, and Hakata especially is noted for its durable silk fabrics. Fukuoka was formerly the residence of the powerful daimio of Chikuzen, and played a conspicuous part in the mediæval history of Japan; the renowned temple of Yeiyas in the district was destroyed by fire during the revolution of 1868. Population (1892), 55,000; (1898), 66,000. There are several other places of this name in Japan, the most important being FUKUOKA in the province of Mutsu, North Nippon, a railway station on the main line from Tôkyô to Aimori Ura Bay. Population (1900) about 5000.

Fulahs. See NIGERIA.

Fulda, a town and episcopal see of Prussia, province Hesse-Nassau, situated between the Rhön and the Vogel mountains, 69 miles by rail north-east from Frankfort-on-Main. The present cathedral dates from 1704–12, and stands on the site of the former abbey churches, for the first three were all burnt (in 937, 1286, and 1398), and the fourth was pulled down to make room for the existing structure. The interior, which was restored in 1895–96, contains the tomb of St Boniface, the Apostle of the Frisians, and a statue of Charlemagne. The former Benedictine monastery is now used as a theological seminary. The former episcopal palace was built in 1710–13, and now serves municipal purposes. There are several interesting churches, including the round church of St Michael's (822, restored in 1853); the parish church (1770–75), and the church of St Severus (15th century, restored in 1899). Amongst the secular buildings and institutions may be mentioned the library, the episcopal residence, town hall, post office, museum of antiquities, house of the Sisters of Mercy (1884), and monument of the war of 1870–71. There are a couple of seminaries and a school of military music. The town, as distinguished from the abbey, dates from 1208. It is a stronghold of the Ultramontane movement in Germany. Population (1885), 12,284; (1900), 16,903.

Fulham, a metropolitan borough in the county of London, Middlesex, situated on the Thames, 5½ miles south-west of St Paul's, and opposite Putney, with which it is connected by a stone bridge of five arches in place of the old bridge closed in 1886. The new bridge was erected on the site of the aqueduct of the Chelsea Waterworks Company between the years 1882 and 1886. Water mains are laid under the footways of the new bridge to obviate the necessity for a separate aqueduct. Fulham and Hammersmith formed one parish down to 1834, in which year the hamlet of Hammersmith was created a district and separate parish. The streets of Fulham have been largely rebuilt, and the market gardens and open spaces, for which the place was once famous, have been mostly built upon. There is no record of the first erection of a parish church, but the first known rector was appointed in 1242, and probably a church existed a century before this. The earliest portion of the church, which was demolished in 1880–81, did not date farther back than the 15th century. The new church, built from the designs of the late Sir Arthur Blomfield, was consecrated in 1881. The fine old monuments have been preserved and placed in the new church. The Manor House or Fulham Palace is the oldest building in the parish, but much of it has been rebuilt at various times. The oldest portion of the building is the western quadrangle, built by Bishop Fitzjames (1506–22). The Manor of Fulham is said to have been given to Bishop Erkenwald about the year 691 for himself and his successors in the see of London, and Holinshed relates that the bishop of London was lodging in his manor place in 1141, when Geoffrey de Mandeville, riding out from the Tower, took him prisoner. The parliamentary division of Fulham is conterminous with the metropolitan borough. Population (1881), 42,900; (1891), 91,790; (1901), 137,289. An exhaustive history of the parish by C. J. Fèret was published in 1900, entitled *Fulham, Old and New* (3 vols. 4to).

Fulton, capital of Callaway county, Missouri, U.S.A., in 38° 51′ N. and 91° 56′ W., on the Chicago and Alton Railroad. Its site is hilly and its plan somewhat irregular. It has an excellent water-supply from deep wells. Westminster College, situated here, is a Presbyterian institution, founded in 1853. In 1899 it had 10 instructors and 99 students. The Synodical Female College, founded in 1872, is of the same denomination, and had, in 1899, 11 instructors and 104 students. Population (1880), 2409; (1890), 4314; (1900), 4883, of whom 244 were foreign-born and 1167 negroes.

Fumay, a town in the arrondissement of Rocroi, department of Ardennes, France, north of Mézières by rail, on the river Meuse. There are valuable subterranean slate workings, whence slate was quarried as early as the 12th century. The blocks detached are of immense size, 50 to 80 feet and even more in length, and 3 to 6 feet in thickness. They are afterwards cut up into sizes suitable for roofings. There are also important engineering works and forges, one establishment employing 300 workmen. Population (1891), 4869; (1901), 5667.

Functions, Analytic.—Roughly speaking, the first principles of the theory of analytical functions may be developed either after Cauchy or after Weierstrass. The present article attempts to show the character and applications of the latter or strictly elementary theory. To this end space is saved by the omission of details in regard to which information is easily accessible in the English authorities cited on p. 544.

Every variable which enters is capable of the complex form $\xi + i\eta$, where ξ and η are real and $i = \sqrt{-1}$, and can be represented by a point whose rectangular cartesian co-ordinates are ξ and η; the positive square root $(\xi^2 + \eta^2)^{\frac{1}{2}}$ is called the modulus or absolute value of the quantity, and often written $|\xi + i\eta|$; denoting it by r, the angle determined by $\xi = r\cos\theta$, $\eta = r\sin\theta$ is called the phase or argument of the quantity, and, without further convention, is ambiguous by additive integral multiples of 2π. A series of positive integral powers of a complex quantity x, shortly called a power series, which converges for a value c of x, converges both absolutely and uniformly for all values of x whose modulus is less than $|c|$; the region within which the series is intelligible is, therefore, that which is interior to a certain circle, called the circle of convergence; within this circle the series can be differentiated any finite number of times, two series can be multiplied together, &c. If M be a real quantity not exceeded by the modulus of the sum of the series for any value of x whose modulus $|x| = r$ is less than the radius of convergence, the coefficient a_m of the term $a_m x^m$ of the series is in absolute value less than or equal to Mr^{-m}. The series may vanish to order r at $x = 0$, in which case the lowest power of x which enters is x^r; but every other point for which the series vanishes must be at a finite distance from $x = 0$. Thus if two power series in x are equal to one another for an infinite number of values of x lying near $x = 0$, and having this as their *point of condensation*, or *limiting point*, they must agree term by term; this is the so-called principle of indeterminate coefficients. A power series may have an infinite number of zeros, that is, points for which it vanishes, lying within its circle of convergence, but the point of condensation of these zeros cannot lie actually within the circumference of convergence; and any two of its zeros are at finite distance from one another. If $f_i(x)$ be one of an infinite number of series of positive and negative integral powers of x, all convergent for $r < |x| < R$, and the sum $\sum_{i=1}^{\infty} f_i(x)$ be, for $|x| = c$, where $r < c < R$, uniformly convergent in regard to the phase of x, then this sum can be legitimately arranged according to powers of x, the coefficient of any power being the sum of the infinite number of corresponding coefficients in the various series $f_i(x)$. This last result may be called Weierstrass's double series theorem, and compared with the following: if for $i = 1, 2, \ldots \infty$, the infinite series $\sum_{j=1}^{\infty} u_{ij}$ be absolutely convergent, the sum of the moduli of its terms being U_i, and if the sum $\sum_{i=1}^{\infty} U_i$ be convergent, then each of the series $\sum_{i=1}^{\infty} u_{ik}$ is convergent, and their sum $\sum_{k=1}^{\infty}\sum_{i=1}^{\infty} u_{ik}$ is the same as $\sum_{i=1}^{\infty}\sum_{k=1}^{\infty} u_{ik}$. When a real quantity can assume values exceeding by as little as desired a specified value K, but cannot be less than K, we speak of K as the *lower outside value*, or *limiting value*, of the quantity; then a real continuous quantity necessarily arrives actually at its lower outside value, as well as its upper outside value. This fact requires mention; it can be applied, for instance, to show that if an infinite series of rational functions of x converge uniformly in the neighbourhood of every point of a finite and connected region, then it converges uniformly over the whole of that region, namely, the least number of terms which must be suppressed that the absolute value of those following may be less than an assigned ϵ can be taken to be the same for the whole region.

Notion of a Monogenic Analytic Function.—Denote by $f(x)$ the value represented within its circle of convergence C, whose centre is c, by a power series $\Sigma a_m(x-a)^m$; let R be the radius of the circle, and c_1 a point within the circle at distance D from its centre c. A circle Γ, of radius R–D, described with c_1 as centre will lie entirely within C, except at the point of contact. For values of x within Γ the series $f(x)$ can be rearranged in powers of $x - c_1$, and will take the form $f_1(x) = \sum_{n=0}^{\infty} \frac{(x-c_1)^n}{n!} f^{(n)}(c_1)$, where $f^{(n)}(c_1)$ is the value at c_1 of the nth differential coefficient of $f(x)$. The possibility of this rearrangement, namely, the fact that within Γ the series $f_1(x)$ is equal to $f(x)$, follows from Weierstrass's double series theorem. Two alternatives are now possible—either the radius of the circle of convergence C_1 of the series $f_1(x)$ is precisely R–D, or it is greater than R–D. Suppose that it is greater. Then it can be shown that for *all* points of C_1 which lie within C, including those points which lie outside Γ, the value represented by $f_1(x)$ is equal to that represented by $f(x)$. In this case we say that the value represented by $f_1(x)$ for points outside C, or upon the circumference of C, is a *continuation* of $f(x)$. It can then be shown, in part justification of this definition, that if, with a point c_2 internal to C, as centre, we similarly construct a series $f_2(x)$, in $x - c_2$, with a circle of convergence C_2 extending beyond C, and these two circles C_1, C_2 have a common region both within and without C, then the values $f_1(x), f_2(x)$ agree in the common region of C_1 and C_2 lying outside C. It is clear that having once *continued* the function $f(x)$ beyond the circle C, it may be possible to continue it beyond the circle C_1, the series $f_1(x)$ being used as basis. We may then at once make the statement: *It is the aggregate of all such possible continuations which we regard as constituting a monogenic analytical function;* the word *monogenic* having reference to the fact that the various series, in $x-c$, $x-c_1$, $x-c_{11}$,..., which represent the function in different parts of the plane, have a single origin, namely, the series $f(x)$, and *all the properties of the function being virtually contained in this one series;* the word *analytical* having reference to the possibility of obtaining the value of the function in all the region of its existence by the well-defined analytical operation of summing a power series. But the statement is not yet complete. It is convenient to regard all the points of the plane for which x is of infinite modulus, which are all given by the single equation $x^{-1}=0$, as constituting one point, and to regard a series of ascending positive integral powers of x^{-1} as similar to a power series in a quantity $x-c$. Such a series will have a region of convergence given by an equation $|x^{-1}|<R$, consisting therefore of points lying *outside* a circle of finite radius whose centre is the point $x=0$; and such a series may represent a continuation of a function given by a power series in $x-c$ when the regions of the two series have a common part at every point of which the values represented by them agree. *The previous statement of what is meant by a monogenic analytic function requires then to be completed by the convention that by a derived series in* $x-a$, *when* a *is infinite, shall be understood a series of positive integral ascending powers of* x^{-1}. In general it will be sufficient to speak of a function, or of an analytic function, the monogenic character being understood. It is obvious, however, that the definition can in the first instance be accepted only as a limitation of the class of functions to be investigated and not as an analysis of the word function as commonly used to cover any sort of numerical dependence. As a fact it is in the establishment of the confidence that the limitation is not too narrow for practical applications that the development of the later theory marks so great an advance. But the reader should consult the earlier parts of Lagrange's *Théorie des Fonctions Analytiques*, and *Leçons sur le Calcul des Fonctions* (1806).

We return, however, to further consideration of the series $f(x)$, in $x-c$, with circle of convergence C. When we rewrite this series in the form $f_1(x)$, in powers of $(x-c_1)$, it is not possible that for every point c_1, interior to C, the circle of convergence, C_1, of $f_1(x)$, should extend beyond the circle C. If for all points a_1 interior to a circle H within which a series $\phi(x)$, in $x-a$, converges, the lower outside value of the radii of convergence of the derived series $\phi_1(x)$ in $x-a_1$ be a finite quantity D other than zero, then the true radius of convergence of the series $\phi(x)$ can be shown to be greater by D than the radius of the circle H. Hence it follows that there is at least one point upon the circumference of the circle of convergence C of the series $f(x)$ *such that as* c_1 *is taken nearer and nearer to this point the radius of convergence of the derived series* $f_1(x)$, *in* $x-c_1$, *approaches indefinitely to zero.* Such a point is called a *singular* point of the function under consideration; *at* it the function, strictly speaking, is undefined. It may happen that such a singular point is found in every arc of the circumference of convergence, however small the arc. An example is given by either of the series $\sum_{n=1}^{\infty} x^{u_n}$, where $u_n=n!$, or $u_n=n^2$. In such a case the function, so to say, *dies out* on the circumference, and, as a *monogenic* function, cannot be continued over the circumference. But in the more common case, when the original circumference of convergence is not the complete boundary of the region of existence of the function, it is still true that this region has a boundary, that is, cannot consist of all points of the plane (the point $x^{-1}=0$ being counted in, as explained above). For if there be an assignable radius for the circle of convergence of a power series there is, as remarked above, necessarily one singular point upon its circumference; while if the radius of convergence is unlimited it is still true that the point $x^{-1}=0$ cannot be regarded as lying within the circle, since this would involve the obvious impossibility of identity in value, for $x=\infty$, of a power series in x^{-1} with a power series in a quantity $x-c$, wherein c is finite. Thus the singular points of a function constitute the boundary of its region of existence. We consider the possible character of these singular points to some further extent in the next paragraph; in regard to the continuation and the monogenic character of a function the further remarks may be added here. Any rational relation connecting the values of power series, which have a common region of convergence, also connects the values of the series formed by any possible continuation of these series, and therefore may be regarded as a relation connecting the monogenic functions to which they give rise; a series which is not a power series may represent, for different regions, different monogenic functions, as is shown, for instance, by the series $\sum_{n=1}^{\infty}(x^{2n}-x^{-2n})^{-1}$, which for $|x|<1$ represents $x(x-x^{-1})^{-1}$, and for $|x|>1$ represents $x^{-1}(x-x^{-1})^{-1}$.

Single-valued Functions.—It follows from the definition of singular points which has been given, that if a power series be continued from a point A to a point B by two different paths enclosing a region containing no singular points, the values thus obtained at B will be the same. A function which by all continuations within a certain region always takes the same value at any point, is called single-valued in that region; for instance the series $\sum_{n=1}^{\infty}\frac{x^n}{n}$ gives a single-valued function in any closed region which does not surround either of the points $x=1$, $x^{-1}=0$. We consider now briefly functions which are single-valued in the whole plane of x. For such a function $f(x)$ we divide the singular points into two categories: firstly, those which are not singular points of the inverse $1/f(x)$, which we call *poles;* secondly, those which are singular points of $1/f(x)$, which we call *essential singularities.* By the definition of a singular point, every point which is not singular is the centre of a circle of finite, though possibly very small radius, within which there is no singular point; hence if $x=c$ be a pole, $1/f(x)$ must be capable of being represented near this point by a power series in $x-c$, necessarily of the form $(x-c)^m\phi$, where ϕ is a power series in $x-c$ which does not vanish for $x=c$; thus $(x-c)^m f(x)$ must, near $x=c$, be capable of being represented by a power series in $x-c$ not vanishing for $x=c$. The positive integer m is >0 since otherwise $x=c$ would not be a singular point; thus as we approach a pole, by whatever path, the function always increases indefinitely in absolute value, so that no ambiguity would arise by agreeing to consider the function as having the definite value infinity at the pole; moreover, the pole can be made the centre of a circle of finite, if small, radius, within which the function has no other singular point; so that also, in cases where the boundary of the region of existence of the function contains a curve upon every arc of which, however small, there are singular points, no pole of the function can be upon this curve. For such reasons the pole is also called an *unessential* singularity. Replacing $x-c$ by x^{-1} similar remarks apply to the consideration of the case in which $x^{-1}=0$ is a pole. The category of essential singularities, on the other hand, includes very various possibilities. In all cases, if A be a finite constant, the essential singularity c of the function $f(x)$ is easily seen to be an essential singularity both of $f(x)-\mathrm{A}$ and of $1/f(x)$. If it be possible to make c the centre of a circle of not zero radius, within which c is the only singularity of $f(x)$, then within this circle, except at c, the function can be represented as a series $\sum_{n=-\infty}^{\infty} a_n(x-c)^n$, wherein the number of negative terms is infinite (see below, *Laurent's* theorem), and the coefficient a_{-m} is in absolute value less than $\mathrm{M}\,|(x-c)^m|$, where M is the greatest modulus of the function for the value of $|x-c|$. Thence it follows that the function increases indefinitely as x approaches c by a suitable path. If every circle whose centre is c, however small, contains poles of $f(x)$, but no other singularities, the same conclusion follows. In either case c is an essential singularity of the function $1/[f(x)-\mathrm{A}]$, and is the centre of a circle within which no other essential singularities of this function are found; thus this function increases indefinitely as we approach c by a suitable path, and therefore the function $f(x)$ approaches indefinitely to the arbitrary value A as we approach c by a suitable path. Both results may be included in the statement that near an essential singularity which is isolated from other essential singularities, points can be found at which the function differs as little as desired from any assigned value, or is greater than any assigned value. In fact it can be proved that there are in general points near $x=c$, at which the function is actually equal to any assigned value, two values, at most, being excepted. For instance, the function $e^{\frac{1}{x-c}}$ approaches as near as we please to any assigned value for values of x near c, and becomes equal to any assigned value other than the two 0 and ∞. But when the essential singularity is not finitely distant from other essential singularities, as for instance is the case of the essential singularities of the function $\sum_{n=1}^{\infty} x^{n^2}$, the matter is still more difficult. Thus the function $x+\sum_{n=1}^{\infty} x^{a^n+2}/(a^n+1)(a^n+2)$, where a is a positive integer greater than unity, has essential singularities in every arc of the circle $|x|=1$, however small, though the series converges for every point on this circle.

A function whose only singularities are poles is easily proved to be a rational function; if it have one or more essential singularities it is called *transcendental;* a function which has no singularity for finite values of x is called an *integral* function, and can then be either rational or transcendental. For a rational integral function $f(x)$ a finite R can be assigned, such that for every $|x|>\mathrm{R}$, the function is in absolute value greater than an assigned value M; thus $f(x)$ must vanish for finite values of x, since otherwise $1/f(x)$ can easily be shown to be also a rational integral function, whereas in fact $1/f(x)$ diminishes indefinitely as $|x|$ increases sufficiently. For a transcendental integral function there are, as follows from the remarks above, points among those for which $|x|$ is greater than an assigned R, at which the function differs as little as desired from any assigned value, or is greater than any assigned value.

Existence and Methods of Representation of Single-valued Functions of given Description.—As soon as any considerable number of descriptive properties of single-valued monogenic analytic functions have been deduced, the question naturally arises how far such properties suffice to identify the functions; with which is connected the further question of obtaining representations having a more extended validity than usually possessed by a power series. We mention the following theorems (1) *Laurent's Theorem.*—If the annular region between the circles $|x-c|=r$, $|x-c|=\mathrm{R}$ lie entirely within the region of existence of a (single-valued monogenic analytic) function, there exists a series, $\sum_{n=-\infty}^{\infty} \mathrm{A}_n(x-c)^n$, valid, and giving the value of the function, for all the points of this region. By definition the function is *developable* (or *holomorphic*), that is, of the form $\sum_{n=0}^{\infty} \mathrm{B}_n(x-a)^n$, about every point a in its region of existence. (2) *Weierstrass's Factor Theorem.*—If $a_1, a_2, a_3,\dots$ be an enumerable aggregate of points with $x=\infty$ as point of condensation, there exists an integral function vanishing to the first order in these and only these points, and expressible by the infinite product $\prod_{n=1}^{\infty}\left[\left(1-\frac{x}{a_n}\right)e^{\phi_n}\right]$, where ϕ_n is a polynomial consisting of a number, at most n, but often fewer, of terms of the series $\frac{x}{a_n}+\frac{x^2}{2a^2_n}+\frac{x^3}{3a^3_n}+\dots$ Conversely an integral function vanishing in $a_1, a_2,\dots$ can be expressed in the form $e^{\phi}\prod_{n=1}^{\infty}\left[\left(1-\frac{x}{a_n}\right)e^{\phi_n}\right]^{r_n}$, where r_n is a positive integer and ϕ is an integral function. Familiar examples are the gamma function $1/\Gamma(1+x)=e^{Cx}\prod_{n=1}^{\infty}\left[\left(1+\frac{x}{n}\right)e^{-\frac{x}{n}}\right]$ and the elliptic sigma function (see below, Elliptic Functions) $\sigma(u)=u\prod\left[\left(1-\frac{u}{\Omega}\right)e^{\frac{u}{\Omega}+\frac{u^2}{2\Omega^2}}\right]$, where $\Omega=2mw+2m'w'$, and the product extends to all integral values of m and m' other than the one combination $m=m'=0$. It is necessary that w'/w should not be real. (3) *Mittag-Leffler's Theorem.*—If $a_1, a_2, a_3,\dots$ be an enumerable aggregate of points with $x=\infty$ as point of condensation, and $f_1(x), f_2(x), f_3(x),\dots$ be a corresponding set of rational functions of which $f_n(x)$ is infinite only at a_n, and, when n is finite, vanishes for $x=\infty$, it is possible to construct a function $\mathsf{F}(x)$ infinite only at $a_1, a_2, a_3,\dots$ and such that in the neighbourhood of a_n the difference $\mathsf{F}(x)-f_n(x)$ remains finite. And a generalization can be made to the case when the functions $f_1(x), f_2(x),\dots$ are not rational, and the point of condensation of the points $a_1, a_2,\dots$ is not at infinity. A familiar example is furnished by the trigonometrical function cot $x\pi$ for which the points $a_1, a_2,\dots$ are the points $x=m$, and the functions $f_1(x), f_2(x),\dots$ are of the form $(x-m)^{-1}+m^{-1}$, where m is a positive or negative integer. (4) The consideration of methods of representation by means of an infinite series of polynomials is too large for the present occasion; Runge has proved that given any connected region, a function can be constructed having this as its region of existence; more recently Mittag-Leffler has announced a method of representing a given function over the whole of its region of existence by means of a single series. *Miscellaneous.*—From many general results that must be omitted here, the following may be selected for bare reference: (1) The theorem of Picard as to the values assumed, in its whole region of existence, by a single-valued integral function, or as to the values actually assumed by a function near an isolated essential singularity (see below under *Elliptic Functions*). (2) The investigations of Darboux, Poincaré, Hadamard, Fabry, Borel, and others, as to the positions of the zero and singular points of a function whose value is to be determined from one given Taylor expansion. (3) The theorem of Poincaré as to the possibility of representing any multiple-valued analytic function by means of single-valued functions.

Algebraic Functions.—Having explained the notion of a monogenic analytical function, and considered its fundamental properties, it becomes proper to inquire as to the scope of the notion. The most natural ways in which a function can enter are perhaps as defined by algebraic equations and as defined by differential equations. Of these the latter belong to another article (DIFFERENTIAL EQUATIONS). Here we consider briefly the properties that arise when y is determined from x by an equation $f(y, x)=0$, wherein f denotes a polynomial rational and integral in both x and y, which is incapable of being written as a product of other polynomials of the same rational form. It can be shown that in the neighbourhood of any finite value of x, say $x=a$, exception being made (1) of those for which the coefficient of the highest power of y in $f(y, x)$ vanishes, (2) of those for which the equations $f(y, x)=0$, $\frac{\delta f}{\delta y}=0$ are consistent, every value of y for which $f(y, x)=0$ is expressible by a power series in $x-a$. But in order to meet the case of all values of x it is desirable to proceed in the first instance somewhat differently. It can be shown that if a, b, be any finite values of x, y for which $f(b, a)=0$, all corresponding values of x, y which satisfy the equation $f(y, x)=0$, and are sufficiently nearly equal to a, b, can be expressed by a pair of power series in a parameter t of the form $x=a+P(t)$, $y=b+Q(t)$, or by a finite number of such pairs, where $P(t)$, $Q(t)$ vanish for $t=0$, the series being such as to give only one value of t within the region of convergence corresponding to specified values of x and y; and that this is equally true for all infinite values of x or y, or both, which arise by a limiting process as satisfying the equation $f(y, x)=0$, provided only it be understood that in such a case $x-a$ or $y-b$ or both shall be replaced respectively by x^{-1} and y^{-1}. And further, if such a pair of simultaneous series be called an *element*, that only a finite number of elements is necessary to exhaust all simultaneous values of x, y satisfying the equation $f(y, x)=0$, *while every element may be regarded as derived from any one element by a succession of continuations expressed by equations of the form* $t=c+c_1\tau+c_2\tau^2+\ldots$, whereby the so-called infinitesimal t of one element is (reversibly) related to the infinitesimal τ of a derived element. The values of x, y which arise by putting $t=0$ in an element, constitute what may be called the centre of the element; but, inasmuch as there may be several different elements which have the same centre, it is desirable not to consider the centre apart from the element with which it arises. So considered the centre is called a place. The aggregate of all such places constitutes a *monogenic algebraic construct* (or *configuration*, or *surface*). This is then to be regarded as a generalization of the infinite plane considered in dealing with functions of a single variable x, and we are to consider functions which are single-valued upon this construct. The notion of monogenic construct is wider than that of a monogenic function, by the inclusion of the exceptional values of x and y referred to above; it appears from what has been stated that y is a multiple-valued monogenic function of x, whose region of existence is bounded by the exceptional values of x. An analytic function upon the construct is one whose value for the neighbourhood of any values of x, y which belong thereto and to the region of existence of the function, is given by a power series in the infinitesimal t; a pole of such a function requires a series of integral powers of t, in which the number of negative powers is finite. Then a single-valued analytic function, whose only singularities are poles, can be shown to be expressible as a rational function of x and y; while conversely a rational function (of x and y) is clearly a single-valued analytic function upon the construct having as singularities only poles. When such a function R has a pole for $x=a$, $y=b$, and r is the smallest possible integer for which t^rR is finite, t being the infinitesimal at (a, b), then R is said to become infinite to order r; similarly if R be equal to C at $x=a$, $y=b$, and r is the greatest positive integer for which $(R-C)\,t^{-r}$ is finite, then R is said to become r times equal to C. With this language we have the theorem that R becomes equal to every assignable value, finite or infinite, and this the same number of times for every value. This number is called the *order* of R. There is a lower limit to the number of poles of arbitrary position, for which there exists a rational function infinite to the first order at each; if this number be $p+1$, the number p is called the *class* of the algebraic construct, and is of fundamental importance in the developments, ramifying into all branches of mathematics, of the theory of an algebraic construct. Historically these developments centre round the theorem of integral calculus known as *Abel's theorem.* If, for the algebraic construct, R be a rational function, the integral $\int R dx$ can, in general, be evaluated in terms of algebraic and logarithmic functions only when the algebraic construct is of class zero, in which case x and y can be expressed as rational functions of a single parameter. When the construct is of class unity the integral can be expressed in terms of elliptic functions (see below). In general we have, however, this theorem; let $x_1, x_2, \ldots x_k$ denote the places where any other rational function than R, say Z, vanishes and $c_1, \ldots c_k$ the places where Z is infinite, to the first order; then the sum of k like integrals, $\sum_{r=1}^{k}\int_{c_r}^{x_r} R dx$, has a calculable value which we express by $\left[\left(R\frac{dx}{dt}\right)\log Z\right]_{t^{-1}}$, where the meaning is that in the neighbourhood of any place where the integral $\int R dx$ becomes infinite we are to substitute for x, y in $R\frac{dx}{dt}\log Z$ their values in terms of the infinitesimal t at the place and determine, in the expansion in ascending powers of t, the coefficient of t^{-1}, and then form the sum of all these coefficients, the number of which is always finite. This theorem can be proved by means of the following lemma: if K be any rational function on the construct the sum of the coefficients of t^{-1} in the various expansions of $K\frac{dx}{dt}$ at the places where the integral $\int K dx$ becomes infinite, is zero; this lemma we may express by $\left[K\frac{dx}{dt}\right]_{t^{-1}}=0$; it is easily deduced from the corresponding theorem for rational functions of one variable. Abel's theorem leads to the study of single-valued analytic functions of several variables with systems of simultaneous periods, which, apart from their intrinsic interest, are of importance as affording clues for the elucidation of the many initial difficulties presenting themselves in regard to functions of more than one variable. On the other hand, the attempt to resolve an algebraical construct, whose class is greater than unity, in terms of single-valued functions of one variable, leads to the discussion of certain functions, with an infinite number of essential singularities, which are unaltered by a set of linear substitutions of the variable forming an infinite discontinuous group. Of such developments, already of vast extent, only the barest mention can be made here.

Elliptic Functions.—If w, w' be two fixed quantities whose ratio is not real, $\Omega=2mw+2m'w'$, it can be shown that the doubly infinite sum $u^{-2}+\Sigma[(u+\Omega)^{-2}-\Omega^{-2}]$, extending to all positive and negative integer values of m and m' other than the one pair $m=m'=0$, is both absolutely and uniformly convergent for all finite values of u other than the values $u=-\Omega$, and represents a single-valued monogenic analytical function; it is generally denoted by $p(u)$. It is *doubly periodic*, satisfying the equations $p(u+2w)=pu$, $p(u+2w')=pu$, and therefore also the equations $p(u+2mw+2m'w')=p(u)$. Thus all the values of which it is susceptible arise for values of u expressed by $u=2xw+2x'w'$, wherein x, x' are real quantities such that $0 \leqslant x<1$, $0 \leqslant x'<1$. Within this range of values, constituting what is known as the parallelogram of periods, the function has no singular point save the pole of the second order at $u=0$, and it takes every assignable value for just two values of u (which may coincide). It is therefore said to be a doubly periodic function of the second order, its differential coefficient, $p'(u)$, whose square is equal to $4[pu-pw][pu-pw'][pu+pw+pw']$, being of the third order. As a rational function of these two functions, $pu, p'u$, every single-valued analytic function of u, having the periods $2w, 2w'$ and having no other singularities than poles, can be represented. In particular $p(u+v)$ can be represented rationally by $pu, pv, p'u, p'v$. Moreover, every single-valued analytic function of u which is periodic, is necessarily either singly periodic, and can then be represented by trigonometric functions, or is doubly periodic. The function pu is the negative of the second differential coefficient of the logarithm of the integral function $\sigma(u)$ which is given by the doubly infinite product $\sigma(u)=u\,\Pi'\left[\left((1-\frac{u}{\Omega}\right)e^{\frac{u}{\Omega}+\frac{u^2}{2\Omega^2}}\right]$, where Ω has the same meaning as before; this function is not periodic, but satisfies such equations as $\sigma(u+2w)=-e^{2\eta(u+w)}\sigma(u)$, $\sigma(u+2w')=e^{-2\eta'(u+w')}\sigma(u)$, where η, η' are constants such that $\eta w'-\eta' w=\frac{i\pi}{2}$ or $-\frac{i\pi}{2}$, according as the real part of $\frac{w'}{iw}$ is positive or negative; we have, in fact, for all values of u and v, the relation $\sigma^2(u)\sigma^2(v)[p(v)-p(u)]=\sigma(u+v)\sigma(u-v)$; this relation shows, moreover, that each of the functions $p(u)-p(w)$, $p(u)-p(w')$, $p(u)-p(w+w')$, is the square of a single-valued function, as also appears from the fact that each has a double pole, at $u=0$, and each a double zero, respectively at $u=w$, $u=w'$, $u=w+w'$. It is as the ratio of the square roots of these functions that the Jacobi elliptic functions, *snu, cnu, dnu*, most naturally arise. But, taking for instance $\phi(u)=\sqrt{pu-pw}$, the sign for all values of u being given by the prescription that the sign for small real positive values of u shall be positive, this function satisfies the equations $\phi(u+2w)=\phi(u)$, $\phi(u+2w')=-\phi(u)$, and has the periods $2w$ and $4w'$; it can therefore be rationally expressed by the functions $p_1(u), p'_1(u)$, formed from the periods $2w, 4w'$ as pu, pu' were formed from $2w, 2w'$; in fact it is equal to $\frac{1}{2}p'_1(u)\div[p_1(2w')-p_1(u)]$. The function pu is easily seen, from the series which represents it, to be unaltered if $2w, 2w'$ be replaced by $2\omega=2pw+2p'w'$, $2\omega'=2qw+2q'w'$, where p, q, p', q' are any integers for which $pq'-p'q=\pm 1$; it is, moreover, a homogeneous function of degree -2 in the three quantities u, w, w'; more generally if $2\omega=2pw+2p'w'$, $2\omega'=2qw+2q'w'$, where p, q, p', q' are integers such that $pq'-p'q=r$, and $p_1(u)$ denote the function formed with $2\omega, 2\omega'$ as periods, we have pu equal to the sum of $p_1(u)$ and $r-1$ terms of the form $p_1\left(u+\frac{2\omega k+2\omega' k'}{r}\right)-p_1\left(\frac{2\omega k+2\omega' k'}{r}\right)$, where k, k' are integers for which $pk+qk'$ and $p'k+q'k'$ are divisible by r. It can be proved that every pair of formulæ $2\omega=2pw+2p'w'$, $2\omega'=2qw+2q'\omega'$, in which p, q, p', q' are such integers that $pq'-p'q=1$ can be derived by repetition of the two pairs given by $(\omega=-w', \omega'=w)$, $(\omega=w, \omega'=w+w')$; these give respectively $-p\omega'/p\omega=-pw/pw'$, and $-p\omega'/p\omega=1+pw'/pw$; or, if $h=-pw'/pw$, they change h respectively into $1/h$ and $1-h$; thus by all substitutions $2\omega=2pw+2p'w'$, $2\omega'=2qw+2qw'$, in which $pq'-p'q=1$, the function h can only take the six values $h, 1/h, 1-h, 1/(1-h)$, $h/(h-1)$, $(h-1)/h$, which are the roots of an equation $(1-\theta+\theta^2)^3/\theta^2(1-\theta)^2=(1-h+h^2)^3/h^2(1-h)^2$. Thus the function $z(\tau)=\frac{4}{27}(p^2w+pwpw'+p^2w')^3/p^2wp^2w'(pw+pw')^2$, which is clearly a single-valued function of the ratio $\tau=w'/w$, is unaltered by any transformation $\tau'=(q+q'\tau)/(p+p'\tau)$, in which p, q, p', q' are integers for which $pq'-p'q=1$. If the imaginary part of $\tau(=\rho+i\sigma)$ be positive, the imaginary part of τ', being equal to $i\sigma(pq'-p'q)\div[(p+p'\rho)^2+p'^2\sigma^2]$, is also positive; it can be shown that the upper half of the infinite plane of τ can be divided into regions, all bounded by arcs of circles (or straight lines), such that every point of any region other than the so-called fundamental region can be obtained from a definite point of the fundamental region by a definite one of the transformations, that is, as remarked above, by a definite combination of the two primary transformations $\tau'=-1/\tau$, $\tau'=1+\tau$, while every such transformation leads from any point of the fundamental region to a corresponding point of a different region. If $\tau=\xi+i\eta$, the fundamental region can be taken to be the region for which $-\frac{1}{2}<\xi<\frac{1}{2}$ and $\xi^2+\eta^2>1$, together with the points, on the curves limiting this region, for which ξ is negative. Upon the infinite half plane the function $z(\tau)$ is a single-valued monogenic analytical function whose only essential singularities are those arising, by the transformations, from $\tau=\infty$, therefore given by all real rational values of τ; the equation $z(\tau')=z(\tau)$ can be shown to require a relation of the form $\tau'=(q+q'\tau)/(p+p'\tau)$, and the function $z(\tau)$ takes every value just once within the fundamental and therefore within every other region. Putting $J(\tau)=\frac{z(\tau)}{z(\tau)-1}=4(p^2w+pwpw'+p^2w')^3 \div(pw-pw')^2(pw+2pw')^2(2pw+pw')^2$ the function $J(\tau)$ is equal to 0 for $\tau=e^{\frac{2\pi i}{3}}$, is equal to 1 for $\tau=i$, and has an essential singularity for $\tau=\infty$; the inverse function $\tau(J)$ is infinitely valued, has branch places with connexion of three values for $J=0$, the circuit of the branch place leading to a linear substitution of period three (such as $\tau'=-(1+\tau)^{-1}$), branch places with connexion of two values for $J=1$, the circuit of the branch place leading to a linear substitution of period two (such as $\tau'=-1/\tau$), and a branch place with connexion of all values for $J=\infty$, the circuit leading to a non-periodic linear substitution (such as $\tau'=1+\tau$); these are the only singularities of the function $\tau(J)$. Each of the functions $\sqrt[3]{J(\tau)}$, $\sqrt{J(\tau)-1}$, $\sqrt[8]{-\frac{pw+2pw'}{pw-pw'}}$, $\sqrt[8]{\frac{2pw+pw'}{pw-pw'}}$, $\sqrt[24]{-\frac{(pw+2pw')(2pw+pw')}{(pw-pw')^2}}$ besides others, is a single-valued function of τ, being expressible without ambiguity in terms of the single function $\eta(\tau)=e^{\frac{i\pi\tau}{12}}\prod_{n=1}^{\infty}(1-e^{2i\pi n\tau})=e^{\frac{i\pi\tau}{12}}\sum_{n=-\infty}^{\infty}(-1)^m e^{(3m^2+m)i\pi\tau}$; these functions are not, however, unaltered by all the linear substitutions; we have in fact $\eta\left(-\frac{1}{\tau}\right)=\sqrt{-i\tau}\,\eta(\tau)$, $\eta(1+\tau)=e^{\frac{i\pi}{12}}\eta(\tau)$. A more general theorem below.

The aggregate of the substitutions $\tau'=(q+q'\tau)/(p+p'\tau)$, wherein p, q, p', q' are integers for which $pq'-p'q=1$, constitutes a *group* (*q.v.*); the function $J(\tau)$, unaltered by all the substitutions of this group, is called a *modular function.* More generally a function unaltered by all the substitutions of any group of linear transformations is called an *automorphic function*; of such functions doubly-periodic functions are a particular case, being unaltered by the transformations of the group arising by repetition and combination of the two transformations

$u'=u+2w$, $u'=u+2w'$. In the case of a single-valued analytic doubly-periodic function which has no essential singularity for finite values of the argument u, we have the three fundamental properties: (1) That if the coefficient of the first negative power of $u-a$ in the expansion of the function for the neighbourhood of the pole a be called the residue of the function for this pole, the sum of the residues of the function at all its poles within any one parallelogram of periods is zero; (2) That the function takes any specified value A, within the parallelogram, a number of times equal to the aggregate order of its poles, this number being not less than 2; this minimum is reached for the function $p(u)$; (3) That the sum of the values of u for which the function takes the value A, can differ from the sum of the values of u for which the function takes any other value B, only by an expression of the form $2mw+2m'w'$, where m, m' are integers. Analogous properties hold for automorphic functions; but space prevents further explanation. The elliptic functions pu, $p'u$ enable us to represent the cubic curve $y^2=4x^3-g_2x-g_3$, in the form $x=p(u)$, $y=p'(u)$, by means of single-valued functions; and a similar representation, by these functions, can be made of any algebraic construct of class unity. In accordance with a theorem of Poincaré, automorphic functions can be constructed whereby a given algebraic construct of any class may be similarly represented by single-valued functions, in a form valid for all places of the construct.

The modular function $J(\tau)$ considered above, unaltered by the group of linear substitutions $\tau'=(q'\tau+q)/(p'\tau+p)$, where p, q, p', q' are any integers for $pq'-p'q=1$, may be regarded as the independent variable of a differential equation (*q.v.*) of the third order of the form $s'''/s'-\frac{3}{2}(s''/s')^2=\frac{1}{2}(1-\alpha^2)(x-1)^{-2}+\frac{1}{2}(1-\beta^2)x^{-2}+\frac{1}{2}(\alpha^2+\beta^2-\gamma^2-1)x^{-1}(x-1)^{-1}$, of which the dependent variable s is equal to τ. A function satisfying this equation being denoted by $s(\alpha, \beta, \gamma, x)$, we have in fact $\tau=s(\frac{1}{2}, \frac{1}{3}, 0, J)$. Putting $\lambda=(2pw'+pw)/(pw'-pw)$, we similarly have $\tau=s(0,0,0,\lambda)$, and λ is a single-valued function of τ, unaltered only by the (self-conjugate) subgroup of modular substitutions in which the coefficients q and p' are even integers, and therefore p and q' odd integers; the fundamental region for this subgroup, if $\tau=\xi+i\eta$, may be taken to be given by $-1<\xi<1$, $(\xi+\frac{1}{2})^2+\eta^2>\frac{1}{4}$, $(\xi-\frac{1}{2})^2+\eta^2>\frac{1}{4}$, and may be divided into six regions which are equivalent to one another by the substitutions of the general modular group. Within this fundamental region λ takes every value just once, except the values 0, 1, ∞, which can arise only at the angular points ($\tau=0$, ∞, -1 and the equivalent point $\tau=1$); these being essential singularities for the function λ. For $\lambda(\tau)$, as for $J(\tau)$, the region of existence is the upper half plane, every short length of the axis $\eta=0$ containing essential singularities.

As bare illustrations of the utility of the function $\tau=s(0, 0, 0, \lambda)$ we refer to the proof of the theorem: (i.) If a single-valued analytic monogenic integral function $\phi(x)$ do not take the values 0 and 1 for finite values of x, then it is a constant; for in that case the function $s[0, 0, 0, \phi(x)]$ is a single-valued analytic monogenic integral function; and it is impossible that the imaginary part of such a function should not become negative, as is the case of $s(0, 0, 0, \lambda)$ for all values of λ. Hence it follows that for a single-valued monogenic analytic function $F(x)$ which has $x=\infty$ as an isolated essential singularity and no other essential singularity, there cannot be three values a, b, c which the function does not assume for finite values of x; for by taking proper linear function of the function we could then obtain a single-valued analytic monogenic function not taking the values 0, 1, ∞ for finite values of x. It can further be shown, by using the function $s(\frac{1}{2}, \frac{1}{3}, 0, J)$, that if there be three values a, b, c which the function does not assume for an infinite number of finite values of x, then $F(x)$ must be a rational function; (ii.) Any function $s(\alpha, \beta, \gamma, x)$ is a single-valued function of $\tau=s(0, 0, 0, x)$; for putting $\tau'=\frac{\tau-i}{\tau+i}$, the values of τ' which correspond to the singular points $x=0$, 1, ∞ of $s(\alpha, \beta, \gamma, x)$, though infinite in number, all lie on the circumference of a circle, $|\tau'|=1$, within which $s(\alpha, \beta, \gamma, x)$ is expressible in the form $\sum_{n=0}^{\infty} a_n \tau'^n$. The same for any function whose only singularities are branch places at $x=0$, $x=1$, $x=\infty$.

Functions of Several Variables.—In order to appreciate the power of Weierstrass's methods it is necessary to study their application to the case of functions of more than one independent variable, for which the Cauchy methods are mostly inapplicable. The region of existence of a monogenic analytical function is as in the simpler case to be defined by a succession of power series; the singular points are either essential or unessential, but there are two sorts of unessential singularities of which only one sort can be called poles. To define an unessential singularity it is necessary to premise that if a power series in the variables x, $x_1,\dots x_n$ vanish at a point $x=0$, $x_1=0,\dots x_n=0$ it is possible to write the series in the form $(x^k+u_1x^{k-1}+\dots+u_k)E$, where $u_1,\dots u_k$ are power series in $x_1,\dots x_n$, all vanishing at $x_1=0,\dots x_n=0$, and E is a power series in x, $x_1,\dots x_n$ not vanishing at $x=0$, $x_1=0,\dots x_n=0$; from this it is possible, given two power series both vanishing at $x=0$, $x_1=0,\dots x_n=0$, to distinguish between the two cases when: (1) The two series have a common factor in the form of a power series vanishing at $x=0$, $x_1=0,\dots x_n\dots 0$; (2) The two series have no such common factor. Now as we approach to a singular point of a function of several variables, and consequently the range of convergence of the derived power series representing the function diminishes without limit, there may exist a power series ϕ, with centre at the singular point, such that for the product of the function F, and the series ϕ, the point is an ordinary point; then the function can be represented in the neighbourhood of the point as the quotient, $F=\psi/\phi$, of two power series, and the point is said to be an unessential singularity. If now any factor, in the form of a power series vanishing at the point, which is common to ψ and ϕ, be divided out, the reduced quotient $F=\psi_1/\phi_1$ will still be such that ϕ_1 vanishes at the point, or the point would be an ordinary point for the function; if then ψ_1 does not vanish at the point, the function F has the value ∞ at the point by whatever path the point is approached, and the point is one which is an ordinary point for $1/F$; this may be called a pole; if, however, ψ_1 also vanish at the point the limiting value of the function F as the singular point is approached is entirely indeterminate and depends on the path of approach. For a function of two complex variables such points of indetermination are generally discrete; for a function of p variables they form a continuum of $2p-4$ dimensions; and the existence of such points constitutes one of the main difficulties of the theory. There exist, however, proofs of the two following propositions, which generalize results for functions of one variable: (1) If a single-valued analytical monogenic function of p variables have no essential singularity, either for finite values of the variables, or at infinity, then it is a rational function of the variables; (2) If a function known to exist, and to be single-valued, be further known to be expressible in the neighbourhood of every *finite* point as a quotient of two power series with a presumably limited range of convergence, then the function can be expressed as a quotient of two integral functions, that is, as a quotient of two power series converging for all finite values of the variables; and this in such a way that these integral functions have no common zero other than the points of the $(2p-4)$-fold over which the function is essentially indeterminate.

The monogenic analytical single-valued functions of several variables other than the algebraic functions in regard to which most definite results have been obtained are those possessing sets of simultaneous periods, and having no essential singularities for finite values of the variables; if $a_1, \ldots a_p$ be such a set of periods the property is $\phi(x_1+a_1, \ldots x_p+a_p) = \phi(x_1, \ldots x_p)$; the greatest possible number of such sets of simultaneous periods is $2p$, but not every $2p$ sets of p quantities can be the periods of such a function; it is necessary, on the contrary, that the $2p^2$ quantities should be connected by $2p^2 - \frac{1}{2}p(p+1)$ relations of a certain form. The main general result for such periodic functions is that, of functions having the same periods, all can be expressed rationally in terms of $(p+1)$ functions chosen of suitable generality, these $(p+1)$ functions being themselves connected by a rational relation. So far as is known two main methods are available for the proof of these statements: (1) When by the general theorem quoted above, the periodic function is expressed as a quotient of two integral functions, these are found to be quasi-periodic, having a property expressed by $\Theta(x_1-a_1, \ldots x_p-a_p) = e^u\Theta(x_1, \ldots x_p)$ where u is a linear function of the variables; these can therefore be expanded, by a theorem not difficult to prove, which is the generalization of Laurent's theorem, in integral powers of quantities $e^{\lambda_1 x_1}, \ldots e^{\lambda_p x_p}$ (wherein $\lambda_1, \ldots \lambda_p$ are constants). On the basis of this expansion the properties of the functions can be developed; (2) Another method of proof is obtained by directly connecting the periodic functions with an algebraic construct and utilizing the methods (of contour integration, &c.) used with such success by Riemann in his investigations in regard to Abelian functions. It is, in fact, as Abelian functions that periodic functions of several variables first arise, being introduced to express the solution of the inversion problem, suggested by Abel's theorem, which generalizes the inversion of the elliptic integral from which elliptic functions take their origin; the quasi-periodic integral functions, denoted above by Θ, by which the periodic functions can be expressed, forming an important part of the development. And, as in the case of one variable, the theory is intimately related to that of *automorphic functions*, that is, of functions of several variables unaltered by groups of linear substitutions of the variables.

Authorities.—On the subject of Weierstrass's methods in general consult Weierstrass, *Mathematische Werke*, Berlin, 1894; Harkness and Morley, *Introduction to Analytic Functions*, London, 1899; Biermann, *Theorie der analytischen Functionen*, Leipzig, 1887; Forsyth, *Theory of Functions*, Cambridge, 1893, which may also be consulted for developments of Cauchy's methods, for Riemann's surfaces and existence theorem, for conformal representation, and for the extent of its bibliographical references. See also Riemann, *Werke*, Leipzig; Schwarz, *Werke*, Berlin, 1890; Neumann, *Riemann's Theorie*, Leipzig, 1884. See also papers by Mittag-Leffler, *Acta Mathematica*, vols. iv. and xxiii. (1884 and 1899); by Runge, *Acta Mathematica*, vol. vi. (1885); by Pringsheim, *Mathematische Annalen*, vol. xlvii. (1896). For the theorems of Poincaré, Picard, Hadamard, and others in regard to integral functions reference may be made to Borel, *Leçons sur les fonctions entières*, Paris, 1900, where references to original papers will be found. For the theory of Algebraic Functions and for Abelian Functions, see Noether, "Die Entwickelung der Theorie der algebraischen Functionen in älterer und neuerer Zeit," *Jahresber. d. deutschen math. Vereinigung*, iii. Berlin, 1894; Hensel, *Crelle Journal für die Mathematik*, Bd. cv. cix. cxi. u.s.w.; Stahl, *Theorie der Abel'schen Functionen*, Leipzig, 1896; Baker, *Abel's Theorem, and the Theory of the Theta Functions*, Cambridge, 1897. For Elliptic Functions there are treatises by Halphen, Paris (1886–1891); Weber, Braunschweig, 1891; Appell and Lacours, Paris, 1897; Tannery and Molk, Paris, 1893–98; Greenhill, London, 1892; and the *Formeln und Lehrsätze zum Gebrauche der elliptischen Functionen*, H. A. Schwarz, Berlin, Reimer. For Modular Functions consult Klein und Fricke, *Modulfunctionen*, Leipzig, 1890, 1892, containing ample reference. For Automorphic Functions, Poincaré, *Acta Mathematica*, vols. i.–v., 1882-84, and *Bulletin de la société math. de France*, 1883, and Fricke u. Klein, *Die Theorie der automorphen Functionen*, Leipzig, 1897. For Functions of Several Variables, Poincaré, *Acta Mathematica*, ii. xxii., 1883, 1899; Kronecker, *Werke*, i., Berlin, 1895; Appell, *Liouville journal de mathématiques*, 1891; Wirtinger, *Monatshefte für Mathematik u. Physik*, vi., 1895, and vii., where many references will be found; Wirtinger, *Akad. d. Wiss. in Wien*, Bd. cviii., 1899; Picard, *Acta Mathematica*, i. ii. v., *Liouville Journal*, 1885; P. Cousin, *Acta Math.* vol. xix., 1895; Baker, *Trans. Camb. Phil. Soc.* vol. xviii., 1899; and Picard, *Théorie des fonctions algébriques de deux variables indépendantes*, Paris, 1897. Consult also the second volume of the German *Ency. of Math.* (H. F. Ba.)

Functions of Real Variables.—

The idea of functional dependence came into Mathematics from analytical geometry; mathematical analysis as founded, and as at first developed, was based on geometrical intuition; a *function* was some variable length connected with a curve; an *irrational number* was the ratio of two incommeasurable geometric magnitudes; approach to a *limit* meant tending continually towards it; none of these essential notions—number, limit, function—was precisely defined. Modern analysis, on the other hand, is throughout arithmetical; all the essential notions are defined arithmetically; the arithmetic even on which analysis rests has been reformulated in such a way as to sever the notion of number from that of magnitude. It is the object of this article to give some account of the Theory of Functions of Real Variables as it has been remodelled in the process of complete arithmetization. Notations and ideas which have been sufficiently explained in the articles Infinitesimal Calculus (*Ency. Brit.* 9th ed. vol. xiii.) and Function (vol. ix.), will be utilized without further discussion. Limitations of space prevent the presentation of proofs of theorems.

The landmarks of the theory are the introduction of the system of ordinal numbers and the establishment of the *continuum* of real numbers; the definition of the domain of a variable or a system of variables by means of the theory of Aggregates[1]; the general principle of convergence to a limit; the definition of functional dependence; the establishment of the notions of continuity, differentiability, and integrability of functions; the representation of functions by means of the results of limiting processes; the conduct of operations on functions so represented. The systematic arithmetical development of the theory is mainly due to Weierstrass.

1. *The Continuum of Real Numbers.*—The capacity of numbers to answer questions of how many and how much, in other words to express the results of operations of counting and measuring, may be regarded as a secondary property derived from the more fundamental one of expressing order. The fact that a formally complete theory of Arithmetic can be based on the notion of order only was pointed out by Dedekind. According to this theory, a natural number is a mark which serves to specify the place of an object in a series or "progression" (see Number), and the essential fact of the theory is the possibility of referring the objects in one series to the objects in another series one by one. Natural numbers form a series with a definite order, and the expressions "greater than" and "less than" mean "more advanced" and "less advanced" in this order. Rational fractions are introduced by means of pairs of natural numbers which obey certain defined laws of operation, and for these also the order is defined.

[1] The term "Theory of Aggregates" is here used as the equivalent of the German "Mengenlehre" and the French "théorie des ensembles."

Negative numbers are introduced in a similar way. The whole system of rational numbers thus constructed has a definite order. The meanings to be attached to addition, subtraction, multiplication, and division, the commutative, associative, and distributive laws of operation, can all be based on the notion of order and the possibility of one-to-one correspondences. The formal system thus developed can be applied to express the results of counting and measuring. Irrational numbers are introduced by means of "cuts" (see NUMBER). An irrational number is the mark of a cut which separates all rational numbers into two classes, the inferior class having no greatest number, and the superior class no least number. The whole system of rational and irrational numbers possesses a definite order, and forms a *continuum*. In fact the notion of a one-dimensional continuum first becomes precise in virtue of the establishment of this system.

2. *Measurement.*—It will be sufficient to consider here the measurement of one kind of concrete quantity, viz., the length of a segment of a straight line (produced indefinitely). We choose any other segment of the line, and mark its ends with the numbers 0 and 1; then we lay off on the straight line a series of segments with contiguous ends each equal to this "unit" segment, and mark their ends with the numbers 1 and 2, 2 and 3, . . . the points marked 1, or 2, . . . being the same for consecutive segments; on the other side of the point marked 0 we lay off segments in the same way as before, and mark their ends with the numbers 0 and -1, -1 and -2. . . . The first requisite for the measurement is the possibility of equal segments; the test of equality of length is congruence. The second requisite for the measurement is that, when the process above described is carried far enough, any point of the line chosen in advance should be found either within a marked segment or at an end of such a segment; this is the "axiom of Archimedes." We now divide the segment between m and $m+1$, where m may be zero or any positive or negative integer, into q equal segments, and mark their extremities in order with the numbers

$$m, \frac{qm+1}{q}, \frac{qm+2}{q}, \ldots \frac{qm+q-1}{q}, m+1,$$

each fraction being reduced to its lowest terms, and we do the same with any other marked segment and with any other integer in place of q. Thus certain points of the line will be marked with rational numbers, and the correspondence between the points and the numbers has these properties—(1) the order of the points is the same as that of the numbers; (2) the difference of the numbers marking two points is the same as the difference of the numbers marking two other points when the distance between the first two is the same as the distance between the second two. The points which can be marked by carrying this process far enough are called rational points. There are points of the line which are not rational points, and the above method of marking the points is completed by marking such points with irrational numbers; each point of the line may be regarded as effecting a "cut" in the system of rational points, to which there corresponds a definite cut in the system of rational numbers; if the point is not a rational point it is marked with the irrational number defined by this cut. By this process any chosen point of the line will be marked by a definite number, rational or irrational, and the correspondence between the points and the numbers has the above properties (1) and (2). That, after choice of any irrational number, one point of the line can be found which must, in carrying out the above process, be marked with that number, is a geometrical axiom first recognized as necessary by Dedekind and G. Cantor; in accordance with this axiom the process effects a one-to-one correspondence of real numbers and points of a straight line, and the length of any segment is measured with reference to the chosen unit segment, by the difference of the numbers that correspond to its ends. On account of this correspondence a real number is frequently referred to as a "point."

3. *Domain of a Variable.*—The notion of an "aggregate" or "manifold" in general underlies the system of ordinal numbers (see NUMBER). An aggregate is said to be "infinite" when it is possible to effect a one-to-one correspondence of all its elements with some of its elements. Thus the aggregates of positive integers and of points on a straight line are infinite aggregates. An aggregate whose elements are real numbers is said to "extend to infinite values" if, after any number N, however great, has been specified, it is possible to find in the aggregate numbers which exceed N in absolute value; such an aggregate is always infinite. The "neighbourhood of a number (or point) a for a positive number h" is the aggregate of all numbers (or points) x for which the absolute value of $x-a$, denoted by $|x-a|$, does not exceed h. The idea of a "variable" is that of a number to which we may assign at pleasure any of the values which constitute a definite aggregate, called the "domain" of the variable. This domain may be an "interval," *i.e.*, it may consist of two terminal numbers, all the numbers between them and no others; when the domain of a variable number is an interval the number is said to be "continuously variable," when the domain consists of all real numbers the variable is said to be "unrestricted." A domain which consists of all real numbers which are greater than some fixed number will be described as an "interval unlimited towards the right"; similarly we may have an "interval unlimited towards the left."

4. *Domain of a Set of Variables.*—The numerical continuum of n dimensions (C_n) is the aggregate that is arrived at by attributing simultaneous values to each of n variables $x_1, x_2, \ldots x_n$, these values being any real numbers. The elements of such an aggregate are called "points," and the numbers $x_1, x_2, \ldots x_n$ the "co-ordinates" of a point. Denoting in general the points $(x_1, x_2, \ldots x_n)$ and $(x'_1, x'_2 \ldots x'_n)$ by x and x', the sum of the differences $|x_1-x'_1| + |x_2-x'_2| + \ldots + |x_n-x'_n|$ may be denoted by $|x-x'|$ and called the "difference of the two points." We can in various ways choose out of the continuum an aggregate of points, which may be an infinite aggregate, and any such aggregate can be the "domain" of a "variable point." The domain is said to "extend to an infinite distance" if, after any number N, however great, has been specified, it is possible to find in the domain points of which one or more co-ordinates exceed N in absolute value. The "neighbourhood" of a point a for a (positive) number h is the aggregate constituted of all the points x, which are such that the "difference" denoted by $|x-a| \leqslant h$. If an infinite aggregate of points does not extend to an infinite distance, there must be at least one point a, which has the property that the points of the aggregate which are in the neighbourhood of a for any number h, however small, themselves constitute an infinite aggregate, and then the point a is called a "limiting point" of the aggregate; it may or may not be a point of the aggregate. An aggregate of points is "perfect" when all its points are limiting points of it, and all its limiting points are points of it; it is "connected" when, after taking any two points a, b of it, and choosing any positive number ϵ, however small, a number m and points $x', x'', \ldots x^{(m)}$ of the aggregate can be found so that all the differences denoted by $|x'-a|$,

$|x''-x'|, \ldots |b-x^{(m)}|$ are less than ϵ. A perfect connected aggregate is a *continuum*. This is G. Cantor's definition.

The definition of a continuum in C_n leaves open the question of the number of dimensions of the continuum, and a further explanation is necessary in order to define arithmetically what is meant by a "homogeneous part" H_n of C_n. Such a part would correspond to an interval in C_1, or to an area bounded by a simple closed contour in C_2; and, besides being perfect and connected, it would have the following properties: (1) There are points of C_n which are not points of H_n; these form a complementary aggregate H'_n. (2) There are points "within" H_n; this means that for any such point there is a neighbourhood consisting exclusively of points of H_n. (3) The points of H_n which do not lie "within" H_n are limiting points of H'_n; they are not points of H'_n, but the neighbourhood of any such point for any number h, however small, contains points within H_n and points of H'_n; the aggregate of these points is called the "boundary" of H_n. (4) When any two points a, b within H_n are taken, it is possible to find a number ϵ and a corresponding number m, and to choose points $x', x'', \ldots x^{(m)}$, so that the neighbourhood of a for ϵ contains x', and consists exclusively of points within H_n, and similarly for x' and x'', x'' and x''', . . . $x^{(m)}$ and b. Condition (3) would exclude such an aggregate as that of the points within and upon two circles external to each other and a line joining a point on one to a point on the other, and condition (4) would exclude such an aggregate as that of the points within and upon two circles which touch externally.

5. *General Notion of Functionality.*—The idea of a function was at first geometrical; the function was regarded as given graphically; nevertheless arithmetical notions were almost from the first associated with geometrical ones, the curve which represents the function being determined by an equation. Among early writers on analysis we find the use of the word "function" in the sense of a power or some other analytical expression; and the two notions (1) that which is determined by a curve supposed drawn, and (2) that which is determined by an analytical expression supposed written down, were not for a long time clearly distinguished. It was for this reason that Fourier's discovery that a single analytical expression is capable of representing (in different parts of an interval) what would in his time have been called different functions so profoundly struck mathematicians (§ 22). The analysts who, in the middle of the 19th century, occupied themselves with the theory of the convergence of Fourier's series were led to impose a restriction on the character of a function in order that it should admit of such representation, and thus the door was opened for the introduction of the general notion of functional dependence. This notion may be expressed as follows: We have a variable number, y, and a variable number or system of such numbers, x, a domain of the variable or variables x, and a rule for assigning one or more definite values to y when x is any point in the domain; then y is said to be a "function" of the variable or variables, and these are called the "argument" of the function. According to this notion a function is, as it were, an indefinitely extended table, like a table of logarithms; to each point in the domain of the argument there correspond values for the function, but it remains arbitrary what values the function is to have at any such point. For the definition of any particular function two things are requisite: (1) a statement of the values of the variable, or of the aggregate of variable points, to which values of the function are to be made to correspond, *i.e.*, of the "domain of the argument"; (2) a rule for assigning the value or values of the function that correspond to any point in this domain. We may refer to the second of these two essentials as "the rule of calculation." The relation of functions to analytical expressions may then be stated in the form that the rule of calculation is: "Give the function the value of the expression at any point at which the expression has a determinate value," or again more generally, "Give the function the value of the expression at all points of a definite aggregate included in the domain of the argument." The former of these is the rule of those among the earlier analysts who regarded an analytical expression and a function as the same thing, and their usage may be retained without causing confusion and with the advantage of brevity, the analytical expression serving to specify the domain of the argument as well as the rule of calculation, *e.g.*, we may speak of "the function $1/x$." But in complicated cases separate statements of the domain of the argument and the rule of calculation cannot be dispensed with. In general, when the rule of calculation is determined as above by an analytical expression at any aggregate of points, the function is said to be "represented" by the expression at those points.

When the rule of calculation assigns a single definite value for a function at each point in the domain of the argument the function is "uniform" or "one-valued." In what follows it is to be understood that all the functions considered are one-valued, and the values assigned by the rule of calculation real.

In the most important cases the domain of the argument of a function of one variable is an interval, and that of a function of n variables is a homogeneous part of the numerical continuum of n dimensions, with the possible exception of isolated points.

6. *Limits.*—Let $f(x)$ be a function of a variable point x, representing a value of one variable number, or simultaneous values of n variable numbers, and let a be a point such that there are points of the domain of the argument x in the neighbourhood of a for any number h however small. If there is a number L which has the property that, after any positive number ϵ, however small, has been specified, it is possible to find a positive number h, so that $|L-f(x)|<\epsilon$ for all points x of the domain (other than a) for which $|x-a|<h$, then L is the limit of $f(x)$ at the point a. The condition for the existence of L is that, after the positive number ϵ has been specified, it must be possible to find a positive number h, so that $|f(x')-f(x)|<\epsilon$ for all points x and x' of the domain (other than a) for which $|x-a|<h$ and $|x'-a|<h$.

If $f(x)$ is a function of one variable x in a domain which extends to infinite values, and if, after ϵ has been specified, it is possible to find a number N, so that $|f(x')-f(x)|<\epsilon$ for all values of x and x' which are in the domain and exceed N, then there is a number L which has the property that $|f(x)-L|<\epsilon$ for all such values of x. In this case $f(x)$ has a limit L at $x=\infty$. In like manner $f(x)$ may have a limit at $x=-\infty$. This statement includes the case where the domain of the argument consists exclusively of positive integers. The values of the function then form a "sequence," $u_1, u_2, \ldots u_n, \ldots$, and this sequence can have a limit at $n=\infty$.

In the case of a function of n variables in a domain which extends to an infinite distance, there is a limit at an infinite distance if, after ϵ has been specified, a number N can be found, so that $|f(x')-f(x)|<\epsilon$ for all points x and x' of the domain which have one or more coordinates exceeding N in absolute value.

The principle common to the above definitions and theorems is called, after P. du Bois Reymond, "the general principle of convergence to a limit."

A function which has not a limit at a point a may be such that, if a certain aggregate of points is chosen out of the domain of the argument, and the points x in the neighbourhood of a are restricted to belong to this aggregate, then the function has a limit at a. For example $\sin(1/x)$ has limit zero at 0 if x is restricted to the aggregate $1/\pi$, $1/2\pi$, . . . $1/n\pi$, . . . or to the aggregate $1/2\pi$, $2/5\pi$, . . . $n/(n^2+1)\pi$, . . ., but if x takes all values in the neighbourhood of 0, $\sin(1/x)$ has not a limit at 0. Again, in the case of a function of one variable, there may be a limit at a if the points x in the neighbourhood of a are restricted by the condition that $x-a$ is positive; then we have a "limit on the right" at a; similarly we may have a "limit on the left" at a point; in the case of a function of several variables we may have a limit for approach to a point by a particular path. Any such limit is described as a "limit for a restricted domain."

The limit L of $f(x)$ at a stands in no necessary relation to the value of $f(x)$ at a. If the point a is in the domain of the argument, the value of $f(x)$ at a is assigned by the rule of calculation, and may be different from L. In case $f(a)=L$ the limit is said to be "attained." If the point a is not in the domain of the argument, there is no value for $f(x)$ at a. In the case where $f(x)$ is defined for all points in an interval (or in a domain H_n [§ 4]), containing a, except the point a, and has a limit L at a, we may arbitrarily annex the point a to the domain of the argument and assign to $f(a)$ the value L; the function is then said to be "extrinsically defined." The so-called "indeterminate forms" (INFINITESIMAL CALCULUS, *Ency. Brit.* vol. xiii. p. 21) are examples.

7. *Superior and Inferior Limits; Infinities.*—The value of a function at every point in the domain of its argument is finite, since, by definition, the value can be assigned, but this does not necessarily imply that there is a number N which exceeds all the values (or is less than all the values). It may happen that however great a number N we take there are among the values of the function numbers which exceed N (or are less than $-N$).

If a number can be found which is greater than every value of the function, then either (α) there is one value of the function which exceeds all the others, or (β) there is a number S which exceeds every value of the function but is such that, however small a positive number ϵ we take, there are values of the function which exceed $S-\epsilon$. In case (α) the function has a greatest value; in case (β) the function has a superior limit S, and then there must be a point a which has the property that there are points of the domain of the argument, in the neighbourhood of a for any h, at which the values of the function differ from S by less than ϵ. Thus S is the limit of the function at a, either for the domain of the argument or for some more restricted domain. If a is in the domain of the argument, and if, after omission of a, there is a superior limit S which is in this way the limit of the function at a, if further $f(a)=S$, then S is the greatest value of the function; in this case the greatest value is a limit (at any rate for a restricted domain) which is attained; it may be called a "superior limit which is attained." In like manner we may have a "smallest value" or an "inferior limit," and a smallest value may be an "inferior limit which is attained."

All that has been said here may be adapted to the description of greatest values, superior limits, &c., of a function in a restricted domain contained in the domain of the argument. In particular, the domain of the argument may contain an interval (or a domain H_n [§ 4]), and therein the function may have a superior limit, or an inferior limit, which is attained; such a limit is a *maximum* value or a *minimum* value of the function.

Again, if, after any number N, however great, has been specified, it is possible to find points of the domain of the argument at which the value of the function exceeds N, the values of the function are said to have an "infinite superior limit," and then there must be a point a which has the property that there are points of the domain, in the neighbourhood of a for any h, at which the value of the function exceeds N. If the point a is in the domain of the argument the function is said to "tend to become infinite" at a; it has of course a finite value at a. If the point a is not in the domain of the argument the function is said to "become infinite" at a; it has of course no value at a. In like manner we may have a (negatively) infinite inferior limit. Again, after any number N, however great, has been specified and a number h found, so that all the values of the function, at points in the neighbourhood of a for h, exceed N in absolute value, all these values may have the same sign; the function is then said to become, or to tend to become, "determinately (positively or negatively) infinite"; otherwise it is said to become, or to tend to become, "indeterminately infinite."

All the infinities that occur in the Theory of Functions of Real Variables are of the nature of variable finite numbers, with the single exception of the infinity of an infinite aggregate. The latter is described as an "actual infinity," the former as "improper infinities." There is no "actual infinitely small" corresponding to the actual infinity. The only "infinitely small" is zero. All "infinite values" are of the nature of superior and inferior limits which are not attained.

8. *Increasing and Decreasing Functions.*—A function $f(x)$ of one variable x, defined in the interval between a and b, is "increasing throughout the interval" if, whenever x and x' are two numbers in the interval and $x'>x$, then $f(x')>f(x)$; the function "never decreases throughout the interval" if, x' and x being as before, $f(x')\geqslant f(x)$ Similarly for decreasing functions, and for functions which never increase throughout an interval. A function which never increases or never diminishes throughout an interval is said to be "monotonous throughout" the interval. Taking in the above definition $b>a$, the definition may apply to a function under the restriction that x' is not b and x is not a; such a function is "monotonous within" the interval. In this case we have the theorem that the function (if it never decreases) has a limit on the left at b and a limit on the right at a, and these are the superior and inferior limits of its values at all points within the interval (the ends excluded); the like holds *mutatis mutandis* if the function never increases. If the function is monotonous throughout the interval, $f(b)$ is the greatest (or least) value of $f(x)$ in the interval; and if $f(b)$ is the limit of $f(x)$ on the left at b, such a greatest (or least) value is an example of a superior (or inferior) limit which is attained. In these cases the function tends continually to its limit.

These theorems and definitions can be extended, with obvious modifications, to the cases of a domain which is not an interval, or extends to infinite values. By means of them we arrive at sufficient, but not necessary, criteria for the existence of a limit; and these are frequently easier to apply than the general principle of convergence to a limit, of which principle they are particular cases.

9. *Continuity of Functions.*—A function $f(x)$ of one variable x is said to be "continuous" at a point a if (1) $f(x)$ is defined in an interval containing a, (2) $f(x)$ has a limit[1] at a, (3) $f(a)$ is equal to this limit. If $f(x)$ has a limit on the left at a and $f(a)$ is equal to this limit, the function is said to be "continuous to the left" at a; similarly the function may be "continuous to the right" at a.

[1] It must be a limit for continuous variation, not for a restricted domain.

A function is said to be "continuous throughout an interval" when it is continuous at every point of the interval. This implies continuity to the right at the smaller end-value and continuity to the left at the greater end-value. When these conditions at the ends are not satisfied the function is said to be continuous "within" the interval. By a "continuous function" of one variable we always mean a function which is continuous throughout an interval.

The principal properties of a continuous function are:

(1) The function is practically constant throughout sufficiently small intervals; this means that, after any point a of the interval has been chosen, and any positive number ϵ, however small, has been specified, it is possible to find a number h, so that the difference between any two values of the function in the interval between $a-h$ and $a+h$ is less than ϵ. There is an obvious modification if a is an end-point of the interval.

(2) The continuity of the function is "uniform"; this means that the number h which corresponds to any ϵ as in (1) may be the same at all points of the interval, or, in other words, that the numbers h which correspond to ϵ for different values of a have a positive inferior limit.

(3) The function has a greatest value and a least value in the interval, and these are superior and inferior limits which are attained.

(4) There is at least one point of the interval at which the function takes any value between its greatest and least values in the interval.

(5) If the interval is unlimited towards the right (or towards the left), the function has a limit at ∞ (or at $-\infty$).

10. *Discontinuity of Functions.*—The discontinuities of a function of one variable, defined in an interval with the possible exception of isolated points, may be classified as follows:

(1) The function may become infinite, or tend to become infinite, at a point.

(2) The function may be undefined at a point.

(3) The function may have a limit on the left and a limit on the right at the same point; these may be different from each other, and at least one of them must be different from the value of the function at the point.

(4) The function may have no limit at a point, or no limit on the left, or no limit on the right, at a point.

In case a function $f(x)$, defined as above, has no limit at a point a, there are four limiting values which come into consideration. Taking any positive number h, the values of the function at points between a and $a+h$ (a excluded) have a superior limit (or a greatest value), and an inferior limit (or a least value); further, as h decreases, the former never increases and the latter never decreases; accordingly each of them tends to a limit. We have in this way two limits on the right—the inferior limit of the superior limits in diminishing neighbourhoods, and the superior limit of the inferior limits in diminishing neighbourhoods. These are denoted by $\overline{f(a+0)}$ and $\underline{f(a+0)}$, and they are called the "limits of indefiniteness" on the right. Similar limits on the left are denoted by $\overline{f(a-0)}$ and $\underline{f(a-0)}$. Unless $f(x)$ becomes, or tends to become, infinite at a, all these must exist, any two of them may be equal, and at least one of them must be different from $f(a)$, if $f(a)$ exists. If the first two are equal, there is a limit on the right denoted by $f(a+0)$; if the second two are equal, there is a limit on the left denoted by $f(a-0)$. In case the function becomes, or tends to become, infinite at a, one or more of these limits is infinite in the sense explained in § 7; and now it is to be noted that, *e.g.*, the superior limit of the inferior limits in diminishing neighbourhoods on the right of a may be negatively infinite; this happens if, after any number N, however great, has been specified, it is possible to find a positive number h, so that all the values of the function in the interval between a and $a+h$ (a excluded) are less than $-N$; in such a case $f(x)$ tends to become negatively infinite when x decreases towards a; other modes of tending to infinite limits may be described in similar terms.

11. *Oscillation of Functions.*—The difference between the greatest and least of the numbers $f(a)$, $\overline{f(a+0)}$, $\underline{f(a+0)}$, $\overline{f(a-0)}$, $\underline{f(a-0)}$, when they are all finite, is called the "oscillation" of the function $f(x)$ at the point a. This difference is the limit for $h=0$ of the difference between the superior and inferior limits of the values of the function at points in the interval between $a-h$ and $a+h$. The corresponding difference for points in a finite interval is called the "oscillation of the function in the interval." When any of the four limits of indefiniteness is infinite the oscillation is infinite in the sense explained in § 7.

For the further classification of functions we divide the domain of the argument into partial intervals by means of points between the end-points. Suppose that the domain is the interval between a and b. Let intermediate points $x_1, x_2, \ldots x_{n-1}$, be taken so that $b>x_{n-1}>x_{n-2}\ldots>x_1>a$. We may devise a rule by which, as n increases indefinitely, all the differences $b-x_{n-1}, x_{n-1}-x_{n-2}, \ldots x_1-a$ tend to zero as a limit. The interval is then said to be divided into "indefinitely small partial intervals."

A function defined in an interval with the possible exception of isolated points may be such that the interval can be divided into a set of finite partial intervals within each of which the function is monotonous (§ 8). When this is the case the sum of the oscillations of the function in those partial intervals is finite, provided the function does not tend to become infinite. Further, in such a case the sum of the oscillations will remain below a fixed number for any mode of dividing the interval into indefinitely small partial intervals. A class of functions may be defined by the condition that the sum of the oscillations has this property, and such functions are said to have "restricted oscillation." It can be proved that any function with restricted oscillation is capable of being expressed as the sum of two monotonous functions, of which one never increases and the other never diminishes throughout the interval. Such a function has a limit on the right and a limit on the left at every point of the interval. This class of functions includes all those which have a finite number of maxima and minima in a finite interval, and some which have an infinite number. It is to be noted that the class does not include all continuous functions.

12. *Differentiable Function.*—The idea of the differentiation of a continuous function is that of a process for measuring the rate of growth; the increment of the function is compared with the increment of the variable. If $f(x)$ is defined in an interval containing the point a, and $a-k$ and $a+k$ are points of the interval, the expression

$$\frac{f(a+h)-f(a)}{h} \quad (1)$$

represents a function of h, which we may call $\phi(h)$, defined at all points of an interval for h between $-k$ and k except the point 0. Thus the four limits $\overline{\phi(+0)}$, $\underline{\phi(+0)}$, $\overline{\phi(-0)}$, $\underline{\phi(-0)}$ exist, and two or more of them may be equal. When the first two are equal either of them is the "progressive differential coefficient" of $f(x)$ at the point a; when the last two are equal either of them is the "regressive differential coefficient" of $f(x)$ at a; when all four are equal the function is said to be "differentiable" at a, and either of them is the "differential coefficient" of $f(x)$ at a, or the "first derived function" of $f(x)$ at a. In this case $\phi(h)$ has a definite limit at $h=0$, or is determinately infinite at $h=0$ (§ 7). The four limits here in question are called, after Dini, the "four derivates" of $f(x)$ at a. In accordance with the notation for derived functions they may be denoted by

$$\overline{f'_+(a)},\ \underline{f'_+(a)},\ \overline{f'_-(a)},\ \underline{f'_-(a)}.$$

A function which has a finite differential coefficient at all points of an interval is continuous throughout the interval, but if the differential coefficient becomes infinite at a point of the interval the function may or may not be continuous throughout the interval; on the other hand a function may be continuous without being differentiable. This result, comparable in importance, from the present point of view, with the discovery of Fourier's theorem, is due to Riemann; but the failure of an attempt made by Ampère to prove that every continuous function must be differentiable may be regarded as the first step in the theory. Examples of analytical expressions which represent continuous functions that are not differentiable have been given by Riemann, Weierstrass, Darboux, and Dini.

13. *Properties of Derived Functions.*—In regard to the first derived function we have the "theorem of intermediate value": if $f'(x)$ is continuous throughout the interval between a and b, there is a value of x in the interval for which

$$f'(x)=\frac{f(b)-f(a)}{b-a}, \qquad \text{(i.)}$$

or, in the usual notation, there is a number θ between 0 and 1 which has the property that

$$f(b)=f(a)+(b-a)f'\{a+\theta(b-a)\}.$$

This theorem lies at the foundation of the Differential Calculus and of all its applications.

The formation of second and higher differential coefficients need not be dwelt upon here, but it is to be observed that, when $f''(x)$ exists, we have the relation

$$f''(x)=\underset{h=0}{L_t}\frac{f(x+h)-2f(x)+f(x-h)}{h^2}; \qquad \text{(ii.)}$$

on the other hand the limit expressed by the right-hand member of (ii.) may exist although $f''(x)$ does not exist. The same remark applies to the relation

$$f^{(n)}(x)=\underset{h=0}{L_t}h^{-n}\Big[f(x+nh)-nf\{x+(n-1)h\}$$
$$+\frac{n(n-1)}{2\,!}f\{x+(n-2)h\}-\cdots+(-)^n f(x)\Big]. \qquad \text{(iii.)}$$

We have the important results (1) that, when $f'(x)$ vanishes throughout an interval, $f(x)$ is constant throughout the interval; (2) when either $f''(x)$ or the right-hand member of (ii.) can be proved to vanish throughout an interval, $f(x)$ will be proved to be a linear function of x in the interval.

14. *Analytic Function.*—The theorem of intermediate value may be generalized. If $f(x)$ and its first n differential coefficients are continuous in the interval between a and $a+h$, then

$$f(a+h)=f(a)+hf'(a)+\frac{h^2}{2!}f''(a)+\dots$$
$$+\frac{(h^{n-1}}{(n-1)!}f^{(n-1)}(a)+R_n,$$

where R_n may have various forms, some of which have been given in the article INFINITESIMAL CALCULUS, *Ency. Brit.* vol. xiii. pp. 19 and 41. This result is known as "Taylor's theorem."

When Taylor's theorem leads to a representation of the function by means of an infinite series, the function is said to be "analytic" (cf. § 20).

15. *Ordinary Function.*—The idea of a curve representing a continuous function in an interval is that of a line which has the following properties: (1) the co-ordinates of a point of the curve are a value x of the argument and the corresponding value y of the function; (2) at every point the curve has a definite tangent; (3) the interval can be divided into a finite number of partial intervals within each of which the function is monotonous; (4) the property of monotony within partial intervals is retained after interchange of the axes of co-ordinates x and y. According to condition (2) y is a continuous and differentiable function of x, but this condition does not include conditions (3) and (4): there are continuous partially monotonous functions which are not differentiable, there are continuous differentiable functions which are not monotonous in any interval however small; and there are continuous, differentiable, and monotonous functions which do not satisfy condition (4) (cf. § 23). A function which can be represented by a curve, in the sense explained above, is said to be "ordinary," and the curve is called the "graph" of the function. All analytic functions are ordinary, but not all ordinary functions are analytic.

16. *Integrable Function.*—The idea of integration is twofold. We may seek the function which has a given function as its differential coefficient, or we may generalize the question of finding the area of a curve. The first inquiry leads directly to the indefinite integral, the second directly to the definite integral. Following the second method we define "the definite integral of the function $f(x)$ through the interval between a and b" to be the limit of the sum

$$\sum_1^n f(x'_r)(x_r-x_{r-1})$$

when the interval is divided into ultimately indefinitely small partial intervals by points $x_1, x_2, \dots x_{n-1}$; here x'_r denotes any point in the rth partial interval, x_0 is put for a, and x_n for b. It can be shown that the limit in question is finite and independent of the mode of division into partial intervals and of the choice of the points such as x'_r, provided (1) the function is defined for all points of the interval, and does not tend to become infinite at any of them; (2) for any one mode of division of the interval into ultimately indefinitely small partial intervals, the sum of the products of the oscillation of the function in each partial interval and the difference of the end-values of that partial interval has limit zero when n is increased indefinitely. When these conditions are satisfied the function is said to be "integrable" in the interval. The numbers a and b which limit the interval are usually called the "lower and upper limits." We shall call them the "nearer and further end-values."

We have the following theorems:—

(1) Any continuous function is integrable.

(2) Any function with restricted oscillation is integrable.

(3) A discontinuous function is integrable if it does not tend to become infinite, and if the points at which the oscillation of the function exceeds a given number σ, however small, can be enclosed in partial intervals[1] the sum of whose breadths can be diminished indefinitely.

(4) The sum or product of two integrable functions is integrable.

As regards integrable functions we have the following theorems:—

(1) If S and I are the superior and inferior limits (or greatest and least values) of $f(x)$ in the interval between a and b, $\int_a^b f(x)dx$ is intermediate between $S(b-a)$ and $I(b-a)$.

[1] These partial intervals must be a set chosen out of some complete set obtained by the process used in the definition of integration.

(2) The integral is a continuous function of each of the end-values.

(3) Taking the further end-value b as variable, and writing $\int_a^x f(x)dx = F(x)$, if $f(x)$ is continuous at b, $F(x)$ is differentiable at b, and $F'(b) = f(b)$.

(4) In case $f(x)$ is continuous throughout the interval $F(x)$ is continuous and differentiable throughout the interval, and $F'(x) = f(x)$ throughout the interval.

(5) In case $f'(x)$ is continuous throughout the interval between a and b,

$$\int_a^b f'(x)dx = f(b) - f(a).$$

(6) In case $f(x)$ is discontinuous at one or more points of the interval between a and b, in which it is integrable,

$$\int_a^x f(x)dx$$

is a function of x, of which the four derivates at any point of the interval are equal to the limits of indefiniteness of $f(x)$ at the point.

(7) It may be that there exist functions which are differentiable throughout an interval in which their differential coefficients are not integrable; if, however, $F(x)$ is a function whose differential coefficient, $F'(x)$, is integrable in an interval, then

$$F(x) = \int_a^x F'(x)dx + \text{const.},$$

where a is a fixed point, and x a variable point, of the interval. Similarly, if any one of the four derivates of a function is integrable in an interval, all are integrable, and the integral of either differs from the original function by a constant only.

The theorems (4), (6), (7) show that there is some discrepancy between the indefinite integral considered as the function which has a given function as its differential coefficient, and as a definite integral with a variable end-value.

We have also two theorems concerning the integral of the product of two integrable functions $f(x)$ and $\phi(x)$; these are known as "the first and second theorems of the mean." The first theorem of the mean is that, if $\phi(x)$ is one-signed throughout the interval between a and b, there is a number M intermediate between the superior and inferior limits, or greatest and least values, of $f(x)$ in the interval, which has the property expressed by the equation

$$M\int_a^b \phi(x)dx = \int_a^b f(x)\phi(x)dx.$$

The second theorem of the mean is that, if $f(x)$ is monotonous throughout the interval, there is a number ξ between a and b which has the property expressed by the equation

$$\int_a^b f(x)\phi(x)dx = f(a)\int_a^\xi \phi(x)dx + f(b)\int_\xi^b \phi(x)dx.$$

(Cf. the article FOURIER'S SERIES.)

17. *Improper Definite Integrals.*—We may extend the idea of integration to cases of functions which are not defined at some point, or which tend to become infinite in the neighbourhood of some point, and to cases where the domain of the argument extends to infinite values. If c is a point in the interval between a and b at which $f(x)$ is not defined, we impose a restriction on the points x'_r of the definition: none of them is to be the point c. This comes to the same thing as defining $\int_a^b f(x)dx$ to be

$$\underset{\epsilon=0}{L_t}\int_a^{c-\epsilon} f(x)dx + \underset{\epsilon'=0}{L_t}\int_{c+\epsilon'}^b f(x)dx, \qquad (1)$$

where, to fix ideas, b is taken $> a$, and ϵ and ϵ' are positive. The same definition applies to the case where $f(x)$ becomes infinite, or tends to become infinite, at c, provided both the limits exist. This definition may be otherwise expressed by saying that a partial interval containing the point c is omitted from the interval of integration, and a limit taken by diminishing the breadth of this partial interval indefinitely; in this form it applies to the cases where c is a or b.

Again, when the interval of integration is unlimited to the right, or extends to positively infinite values, we have as a definition

$$\int_a^\infty f(x)dx = \underset{h=\infty}{L_t}\int_a^h f(x)dx,$$

provided this limit exists. Similar definitions apply to

$$\int_a^{-\infty} f(x)dx, \text{ and to } \int_{-\infty}^\infty f(x)dx.$$

All such definite integrals as the above are said to be "improper," for example $\int_0^\infty \frac{\sin x}{x}dx$ is improper in two ways. It means

$$\underset{h=\infty}{L_t}\ \underset{\epsilon=0}{L_t}\int_\epsilon^h \frac{\sin x}{x}dx,$$

in which the positive number ϵ is first diminished indefinitely, and the positive number h is afterwards increased indefinitely.

The "theorems of the mean" (§ 16) require modification when the integrals are improper (cf. the article FOURIER'S SERIES).

When the improper definite integral of a function which becomes, or tends to become, infinite, exists, the integral is said to be "convergent." If $f(x)$ tends to become infinite at a point c in the interval between a and b, and the expression (1) does not exist, then the expression $\int_a^b f(x)dx$, which has no value, is called a "divergent integral," and it may happen that there is a definite value for

$$L_t\left\{\int_a^{c-\epsilon} f(x)dx + \int_{c+\epsilon'}^b f(x)dx\right\}$$

provided that ϵ and ϵ' are connected by a definite relation, and both, remaining positive, tend to limit zero. The value of the above limit is then called a "principal value" of the divergent integral. Cauchy's principal value is obtained by making $\epsilon' = \epsilon$, *i.e.*, by taking the omitted interval so that the infinity is at its middle point. A divergent integral which has one or more principal values is sometimes described as "semi-convergent."

18. *Functions of several Variables.*—We have already explained what is meant by the domain of the argument and the rule of calculation of a function of several independent variables, by the limit of such a function at a point, by a function extrinsically defined or tending to become infinite. We shall now suppose that the domain of the argument is a homogeneous part of the numerical

continuum of n dimensions, with the possible exception of isolated points. The definition of a continuous function admits of immediate extension to functions of several variables, but then it is to be noted that a function of n variables may be a continuous function of each set of r variables $(r < n)$ when the rest are kept constant, without being a continuous function of the n variables; more generally the function may be continuous in a restricted domain. The definition of partial differentiation presents no difficulty. The extension of the theorem of intermediate value (§ 13) leads to the theorem of the total differential; for two variables x, y the theorem is that there exist numbers θ and η between 0 and 1, for which

$$f(a+h,\ b+k)-f(a,\ b)=hf_x(a+\theta h,\ b+k)+kf_y(a,\ b+\eta k),$$

provided that the function $f(x, y)$ has continuous partial differential coefficients, $f_x(x, y)$ and $f_y(x, y)$, at all points with a x in the interval between a and $a+h$, and a y in the interval between b and $b+k$. In regard to higher differential coefficients the theorem expressed by $\frac{\partial}{\partial x}\frac{\partial f}{\partial y}=\frac{\partial}{\partial y}\frac{\partial f}{\partial x}$ holds, provided one of the first partial differential coefficients, say $\frac{\partial f}{\partial x}$, and also the corresponding second partial differential coefficient, $\frac{\partial}{\partial y}\frac{\partial f}{\partial x}$, are continuous at the point (x, y). Taylor's theorem, with a remainder after n terms, can be extended to a function of several variables, provided all the partial differential coefficients up to the nth order inclusive are continuous.

With a view to the establishment of the notion of integration through a domain, we must define the "extent" of the domain. Take first a domain consisting of the point a and all the points x for which $| x-a | \leqq \frac{1}{2}h$, where h is a chosen positive number; the extent of this domain is h^n, n being the number of variables; such a domain may be described as "square," and the number h may be called its "breadth"; it is a homogeneous part of the numerical continuum of n dimensions, and its boundary consists of all the points for which $| x-a | = \frac{1}{2}h$. Now the points of any domain, which does not extend to an infinite distance, may be assigned to a finite number m of square domains of finite breadths, so that every point of the domain is either within one of these square domains or on its boundary, and so that no point is within two of the square domains; also we may devise a rule by which, as the number m increases indefinitely, the breadths of all the square domains are diminished indefinitely. When this process is applied to a homogeneous part, H of the numerical continuum C_n, then, at any stage of the process, there will be some square domains of which all the points belong to H, and there will generally be others of which some, but not all, of the points belong to H. As the number m is increased indefinitely the sums of the extents of both these categories of square domains will tend to definite limits, which cannot be negative; when the second of these limits is zero the domain H is said to be "measurable," and the first of these limits is its "extent"; it is independent of the rule adopted for constructing the square domains and contracting their breadths. The notion thus introduced may be adapted by suitable modifications to continua of lower dimensions in C_n.

The integral of a function $f(x)$ through a measurable domain H, which is a homogeneous part of the numerical continuum of n dimensions, is defined in just the same way as the integral through an interval, the extent of a square domain taking the place of the difference of the end-values of a partial interval; and the condition of integrability takes the same form as in the simple case. In particular, the condition is satisfied when the function is continuous throughout the domain. The definition of an integral through a domain may be adapted to any domain of measurable extent. The extensions to "improper" definite integrals may be made in the same way as for a function of one variable; in the particular case of a function which tends to become infinite at a point in the domain of integration, the point is enclosed in a partial domain which is omitted from the integration, and a limit is taken when the extent of the omitted partial domain is diminished indefinitely; a divergent integral may have different (principal) values for different modes of contracting the extent of the omitted partial domain. In applications to mathematical physics great importance attaches to convergent integrals and to principal values of divergent integrals. Delicate questions arise as to the possibility of representing the integral of a function of n variables through a domain H_n, as a multiple integral, of evaluating it by successive integrations with respect to the variables one at a time, and of interchanging the order of such integrations. These questions have been discussed very completely by C. Jordan, and we may quote the result that all the transformations in question are valid when the function is continuous throughout the domain. The same investigations may be applied to answer the questions of the validity of differentiation and integration of an integral with respect to a parameter by performing the like processes on the subject of integration. Taking for simplicity the case of a function of one variable x integrated in the interval between a and b, the parameter being allowed to vary in an interval containing the value α, the process of differentiation under the sign of integration certainly succeeds for α, if the function of x involving the parameter α becomes a function of x and y which is continuous in a domain consisting of all points (x, y) for which x lies between a and b, and y lies between $\alpha+k$ and $\alpha-k$, where k may be as small as we please. The corresponding theorem for integration under the sign of integration can be stated without difficulty. The condition of continuity in the domain of the increased number of variables is sufficient though it is not necessary. When the domain extends to an infinite distance additional conditions, restricting the manner of approach of the function to zero at infinite distances, are requisite for the validity of the processes.

19. *Representation of Functions in general: Series.*—Rational functions are represented by rational algebraic expressions. Some, but not all, implicit algebraic functions which are not rational can be represented rationally in terms of fractional powers of rational algebraic expressions. For the representation of all other one-valued functions of a real variable recourse must be had to limiting processes. We may have functions represented by infinite series, infinite products, definite integrals, or by limits of rational functions of two or more variables in a domain in which all but one of them vary. As an example of the last-named method

$$\underset{y=\infty}{Lt}\ \frac{xy}{x^2y+1}$$

represents a function of x, which vanishes at $x=0$, and at all other points has the value of $1/x$. The two definitions of the Γ function as a definite integral and as an infinite product may serve as examples of the representation of functions by such means. In another method, elaborated by T. Brodén, a continuous function is arrived at graphically, by beginning with a function having a graph in the form of a polygon, and interpolating additional angular points in an ordered sequence without limit. But much the most important method is that of series. From a sequence of numbers a_r, $(r=0, 1, \ldots)$ we may form a new sequence s_n, $(n=0, 1, \ldots)$ by the rule $s_n=\sum_{r=0}^{n} a_r$. If the new sequence has a limit s at $n=\infty$ (§ 6), the "infinite series of numbers" $\sum_{r=0}^{\infty} a_r$ "converges," and s is its "sum." If the series $\sum_{r=0}^{\infty} | a_r |$ also converges, the series $\sum_{r=0}^{\infty} a_r$ is said to converge "absolutely"; otherwise its convergence is "conditional." The importance of this distinction lies in the fact that the sum of an absolutely convergent series is independent of the order of its terms, but this is not the case for a conditionally convergent series (cf. the article SERIES, *Ency. Brit.* vol. xxi.). The numbers a_r may be the values at a point a of an infinite aggregate of functions of a variable x, represented in a domain containing a by analytical expressions $f_r(x)$, $(r=0, 1, \ldots)$. The analytical expression $f_0(x)+f_1(x)+\ldots$ is then called an "infinite series of functions," and the aggregate of the points a at which it converges form the "domain of convergence." The expression represents a function in this domain.

20. *Power Series.*—Taylor's theorem leads in certain cases to a representation of a function by an infinite series. We have under certain conditions (§ 14)

$$f(x)=f(a)+\sum_{r=1}^{n-1}\frac{(x-a)^r}{r!}f^{(r)}(a)+R_n;$$

and this becomes

$$f(x)=f(a)+\sum_{r=1}^{\infty}\frac{(x-a)^r}{r!}f^{(r)}(a), \qquad (1)$$

provided that (α) a positive number k can be found so that at all points in the interval between a and $a+k$ (except these points) $f(x)$ has continuous differential coefficients of all finite orders, and at a has progressive differential coefficients of all finite orders; (β) Cauchy's form of the remainder $\frac{(x-a)^n}{(n-1)!}(1-\theta)^{n-1}f^{(n)}\{a+\theta(x-a)\}$ has the limit zero when n increases indefinitely, for all values of θ between 0 and 1, and for all values of x in the interval between a and $a+k$, except possibly $a+k$. When these conditions are satisfied, the series (1) represents the function at all points of the interval between a and $a+k$, except possibly $a+k$, and the function is "analytic" (§ 14) in this domain. Obvious modifications admit of extension to an interval between a and $a-k$, or between $a-k$ and $a+k$. When a series of the form (1) represents a function it is called "the Taylor's series for the function."

Taylor's series is a power series, *i.e.*, a series of the form

$$\sum_{n=0}^{\infty} a_n(x-a)^n.$$

As regards power series we have the following theorems:

(1) If the power series converges at any point except a there is a number k which has the property that the series converges absolutely in the interval between $a-k$ and $a+k$, with the possible exception of one or both end-points.

(2) The power series represents a continuous function in its domain of convergence (the end-points may have to be excluded).

(3) This function is analytic in the domain, and the power series representing it is the Taylor's series for the function.

The theory of power series has been developed chiefly from the point of view of the theory of functions of complex variables.

21. *Uniform Convergence.*—We shall suppose that the domain of convergence of an infinite series of functions is an interval with the possible exception of isolated points. Let $f(x)$ be the sum of the series at any point x of the domain, and $f_n(x)$ the sum of the first $n+1$ terms. The condition of convergence at a point a is that, after any positive number ϵ, however small, has been specified, it must be possible to find a number n so that $| f_m(a)-f_p(a) | < \epsilon$ for all values of m and p which exceed n, and the sum, $f(a)$, is the limit of the sequence of numbers $f_n(a)$ at $n=\infty$. The convergence is said to be "uniform" in an interval if, after specification of ϵ, the same number n suffices at all points of the interval to make $| f(x)-f_m(x) | < \epsilon$ for all values of m which exceed n. The numbers n corresponding to any ϵ are all finite, but, when ϵ is less than some fixed finite number, they may have an infinite superior limit (§ 7); when this is the case there must be at least one point, α, of the interval which has the property that, whatever number N we take, ϵ can be taken so small that, at some point in the neighbourhood of α, n must be taken $>N$ to make $| f(x)-f_m(x) | < \epsilon$ when $m>n$; then the series does not converge uniformly in the neighbourhood of α. This distinction may be otherwise expressed thus:—Choose a first and ϵ afterwards, then the number n is finite; choose ϵ first and allow a to vary, then the number n becomes a function of a, which may tend to become infinite, or may remain below a fixed number; if such a fixed number exists, however small ϵ may be, the convergence is uniform.

As regards series whose terms represent continuous functions we have the following theorems:

(1) If the series converges uniformly in an interval it represents a function which is continuous throughout the interval.

(2) If the series represents a function which is discontinuous in an interval it cannot converge uniformly in the interval.

(3) A series which does not converge uniformly in an interval may nevertheless represent a function which is continuous throughout the interval.

(4) A power series converges uniformly in any interval contained within its domain of convergence, the end-points being excluded.

(5) If $\sum_{r=0}^{\infty} f_r(x)=f(x)$ converges uniformly in the interval between a and b

$$\int_a^b f(x)dx=\sum_{r=0}^{\infty}\int_a^b f_r(x)dx,$$

or a series which converges uniformly may be integrated term by term.

(6) If $\sum_{r=0}^{\infty} f'_r(x)$ converges uniformly in an interval, then $\sum_{r=0}^{\infty} f_r(x)$ converges in the interval, and represents a continuous differentiable function, $\phi(x)$; in fact we have

$$\phi'(x)=\sum_{r=0}^{\infty} f'_r(x),$$

or a series can be differentiated term by term if the series of derived functions converges uniformly.

A series whose terms represent functions which are not continuous throughout an interval may converge uniformly in the interval. If $\sum_{r=0}^{\infty} f_r(x), =f(x)$, is such a series, and if all the functions $f_r(x)$ have limits at a, then $f(x)$ has a limit at a, which is $\sum_{r=0}^{\infty} \underset{x=a}{Lt} f_r(x)$. A similar theorem holds for limits on the left or on the right.

22. *Fourier's Series.*—An extensive class of functions admit of being represented by series of the form

$$a_0+\sum_{n=1}^{\infty}\left(a_n\cos\frac{n\pi x}{c}+b_n\sin\frac{n\pi x}{c}\right), \qquad \text{(i.)}$$

and the rule for determining the coefficients a_n, b_n of such a series, in order that it may represent a given function

$f(x)$ in the interval between $-c$ and c, was given by Fourier, viz., we have

$$a_0 = \frac{1}{2c}\int_{-c}^{c} f(x)dx, \quad a_n = \frac{1}{c}\int_{-c}^{c} f(x)\cos\frac{n\pi x}{c}dx,$$

$$b_n = \frac{1}{c}\int_{-c}^{c} f(x)\sin\frac{n\pi x}{c}dx.$$

The interval between $-c$ and c may be called the "periodic interval," and we may replace it by any other interval, *e.g.*, that between 0 and 1, without any restriction of generality. When this is done the sum of the series takes the form

$$\underset{n=\infty}{Lt}\int_0^1 \sum_{r=-n}^{r=n} f(z)\cos\{2r\pi(z-x)\}dz,$$

and this is

$$\underset{n=\infty}{Lt}\int_0^1 f(z)\frac{\sin\{(2n+1)(z-x)\pi\}}{\sin\{(z-x)\pi\}}dz. \qquad \text{(ii.)}$$

Fourier's theorem is that, if the periodic interval can be divided into a finite number of partial intervals within each of which the function is ordinary (§ 15), the series represents the function within each of those partial intervals. In Fourier's time a function of this character was regarded as completely arbitrary. By a discussion of the integral (ii.) based on the Second Theorem of the Mean (§ 16) it can be shown that, if $f(x)$ has restricted oscillation in the interval (§ 11), the sum of the series is equal to $\frac{1}{2}\{f(x+0)+f(x-0)\}$ at any point x within the interval, and that it is equal to $\frac{1}{2}\{f(+0)+f(1-0)\}$ at each end of the interval. (See the article FOURIER'S SERIES.) It therefore represents the function at any point of the periodic interval at which the function is continuous (except possibly the end-points), and has a definite value at each point of discontinuity. The condition of restricted oscillation includes all the functions contemplated in the statement of the theorem and others. Further, it can be shown that, in any partial interval throughout which $f(x)$ is continuous, the series converges uniformly, and that no series of the form (i.), with coefficients other than those determined by Fourier's rule, can represent the function at all points, except points of discontinuity, in the same periodic interval. The result can be extended to a function $f(x)$ which tends to become infinite at a finite number of points α of the interval, provided (1) $f(x)$ tends to become determinately infinite at each of the points α, (2) the improper definite integral of $f(x)$ through the interval is convergent, (3) $f(x)$ has not an infinite number of discontinuities or of maxima or minima in the interval.

23. *Representation of Continuous Functions by Series.*—If the series for $f(x)$ formed by Fourier's rule converges at the point a of the periodic interval, and if $f(x)$ is continuous at a, the sum of the series is $f(a)$; but it has been proved by P. du Bois Reymond that the function may be continuous at a, and yet the series formed by Fourier's rule may be divergent at a. Thus some continuous functions do not admit of representation by Fourier's series. All continuous functions, however, admit of being represented with arbitrarily close approximation in either of two forms, which may be described as "terminated Fourier's series" and "terminated power series," according to the two following theorems:—

(1) If $f(x)$ is continuous throughout the interval between 0 and 2π, and if any positive number ϵ however small is specified, it is possible to find an integer n, so that the difference between the value of $f(x)$ and the sum of the first n terms of the series for $f(x)$, formed by Fourier's rule with periodic interval from 0 to 2π, shall be less than ϵ at all points of the interval. This result can be extended to a function which is continuous in any given interval.

(2) If $f(x)$ is continuous throughout an interval, and any positive number ϵ however small is specified, it is possible to find an integer n and a polynomial in x of the nth degree, so that the difference between the value of $f(x)$ and the value of the polynomial shall be less than ϵ at all points of the interval.

Expansions in series of the kinds described in the above theorems (1) and (2) are called "asymptotic expansions." Suppose that $f_0(x)+f_1(x)+\dots$ is an infinite series of functions which does not converge in a certain domain; it may happen that, after any number ϵ, however small, is specified, an integer n can be found so that, at any point a of the domain, $|f(a)-\sum_{r=0}^{n} f_r(a)|<\epsilon$; but it will also happen that, after any number N, however great, is specified, an integer $n'(>n)$ can be found so that $|\sum_{r=0}^{m} f_r(a)|>\text{N}$ for all values of m which exceed n'. The divergent series $f_0(x)+f_1(x)+\dots$ is then an asymptotic expansion for the function $f(x)$.

Again it can be proved that, if $f(x)$ is continuous throughout a given interval, polynomials in x of finite degrees can be found, so as to form an infinite series of polynomials whose sum is equal to $f(x)$ at all points of the interval. Methods of representation of continuous functions by infinite series of rational fractional functions have also been devised.

Particular interest attaches to continuous functions which are not differentiable. Weierstrass gave as an example the function represented by the series $\sum_{n=0}^{\infty} a^n\cos(b^n x\pi)$, where a is positive and less than unity, and b is an odd integer exceeding $(1+\frac{3}{2}\pi)/a$. It can be shown that this series is uniformly convergent in every interval, and that the continuous function $f(x)$ represented by it has the property that there is, in the neighbourhood of any point x_0, an infinite aggregate of points x', having x_0 as a limiting point, for which $\{f(x')-f(x_0)\}/(x'-x_0)$ tends to become infinite with one sign when $x'-x_0$ approaches zero through positive values, and infinite with the opposite sign when $x'-x_0$ approaches zero through negative values. Accordingly the function is not differentiable at any point. The definite integral of such a function $f(x)$ through the interval between a fixed point and a variable point x, is a continuous differentiable function $F(x)$, for which $F'(x)=f(x)$; and, if $f(x)$ is one-signed throughout any interval, $F(x)$ is monotonous throughout that interval, but yet $F(x)$ cannot be represented by a curve; in any interval, however small, the tangent would have to take the same direction for infinitely many points, and yet there is no interval in which the tangent has everywhere the same direction. Further, it can be shown that all functions which are everywhere continuous and nowhere differentiable are capable of representation by series of the form $\Sigma a_n\phi_n(x)$, where Σa_n is an absolutely convergent series of numbers, and $\phi_n(x)$ is an analytic function whose absolute value never exceeds unity.

24. *Interchange of Limiting Operations.*—When we require to perform any limiting operation upon a function which is itself represented by the result of a limiting process, the question of the possibility of interchanging the order of the two processes always arises. In the more elementary problems of analysis it usually happens that such an interchange is possible; but in general it is not possible, or, in other words, the performance of the two processes in different orders may lead to two different results, or the performance of them in one of the two orders may lead to no result. The fact that the inter-

change is possible under suitable restrictions for a particular class of cases is a theorem to be proved. Among examples of such interchanges we have the differentiation and integration of an infinite series term by term (§ 21), and the differentiation and integration of a definite integral with respect to a parameter by performing the like processes upon the subject of integration (§ 18). As a last example we may take the limit of the sum of an infinite series of functions at a point in the domain of convergence. Suppose that the series $\sum_{r=0}^{\infty} f_r(x)$ represents a function $f(x)$ in an interval containing a point a, and that each of the functions $f_r(x)$ has a limit at a. If we first put $x=a$, and then sum the series, we have the value $f(a)$; if we first sum the series for any x, and afterwards take the limit of the sum at $x=a$, we have the limit of $f(x)$ at a; if we first replace each function $f_r(x)$ by its limit at a, and then sum the series, we may arrive at a value different from either of the foregoing. If the function $f(x)$ is continuous at a, the first and second results are equal; if the functions $f_r(x)$ are all continuous at a, the first and third results are equal; if the series is uniformly convergent, the second and third results are equal. This last case is an example of the interchange of the order of two limiting operations, and a sufficient, though not always a necessary, condition, for the validity of such an interchange will usually be found in some suitable extension of the idea of uniform convergence.

AUTHORITIES.—Among the more important treatises and memoirs connected with the subject are: BIERMANN. *Analytische Functionen.* Leipzig, 1887.—BOREL. *Théorie des Fonctions*, Paris, 1898 (containing an introductory account of the Theory of Aggregates), and *Séries divergentes*, Paris, 1901.—DINI. *Functionen e. reellen Grösse*, Leipzig, 1892, and *Serie di Fourier*, Pisa, 1880.—GENOCCHI-PEANO. *Diff.- u. Int.-Rechnung.* Leipzig, 1899.—HARKNESS and MORLEY. *Introduction to the Theory of Analytic Functions.* London, 1898.—HARNACK. *Diff. and Int. Calculus.* London, 1891.—JORDAN. *Cours d'Analyse.* Paris, 1893–1896.—KRONECKER. *Theorie d. einfachen u. vielfachen Integrale.* Leipzig, 1894.—PASCH. *Diff.- u. Int.-Rechnung.* Leipzig, 1882.—PICARD. *Traité d'Analyse.* Paris, 1891.—STOLZ. *Allgemeine Arithmetik*, Leipzig, 1885, and *Diff.- u. Int.-Rechnung*, Leipzig, 1893–1899.—TANNERY, J. *Théorie des Fonctions.* Paris, 1886.—BRODÉN. "Stetige Functionen e. reellen Veränderlichen," *Crelle*, Bd. cxviii.—CANTOR, G. A series of memoirs on the "Theory of Aggregates" and on "Trigonometric series" in *Acta Math.* tt. ii., vii., and *Math. Ann.* Bde. iv.–xxiii.—DARBOUX. "Fonctions discontinues," *Ann. Sci. École normale sup.* (2), t. iv.—DEDEKIND. *Was sind u. was sollen d. Zahlen?* Brunswick, 1887, and *Stetigkeit u. irrationale Zahlen*, Brunswick, 1872.—DIRICHLET. "Convergence des séries trigonométriques," *Crelle*, Bd. iv.—DU BOIS REYMOND, P. *Allgemeine Functionentheorie*, Tübingen, 1882, and many memoirs in *Crelle* and in *Math. Ann.*—HEINE. "Functionenlehre," *Crelle*, Bd. lxxiv.—KLEIN, F. "Allgemeine Functionsbegriff," *Math. Ann.* Bd. xxii.—PINCHERLE. "Funzioni analitiche secondo Weierstrass," *Giorn. di mat.* t. xviii.—PRINGSHEIM. "Bedingungen d. Taylorschen Lehrsatzes," *Math. Ann.* Bd. xliv.—RIEMANN. "Trigonometrische Reihe," *Ges. Werke*, Leipzig, 1876.—SCHOENFLIES. "Entwickelung d. Lehre v. d. Punctmannigfaltigkeiten," *Jahresber. d. Deutschen Math.-Vereinigung*, Bd. viii.—STUDY. Memoir on "Functions with Restricted Oscillation," *Math. Ann.* Bd. lvxii.—WEIERSTRASS. Memoir on "Continuous Functions that are not Differentiable," *Ges. math. Werke*, Bd. ii., Berlin, 1895, and "Représentation des fonctions arbitraires," *Liouville* (4), t. 2. Further information and very full references will be found in the Articles by PRINGSHEIM, SCHOENFLIES, and VOSS in the *Encyclopädie der math. Wissenschaften*, Bde. 1, 2, now in course of publication at Leipzig. (A. E. H. L.)

Fundy, Bay of, an inlet of the North Atlantic, separating New Brunswick from Nova Scotia. It is 145 miles long, 48 miles wide at the mouth and gradually narrows towards the head. It is remarkable for the great rise and fall of the tide, which at the head of the bay is about 55 feet. At spring tides the water in the Bay of Fundy is 19 feet higher than it is in Bay Verte, in Northumberland Strait, only 15 miles distant. Large areas of fertile marshes are situated at the head of the bay, and the remains of a submerged forest show that the land has subsided in the latest geological period at least 40 feet.

Fünfhaus, formerly a suburb of Vienna, but, since 1891, incorporated with the Austrian capital, of which it forms the 15th Ward. In 1890 the population was 44,162; in 1900, 45,371.

FUNGI.

FUNGI in the broad sense include all the lower cellular Cryptogams devoid of chlorophyll, which arise from spores, and the thallus of which is either unicellular or composed of branched or unbranched tubes or cell-filaments, with apical growth (hyphæ), or of more or less complex wefted sheets or tissue-like masses of such (mycelium). The latter may in certain cases attain large dimensions, and even undergo cell-divisions in their interior, resulting in the development of true tissues. The spores, which may be uni- or multi-cellular, are either abstricted free from the ends of hyphæ (acrogenous), or formed from segments in their course (*Chlamydospores*), or from protoplasm in their interior (endogenous). The want of chlorophyll restricts their mode of life—which is rarely aquatic—since they are therefore unable to decompose the carbon dioxide of the atmosphere, and renders them dependent on other plants or (rarely) animals for their carbonaceous food-materials. These they obtain usually in the form of carbohydrates from the dead remains of other organisms, or in this or other forms from the living cells of their hosts; in the former case they are termed *Saprophytes*, in the latter *Parasites*. While some moulds (*Penicillium*, *Aspergillus*) can utilize almost any organic food-materials, other Fungi are more restricted in their choice—*e.g.*, insect-parasites, horn- and feather-destroying Fungi, and parasites generally. It was formerly the custom to include with the Fungi the Schizomycetes or Bacteria, and the Myxomycetes or Mycetozoa; but the peculiar mode of growth and division, the cilia, spores, and other peculiarities of the former, and the emission of naked amœboid masses of protoplasm, which creep and fuse to streaming plasmodia, with special modes of nutrition and spore-formation of the latter, have led to their separation as groups of organisms independent of the true Fungi. On the other hand, Lichens, previously regarded as autonomous plants, are now known to be dual organisms—Fungi symbiotic with Algæ.

The number of species in 1889 was estimated by Saccardo at about 32,000, but of these 8500 were so-called *Fungi imperfecti*—*i.e.*, forms of which we only know certain stages, such as conidia, pycnidia, &c., and which there are reasons for regarding as merely the corresponding stages of higher forms. Saccardo also included about 400 species of Myxomycetes and 650 of Schizomycetes. Allowing for these and for the cases, undoubtedly not few, where one and the same fungus has been described under different names, we obtain Schroeter's estimate (in 1892) of 20,000 species. In illustration of the very different estimates that have been made, however, may be mentioned that of De Bary in 1872 of 150,000 species, and that of Cooke in 1895 of 40,000, and Massee in 1899 of over 50,000 species, the fact being that no sufficient data are as yet to hand for any accurate census. As regards their geographical distribution, Fungi, like flowering plants, have no doubt their centres of origin and of dispersal; but we must not forget that every exchange of wood, wheat, fruits, plants, animals, or other commodities involves transmission of Fungi from one country to another; while the migrations of birds and other animals, currents of air and water, and so forth, are particularly efficacious in transmitting these minute organisms. Against this, of course, it may be argued that parasitic forms can only go where their hosts grow, as is proved to be the case by records concerning the introduction of *Puccinia malvacearum*, *Peronospora viticola*, *Hemileia vastatrix*, &c. Some Fungi—*e.g.*, moulds and yeasts—appear to be distributed all over the earth. That the north temperate regions appear richest in Fungi may be due only to the fact that North America and Europe have been much more thoroughly investigated than other countries; it is certain that the tropics are the home of very numerous species. Again, the accuracy of the statement that the fleshy Agaricini, Polyporei, Pezizæ, &c., are relatively rarer in the tropics may depend on the fact that they are more difficult to collect and remit for identification than the abundantly recorded woody and coriaceous forms of these regions. When we remember that practically all Asia with the exception of parts of the Himalaya, Ceylon, and Java, the whole of Africa except the Cape and parts of Egypt and Algeria, and South America except a small stretch of the south-east coast, the Andes, and Brazil are practically unexplored as regards Fungi, that we know almost nothing of the Fungi of New Zealand, Canada, and the Pacific Islands, the West Indies, or even of those of Turkey, the greater part of Russia and Spain, and that new species are constantly being discovered in the United States, Australia, and Northern Europe—the best explored of all—it is clear that no very accurate census of Fungi can as yet be made, and no generalizations of value as to their geographical distribution are possible.

The existence of fossil Fungi is undoubted, though very few of the identifications can be relied on as regards species or genera. They extend back beyond the Carboniferous, where they occur as hyphæ, &c., preserved in the fossil woods, but the best specimens are probably those in amber and in siliceous petrifactions of more recent origin.

Organs.—Individual hyphæ or their branches often exhibit specializations of form. In many Basidiomycetes minute branches arise below the septa, their tips curve over the outside of the latter, and fuse with the cell above just beyond it, forming a *clamp-connexion*. Many parasitic hyphæ put out minute lateral branches, which pierce the cell-wall of the host and form a peg-like (*Trichosphæria*), sessile (*Cystopus*), or stalked (*Hemileia*), knot-like, or a more or less branched (*Peronospora*) or coiled (*Protomyces*) *haustorium*. In *Rhizopus* certain hyphæ creep horizontally on the surface of the substratum, and then anchor their tips to it by means of a tuft of short branches (*Appressorium*), the walls of which soften and gum themselves to it, then another branch shoots out from the tuft and repeats the process, like a strawberry runner. Appressoria are also formed by some parasitic Fungi, as a minute flattening of the tip of a very short branch (*Erysiphe*), or the swollen end of any hypha which comes in contact with the surface of the host (*Piptocephalis*, *Syncephalis*), haustoria piercing in each case the cell-wall below. In *Botrytis* the appressoria assume the form of dense tassels of short branches. In *Arthrobotrys* side-branches of the mycelium sling themselves around the host (*Tylenchus*) much as tendrils round a support.

Many Fungi (*Phallus*, *Agaricus*, *Fumago*, &c.) when strongly growing put out ribbon-like or cylindrical cords, or sheet-like mycelial plates of numerous parallel hyphæ, all growing together equally, and fusing by anastomoses, and in this way extend long distances in the soil, or over the surfaces of leaves, branches, &c. These mycelial strands may be white and tender, or the outer hyphæ may be hard and black, and very often the resemblance of the subterranean forms to a root is so marked that they are termed *Rhizomorphs*. The outermost hyphæ may even put forth thinner hyphæ, radiating into the soil like root-hairs, and the convergent tips may be closely appressed and so divided by septa as to resemble the root-apex of a higher plant (*Armillaria mellea*).

Sclerotia.—Fungi, like other plants, are often found to store up large quantities of reserve materials (oil, glycogen, carbohydrates, &c.) in special parts of their vegetative tissues, where they lie accumulated between a period of active assimilation and one of renewed activity, forming reserves to be consumed particularly during the formation of large fructifications. These reserve-stores may be packed away in single hyphæ or in swollen cells, but the hyphæ containing them are often gathered into thick cords or *mycelial strands* (*Phallus*, mushroom, &c.), or flattened and anastomosing ribbons and plates, often containing several kinds of hyphæ (*Merulius lacrymans*). In other cases the strands undergo differentiation into an outer layer with blackened, hardened cell-walls and a core of ordinary hyphæ, and are then termed *Rhizomorphs* (*Armillaria mellea*), capable not only of extending the fungus in the soil, like roots, but also of lying dormant, protected by the outer casing. Such aggregations of hyphæ frequently become knotted up into dense masses of interwoven and closely packed hyphæ, varying in size from that of a pin's head or a pea (*Peziza*, *Coprinus*) to that of a man's fist or head, and weighing 10 to 25 ℔ or more (*Polyporus Mylittæ*, *P. tumulosus*, *Lentinus Wœrmanni*, *P. Sapurema*, &c.). The interwoven hyphæ fuse and branch copiously, filling up all interstices. They also undergo cutting up by numerous septa into short cells, and these often divide again in all planes, so that a pseudoparenchyma results, the walls of which may be thickened and swollen internally, or hardened and black on the exterior. In many cases the swollen cell-walls serve as reserves, and sometimes the substance is so thickly deposited in strata as to obliterate the lumen, and the hyphæ become nodular (*Polyporus sacer*, *P. rhinoceros*, *Lentinus Wœrmanni*). The various Sclerotia, if kept moist, give rise to the fructifications of the Fungi concerned, much as a potato-tuber does to a potato-plant, and in the same way the reserve materials are consumed. They are principally Polyporei, Agaricini, Pezizæ; none are known among the Phycomycetes, Uredineæ, or Ustilagineæ. The functions of mycelial strands, Rhizomorphs, and Sclerotia are not only to collect and store materials, but also to extend the fungus, and in many cases similar strands act as organs of attack. The same functions of storage in advance of fructification are also exercised by the stromata so common in Ascomycetes.

Tissue Differentiations.—The simpler mycelia consist of hyphæ all alike and thin-walled, or merely differing in the diameter of the branches of various orders, or in their relations to the environment, some plunging into the substratum like roots, others remaining on its surface, and others (aërial hyphæ) rising into the air. Such hyphæ may be multicellular, or they may consist of simple tubes with numerous nuclei and no septa (*Phycomycetes*), and are then non-cellular. In the more complex tissue-bodies of higher Fungi, however, we find considerable differences in the various layers or strands of hyphæ.

An epidermis-like or cortical protective outer layer is very common, and is usually characterized by the close septation of the densely interwoven hyphæ and the thickening and dark colour of their outer walls (Sclerotia, *Xylaria*, &c.). Fibre-like hyphæ with the lumen almost obliterated by the thick walls occur in mycelial cords (*Merulius*). Latex-tubes abound in the tissues of *Lactarius*, *Stereum*, *Mycena*, *Fistulina*, filled with white or coloured milky fluids, and Istvanffi has shown that similar tubes with fluid or oily contents are widely spread in other Hymenomycetes. Sometimes fatty oil or watery sap is found in swollen hyphal ends, or such tubes contain coloured sap. *Cystidia* and *Paraphyses* may be also classed here. In *Merulius lacrymans* Hartig has observed thin-walled hyphæ with large lumina, the septa of which are perforated like those of sieve-tubes.

As regards its composition, the cell-wall of Fungi exhibits variations of the same kind as those met with in higher plants. While the fundamental constituent is a cellulose in many Mucorini and other Phycomycetes, in others bodies like pectose, callose, &c., commonly occur, and Wisselingh's researches show that chitin, a gluco-proteid common in animals, forms the main constituent in many cases, and is probably deposited directly as such, though, like the other substances, it may be mixed with cellulose. As in other cell-walls, so here the older membranes may be altered by deposits of various substances, such as resin, calcium oxalate, colouring matters; or more profoundly altered throughout, or in definite layers, by lignification, suberization (*Trametes*, *Dædalia*), or swelling to a gelatinous mucilage (*Tremella*, *Gymnosporangium*), while cutinization of the outer layers is common. One of the most striking alterations of cell-walls is that termed *carbonization*, in which the substance gradually turns black, hard, and brittle, as if charred—e.g., *Xylaria*, *Ustulina*, some sclerotia. At the other extreme the cell-walls of many Lichen-Fungi are soft and colourless, but turn blue in iodine, as does starch. The young cell-wall is always tenuous and flexible, and may remain so throughout, but in many cases thickenings and structural differentiations, as well as the changes referred to above, alter the primary wall considerably. Such thickening may be localized, and *pits* (e.g., *Uredospores*, septa of Basidiomycetes), *spirals*, *reticulations*, *rings*, &c. (capillitium fibres of *Podaxon, Calostoma, Battarrea*), occur as in the vessels of higher plants, while sculptured networks, pittings, and so forth are as common on fungus-spores as they are on pollen grains.

Cell-Contents.—The cells of Fungi, in addition to protoplasm, nuclei, and sap-vacuoles, like other vegetable cells, contain formed and amorphous bodies of various kinds. Among those directly visible to the microscope are oil drops, often coloured (*Uredineæ*) crystals of calcium oxalate (*Phallus, Russula*), proteid crystals (*Mucor, Pilobolus*, &c.), and resin (Polyporei). The oidia of Erysipheæ contain fibrosin bodies and the hyphæ of Saprolegnieæ cellulin bodies, but starch apparently never occurs. Invisible to the microscope, but rendered visible by reagents, are, glycogen (*Mucor*, Ascomycetes, yeast, &c.). In addition to these cell-contents we have good indirect evidence of the existence of large series of other bodies, such as proteids, carbohydrates, organic acids, alkaloids, enzymes, &c. These must not be confounded with the numerous substances obtained by chemical analysis of masses of the fungus, as there is often no proof of the manner of occurrence of such bodies, though we may conclude with a good show of probability that some of them also exist preformed in the living cell. Such are sugars (glucose, mannite, &c.), acids (acetic, citric, and a whole series of lichen-acids), aetherial oils and resinous bodies, often combined with the intense colours of Fungi and Lichens, and a number of powerful alkaloid poisons, such as Muscarin (*Amanita*), Ergotin (*Claviceps*), &c.

Among the enzymes already extracted from fungi are *invertases* (yeasts, moulds, &c.), which split cane-sugar, and other complex sugars with hydrolysis into simpler sugars such as dextrose and levulose; *diastases*, which convert starches into sugars (*Aspergillus*, &c.); *cytases*, which dissolve cellulose similarly (*Botrytis*, &c.); *peptases*, using the term as a general one for all enzymes which convert proteids into peptones and other bodies (*Penicillium*, &c.); *lipases*, which break up fatty oils (*Empusa, Phycomyces*, &c.); and *oxydases*, which bring about the oxidations and changes of colour observed in *Boletus*, &c. That such enzymes are formed in the protoplasm is evident from the behaviour of hyphæ, which have been observed to pierce cell-membranes, the chitinous coats of insects, artificial collodion films and layers of wax, &c. Whether the material which Buchner extracted from yeast-cells, finely ground and subjected to extremely high pressures, and which is capable of rapidly breaking down sugar to form carbon dioxide and alcohol, is, as he believes, a true enzyme, or merely finely divided protoplasmic remnants, is not yet clear; if it is an enzyme, its properties are remarkable. That a fungus can secrete more than one enzyme, according to the materials its hyphæ have to attack, has been shown by the extraction of diastase, inulase, trehalase, invertase, maltase, raffinase, malizitase, emulsin, trypsin, and lipase from *Aspergillus* by Bourquelot, and similar events occur in other Fungi. The same fact is indicated by the wide range of organic substances which can be utilized by *Penicillium* and other moulds, and by the behaviour of parasitic Fungi which destroy various cell-contents and tissues. Many of the coloured pigments of Fungi are fixed in the cell-walls or excreted to the outside (*Peziza æruginosa*). Matruchot has used them for staining the living protoplasm of other Fungi by growing the two together. Striking instances of coloured mycelia are afforded by *Corticium sanguineum*, blood red; *Elaphomyces Leveillei*, yellow-green; *Chlorosplenium æruginosum*, verdigris green; and the *Dematei*, brown or black.

Nuclei.—Although many Fungi have been regarded as devoid of nuclei, and all have not as yet been proved to contain them, the numerous investigations of recent years have revealed them in the cells of all forms thoroughly examined, and we are justified in concluding that the nucleus is as essential to the cell of a fungus as to that of other organisms. The hyphæ of many contain numerous, even hundreds of nuclei (Phycomycetes); those of others have several (*Aspergillus*) in each segment, or only two (*Exoascus*), or one (*Erysiphe*) in each cell. Even the isolated cells of the yeast plant have each one nucleus. As a rule the nuclei of the mycelium are very minute (1·5–2 μ in Phycomyces), but those of many asci and spores are large and easily rendered visible. As with other plants, so in Fungi the essential process of fertilization consists in the fusion of two nuclei, but owing to the absence of sexual organs from all but a very few Fungi, a peculiar interest attaches to certain nuclear fusions in the vegetative cells or in young spores of many forms, the significance of which is by no means clear. Thus in Ustilagineæ the Chlamydospores, in Uredineæ the Uredo-, Teleuto-, and Æcidiospores, each contain two nuclei when young which fuse as the spores mature. In many young asci a similar fusion of two or even four nuclei occurs, and also in basidia, in each case the nucleus of the Ascus or of the Basidium resulting from the fusion subsequently giving rise by division to the nuclei of the ascospores and basidiospores respectively. Since this fusion may occur in young asci which have arisen from a fertilized ascogonium (*Sphærotheca*) as well as in such as are not developed as the result of such a sexual process (*Exoascus*), it has been regarded as a secondary phenomenon, the true significance of which is still unexplained, and not as being itself the sexual act. Nuclear division may be accompanied by all the essential features of Karyokinesis (*Peziza Stevensoniana*), or may be direct (mushroom).

Spores.—No agreement has ever been arrived at regarding the consistent use of the term spore. This is apparently owing to the facts that too much has been attempted in the definition, and that differences arise according as we aim at a morphological or a physiological definition. Physiologically, any cell or group of cells separated off from a hypha or unicellular fungus, and capable of itself growing out—germinating—to reproduce the fungus, is a spore; but it is evident that so wide a definition does not exclude the ordinary vegetative cells of sprouting Fungi, such as yeasts, or small sclerotium like cell-aggregates of forms like *Coniothecium*. Morphologically considered, spores are marked by peculiarities of form, size, colour, place of origin, definiteness in number, mode of preparation, and so forth, such that they can be distinguished more or less sharply from the hyphæ which produce them. The only physiological peculiarity exhibited in common by all spores is that they germinate and initiate the production of a new fungus-plant. Whether a spore results from the sexual union of two similar gametes (*zygospore*) or from the fertilization of an egg-cell by the protoplasm of a male organ (*oospore*); or is developed asexually (*gonidium*) as a motile (*zoospore*) or a quiescent body cut off from a hypha (*conidium*) or developed along its course (*oidium* or *chlamydospore*), or in its protoplasm (*endospore*), are matters of importance which have their uses in the classification and terminology of spores, though in many respects they are largely of academic interest.

Klebs has recently attempted to divide spores into three categories as follows:—(1) *Kinospores*, arising by relatively simple cell-divisions and subserving rapid dissemination and propagation, *e.g.*, zoospores, conidia, endogonidia, stylospores, &c.; (2) *Paulospores*, due to simple rearrangement of cell contents, and subserving the persistence of the fungus through periods of exigency, *e.g.*, gemmæ, chlamydospores, resting-cells, cysts, &c.; (3) *Carpospores*, produced by a more or less complex formative process, often in special fructifications, and subserving either or both multiplication and persistence, *e.g.*, zygospores, oospores, Brand-spores, æcidiospores, ascospores, basidiospores, &c. Little or nothing is gained by these definitions, however, which are especially physiological. In practice these various kinds of spores of Fungi receive further special names in the separate groups, and names, moreover, which will appear, to those unacquainted with the history, to have been given without any consistency or regard to general principles; nevertheless, for ordinary purposes these names are far more useful in most cases, owing to their descriptive character, than the proposed new names which have been only partially accepted.

Sporophores.—In some of the simpler Fungi the spores are not borne on or in hyphæ which can be distinguished from the vegetative parts or mycelium, but in the vast majority of cases the sporogenous hyphæ either ascend free into the air or radiate into the surrounding water as distinct branches, or are grouped into special columns, cushions, layers, or complex masses obviously different in colour, consistency, shape, and other characters from the parts which gather up and assimilate the food-materials. The term "receptacle" sometimes applied to these spore-bearing hyphæ is better replaced by *Sporophore*. The sporophore is *obsolete* when the spore-bearing hyphæ are not sharply distinct from the mycelium, *simple* when the constituent hyphæ are isolated, and *compound* when the latter are conjoined. The chief distinctive characters of the sporogenous hyphæ are their orientation, usually vertical; their limited apical growth; their peculiar branching, form, colour, contents, consistency; and their spore-production. According to the characters of the last, we might theoretically divide them into *Conidiophores, Sporangiophores, Gametophores, Oïdiophores*, &c.; but since the two latter rarely occur, and more than one kind of spore or spore-case may occur on a sporophore, it is impossible to carry such a scheme fully into practice.

A simple sporophore may be merely a single short hypha, the end of which stops growing and becomes cut off as a conidium by the formation of a septum, which then splits and allows the conidium to fall. More generally the hypha below the septum grows forwards again, and repeats this process several times before the terminal conidium falls, and so a chain of conidia results, the oldest of which terminates the series (*Erysiphe*); when the primary branch has thus formed a *basipetal* series, branches may arise from below and again repeat this process, thus forming a tuft (*Penicillium*). Or the primary hypha may first swell at its apex, and put forth a series of short peg-like branches (*sterigmata*) from the increased surface thus provided, each of which develops a similar basipetal chain of conidia (*Aspergillus*), and various combinations of these processes result in the development of numerous varieties of exquisitely branched sporophores of this type (*Botrytis, Botryosporium, Verticillium*, &c.).

A second type is developed as follows:—The primary hypha forms a septum below its apex as before, and the terminal conidium, thus abstricted, puts out a branch at its apex, which starts as a mere point and rapidly swells to a second conidium; this repeats the process, and so on, so that we now have a chain of conidia developed in *acropetal* succession, the oldest being below, and, as in *Penicillium*, &c., branches put forth lower down may repeat the process (*Hormodendron*). In all these cases we may speak of simple *conidiophores*. The simple sporophore does not necessarily terminate in conidia, however. In *Mucor*, for example, the end of the primary hypha swells into a spheroidal head (*Sporangium*), the protoplasm of which undergoes segmentation into more or less numerous globular masses, each of which secretes an enveloping cell-wall and becomes a spore (*endospore*), and branched systems of sporangia may arise as before (*Thamnidium*). Such may be termed *Sporangiophores*. In *Sporodinia* the branches give rise also to short branches, which meet and fuse their contents to form *zygospores*. In *Peronospora*, *Saprolegnia*, &c., the ends of the branches swell up into sporangia, which develop zoospores in their interior (*zoosporangia*), or their contents become oospheres, which may be fertilized by the contents of other branches (*pollinodia*) and so form egg-cases (*oogonia*). Since in such cases the sporophore bears sexual cells, they are conveniently termed *gametophores*.

Compound sporophores arise when any of the branched or unbranched types of spore-bearing hyphæ described above ascend into the air in consort, and are more or less crowded into definite layers, cushions, columns, or other complex masses. The same laws apply to the individual hyphæ and their branches as to simple sporophores, and as long as the conidia, sporangia, gametes, &c., are borne on their external surfaces, it is quite consistent to speak of these as compound sporophores, &c., in the sense described, however complex they may become. Among the simplest cases are the sheet-like aggregates of sporogenous hyphæ in *Puccinia*, *Uromyces*, &c., or of basidia in *Exobasidium*, *Corticium*, &c., or of asci in *Exoascus*, *Ascocorticium*, &c. In the former, where the layer is small, it is often termed a *Sorus*, but where, as in the latter, the sporogenous layer is extensive, and spread out more or less sheet-like on the supporting tissues, it is more frequently termed a *Hymenium*. Another simple case is that of the columnar aggregates of sporogenous hyphæ in forms like *Stilbum*, *Coremium*, &c. These lead us to cases where the main mass of the sporophore forms a supporting tissue of closely crowded or interwoven hyphæ, the sporogenous terminal parts of the hyphæ being found at the periphery or apical regions only. Here we have the cushion-like type (*stroma*) of *Nectria* and many Pyrenomycetes, the clavate "receptacle" of *Clavaria*, &c., passing into the complex forms met with in *Sparassis*, *Xylaria*, *Polyporei*, and *Agaricini*, &c. In these cases the compound sporophore is often termed the *Hymenophore*, and its various parts demand special names (*Pileus*, *Stipes*, *Gills*, *Pores*, &c.) to denote peculiarities of distribution of the *Hymenium* over the surface.

Other series of modifications arise in which the tissues corresponding to the *stroma* invest the sporogenous hyphal ends, and thus enclose the spores, asci, basidia, &c., in a cavity. In the simplest case the *stroma*, after bearing its crop of conidia or oidia, develops ascogenous branches in the loosened meshes of its interior (e.g., *Onygena*). Another simple case is where the plane or slightly convex surface of the *stroma* rises at its margins and overgrows the sporogenous hyphal ends, so that the spores, asci, &c., come to lie in the depression of a cavity—e.g., *Solenia*, *Cyphella*—and even simpler cases are met with in *Mortierella*, where the zygospore is invested by the overgrowth of a dense mat of closely branching hyphæ, and in *Gymnoascus*, where a loose mat of similarly barren hyphæ covers in the tufts of asci as they develop.

In such examples as the above we may regard the hymenium (*Solenia*, *Cyphella*), zygospores, or asci as truly invested by later growth, but in the vast majority of cases the processes which result in the enclosure of the spores, asci, &c., in a "fructification" are much more involved, inasmuch as the latter is developed in the interior of hyphal tissues, which are by no means obviously homologous with a *stroma*. Thus in *Penicillium*, *Eurotium*, *Erysiphe*, &c., hyphal ends which are the initials of ascogenous branches, are invested by closely packed branches at an early stage of development, and the asci develop inside what has by that time become a complete investment. Whether a true sexual process precedes these processes or not does not affect the present question, the point being that the resulting spheroidal "fructification" (*Cleistocarp*, *Perithecium*) has a definite wall of its own not directly comparable with a stroma. In other cases (*Hypomyces*, *Nectria*) the perithecia arise on an already mature stroma, while yet more numerous examples can be given (*Poronia*, *Hypoxylon*, *Claviceps*, &c.) where the perithecia originate below the surface of a stroma formed long before. Similarly with the various types of conidial or oidial "fructifications," termed *Pycnidia*, *Spermogonia*, *Æcidia*, &c. In the simplest of these cases—e.g., *Fumago*—a single mycelial cell divides by septa in all three planes until a more or less solid clump results. Then a hollow appears in the centre owing to the more rapid extension of the outer parts, and into this hollow the cells lining it put forth short sporogenous branches, from the tips of which the spores (*Stylospores*, *Conidia*, *Spermatia*) are abstricted. In a similar way are developed the pycnidia of *Cicinnobolus*, *Pleospora*, *Cucurbitaria*, *Leptosphæria*, and others. In other cases (*Diplodia*, *Æcidium*, &c.) conidial or oidial "fructifications" arise by a number of hyphæ interweaving themselves into a knot, as if they were forming a *sclerotium*. The outer parts of the mass then differentiate as a wall or investment, and the interior becomes a hollow, into which hyphal ends grow and abstrict the spores. Much more complicated are the processes in a large series of "fructifications," where the mycelium first develops a densely-packed mass of hyphæ, all alike, in which labyrinths of cavities subsequently form by separation of hyphæ in the previously homogeneous mass, and the hymenium covers the walls of these cavities and passages as with a lining layer. Meanwhile differences in consistency appear in various strata, and a dense outer protective layer (*Peridium*), soft gelatinous layers, and so on are formed, the whole eventually attaining great complexity—*e.g.*, puff-balls, earth-stars, and various *Phalloideæ*.

Spore-distribution.—Ordinary conidia and similarly abstricted dry spores are so minute, light, and numerous that their dispersal is ensured by any current of air or water, and we also know that rats and other burrowing animals often carry them on their fur; similarly with birds, insects, slugs, worms, &c., on claws, feathers, proboscides, &c., or merely adherent to the slimy body. In addition to these accidental modes of dispersal, however, there is a series of interesting adaptations on the part of the fungus itself. Passing over the locomotor activity of zoospores (*Pythium*, *Peronospora*, *Saprolegnia*) we often find spores held under tension in sporangia (*Pilobolus*) or in asci (*Peziza*) until ripe, and then forcibly shot out by the sudden rupture of the sporangial wall under the pressure of liquid behind—mechanism comparable to that of a pop-gun, if we suppose air replaced by watery-sap. Even a single conidium, held tense to the last moment by the elastic cell-wall, may be thus shot forward by a spurt of liquid under pressure in the hypha abstricting it (e.g., *Empusa*), and similarly with basidiospores (*Coprinus*, *Agaricus*, &c.). A more complicated case is illustrated by *Sphærobolus*, where the entire mass of spores, enclosed in its own peridium, is suddenly shot up into the air like a bomb from a mortar by the elastic retroversion of a peculiar layer which, up to the last moment, surrounded the bomb, and then suddenly splits above, turns inside out, and drives the former as a projectile from a gun. Gelatinous or mucilaginous degenerations of cell-walls are frequently employed in the interests of spore dispersal. The mucilage surrounding endospores of *Mucor*, conidia of *Empusa*, &c., serve to gum the spore to animals. Such gums are formed abundantly in *pycnidia*, and, absorbing water, swell and carry out the spores in long *tendrils*, which emerge for days and dry as they reach the air, the glued spores gradually being set free by rain, wind, &c. In oidial chains (*Sclerotinia*) a minute double wedge of wall-substance arises in the middle lamella between each pair of contiguous oidia, and by its enlargement splits the separating lamella. These *disjunctors* serve as points of application for the elastic push of the swelling spore-ends, and as the connecting outer lamella of cell-wall suddenly gives way, the spores are jerked asunder. In many cases the slimy masses of spermatia (*Uredineæ*), conidia (*Claviceps*), basidiospores (*Phallus*, *Coprinus*), &c., emit more or less powerful odours, which attract flies or other insects, and it has been shown that bees carry the fragrant oidia of *Sclerotinia* to the stigma of *Vaccinium* and infect it, and that flies carry away the fœtid spores of *Phallus*, just as pollen is dispersed by such insects. Whether the strong odour of trimethylamine evolved by the spores of *Tilletia* attracts insects is not known.

Classification.—Modern workers are agreed that the vast majority of the Fungi proper fall principally into three great groups, the Phycomycetes, Ascomycetes, and Basidiomycetes, the differences of opinion between various authorities referring chiefly to the details of delimitation of subordinate groups within these, and the relations of these to one another. Even the extreme divergence between the views of De Bary and Brefeld permits this statement, since the principal differences between their schemes concern (1) the relations of origin of the Ascomycetes and Basidiomycetes to the Phycomycetes, (2) the position of the Ustilagineæ within the system, (3) the exact rank of the Uredineæ and their possible relations to Ascomycetes—their alliance with Basidiomycetes not being questioned, and (4) the delimitations of minor groups. Almost all authorities are agreed that Schizomycetes and Myxomycetes are independent groups not coming into the true Fungi at all, a view we adopt here.

When we come to examine the schemes of classification in detail, however, there are many points to be considered. Whether we take the system of Saccardo (1882–92), of

Brefeld and Von Tavel (1892), of Van Tieghem (1893), or of Schroeter (1892), the two former only of which have materially influenced modern mycology, the same truth comes out; each is a purely morphological scheme, and all agree in the main subdivisions, but differ in details as regards the delimitations of frontiers and the inter-relations of the subordinate groups. Saccardo's system is floristic, and designed apart from theory to facilitate the recognition of species, and the recording of synonyms. It has never been drawn up in tabular form, and admits numerous artificial devices to aid in the determination of imperfectly studied forms.

Brefeld's system, which has been more widely accepted than any other since De Bary, is based on (1) the denial of any trace of sexual organs in Ustilagineæ, Uredineæ, Ascomycetes and Basidiomycetes, or indeed in any fungi outside the group of Phycomycetes; (2) on the purely morphological interpretation of the homologies of spores, asci and sporangia, and basidia in the various groups; and (3) on theoretical conclusions from these interpretations as to the evolution of the higher groups from the lower. The following is a brief tabular survey of Brefeld's scheme, though in this form it does not clearly show the cross-connexions he assumes:—

A. **Phycomycetes.**—Alga-like Fungi, with unicellular thallus and sexual organs.

Class 1. OOMYCETES.—Sexual fructification in the form of Oospores; asexual in that of sporangia and conidia.

1. Antheridia and Oogonia as sporangia; asexual reproduction by means of sporangia:—*Monoblepharideæ.*
2. Antheridia reduced, Oogonia as sporangia; asexual reproduction by means of sporangia or conidia:—*Peronosporeæ, Ancylisteæ, Saprolegnieæ (? Chytridiaceæ).*
3. Antheridia and Oogonia reduced; asexual organs conidia:—*Entomophthoreæ.*

Class 2. ZYGOMYCETES.—Sexual fructification in the form of zygospores; asexual as sporangia and conidia.

(α) Exosporangial series:—

1. Sporangia only:—*Mucorinæ, Thamnideæ.*
2. Sporangia and conidia:—*Choanephoreæ.*
2. Conidia only:—*Chætocladieæ, Piptocephalideæ.*

(β) Carposporangial series:—*Rhizopeæ, Mortierelleæ.*

B. **Eumycetes.**—Higher Fungi, with segmented thallus and no sexual organs.

I. MESOMYCETES.—Intermediate forms between the Phycomycetes and Ascomycetes (Hemiasci) on the one hand, and between Phycomycetes and Basidiomycetes (Hemibasidii) on the other.

Class 3. HEMIASCI.—Fructification in the form of sporangia and conidia; sporangia ascus-like.

(α) Exohemiasci:—*Ascoideæ, Protomycetes.*

(β) Carpohemiasci:—*Theleboleæ.*

Class 4. HEMIBASIDII.—Fructification in the form of conidia, no sporangia; conidiophores basidium-like:—*Ustilageæ, Tilletiæ.*

II. MYCOMYCETES, including the vast majority of higher Fungi.

Class 5. ASCOMYCETES.—Fructification as sporangia and conidia; the sporangia definite, and termed Asci.

(α) *Exoasci.*—Asci free, *i.e.*, exoascous:—*Endomycetes, Taphrineæ, Saccharomycetes.*

(β) *Carpoasci.*—Asci enclosed in "fructifications," *i.e.*, carpoascous.

(1) Angiocarpous:—*Gymnoasceæ, Perisporiaceæ, Pyrenomycetes.*

(2) Hemiangiocarpous:—*Hysteriaceæ, Discomycetes, Helvellaceæ.*

Class 6. BASIDIOMYCETES.—Fructification as conidia, no sporangia; Conidiophores definite, and termed Basidia.

(α) *Protobasiomycetes.*—Basidia septate.

(i) Basidia tranversely septate.

(a) Gymnocarpic series:—*Uredineæ, Auricularieæ.*

(b) Angiocarpic series:—*Pilacreæ.*

(ii) Basidia vertically septate:—*Tremellineæ.*

(β) *Autobasidiomycetes.*—Basidia without septa.

(a) Gymnocarpic series:—*Dacryomycetes.*

(b) Angiocarpic:—*Gastromycetes, Phalloideæ.*

(c) Gymnocarpic and Hemiangiocarpic:—*Hymenomycetes.*

Put shortly, Brefeld regards it as proved that the sexual process, so well seen in many Phycomycetes (e.g., *Pythium*), and confirming their derivation from Algæ such as *Vaucheria*, gradually disappears within the limits of the group (e.g., *Peronospora, Phytophthora*), never to reappear in the Fungi. Contrary to the view of De Bary, who considered the Peronosporeæ as the starting-point for the great Ascomycetous series, and saw homologies between the sexual organs of the former and the organs initiating the inception of the cleistocarps of Erysipheæ, Brefeld regards the asci of the latter and of other Ascomycetes as simply sporangia which have become definite in shape, size, and the number of their spores, instead of being indefinite in these respects. In this view he is confirmed by his conviction that the sporangia of *Ascoidea* and *Protomyces* are on the way to become fixed and definite asci, and that the spore-producing cells of yeast have practically become such, while *Thelebolus* can be compared to a sporangium of *Mortierella* with the pedicel suppressed, and with an envelope of barren hyphæ comparable to the weft at the base of the latter. The obviously weak point in this argument is that no explanation is left for the difficult cases of Erysipheæ, *Dipodascus, Eremascus, Eurotium, Pyronema confluens, Collema,* and Laboulbeniaceæ, beyond mere denial that the structures observed are sexual organs, a denial which is seriously discounted by the observations of Harper on *Sphærotheca*, Bauer on *Collema*, and Thaxter on Laboulbeniaceæ, observations which in the opinion of many authorities establish beyond reasonable doubt that a sexual process does occur in these Fungi. It is even more difficult to reconcile this view with the facts of conjugation recently discovered in certain yeasts and described by Barker (*Proc. R.S.*, 1901). As regards Dangeard's views, see below. It is impossible in the space at command to do more than call attention to salient features in the principal groups.

A. PHYCOMYCETES.—Most of the recent work in this group concerns the studies in Cytology by Wager, Dangeard, &c., and the effect of external conditions on the formation of sporangia and zygotes by Klebs. Brefeld's speculations on the morphology have been referred to.

The *Oomycetes* are characterized by the general development of oospheres and pollinodia (antheridia), and in the typical cases by the fertilization of the former by motile antherozoids or nuclear contents discharged from the latter, the sexual organs being therefore dissimilar. Most of them are aquatic or parasitic, and interesting series of degenerations, loss of sexuality, motile and non-motile asexual spores occur. The group is of theoretical importance owing to their alga-like characters, and to the fact that De Bary regarded the oogonium with its oospheres and the pollinodium as the starting-point whence could be derived the sexual organs in certain Ascomycetes (*e.g.*, Erysipheæ), and thus of the whole Ascomycetous series of Fungi.

The *Saprolegnieæ* comprise about fifty to sixty species of chiefly aquatic Fungi. *Pythium* causes the "damping off" of seedlings, its hyphæ penetrating the cell-walls and rapidly destroying the watery tissues of the living plant, and also living on the dead remains. As the free ends emerge again into the air they swell up into spherical bodies, each of which may either fall off as a *conidium* and germinate by means of a germ tube, which again infects the host; or the germ-tube is put forth while the conidial swelling is still attached and itself swells up into a *zoosporangium*, the protoplasm in which develops swarm-spores. In the rotting tissues branches of the older mycelium similarly swell up at the ends (*oogonia*) and the contents become an *oosphere*, into which the protoplasmic contents of a short branch (*pollinodium* or "antheridial branch"), developed elsewhere on the hypha, are poured and fertilize it; the oosphere thus becomes an *oospore*. *Pythium* is of theoretical importance (1) as a fungus where true sexual reproduction is perfected, (2) as illustrating the dependence of zoospore-formation on the conditions and the indeterminate nature of *conidia*, and (3) as a case where the saprophytic and parasitic habits are alike practised. *Pythium* is also (4) the best type of the group, showing possible transition to the rest of the Saprolegnieæ, e.g., *Saprolegnia*, *Achlya*, &c., with cylindrical zoosporangia, and usually several oospores in the oogonia, and becoming parthenogenetic in extreme cases; the Peronosporineæ, distinguished chiefly by the more pronounced conidiophores and abstriction of conidia; and the Monoblepharideæ. Klebs has shown that the development of zoosporangia or of oogonia and pollinodia respectively in *Saprolegnia* is dependent on the external conditions; so long as a continued stream of suitable food-material is ensured the mycelium grows on without forming reproductive organs, but directly the supplies of nitrogenous and carbonaceous food fall below a certain degree of concentration sporangia are developed. Further reduction of the supplies of food effects the formation of oogonia. This explains the sequence of events in the case of a *Saprolegnia*-mycelium radiating from a dead fly in water. Those parts nearest the fly and best supplied develop barren hyphæ only; in a zone at the periphery, where the products of putrefaction dissolved in the water form a dilute but easily accessible supply, the zoosporangia are developed in abundance; oogonia, however, are only formed in the depths of this radiating mycelium, where the supplies of available food materials are least abundant. Saprolegnieæ do not form motile spermatozoids, statements alleging their existence not having been confirmed. Nevertheless, the nuclear masses passed over to the oospheres in those species in which fertilization is completed are doubtless homologous with spermatozoids. Each zoospore has one nucleus. The oogonia are multinucleate, reduction occurring before fertilization. The possible origin of this group from Siphoneæ—e.g., *Vaucheria*-like Algæ—has been suggested, and in connexion with the primitive forms—e.g., *Pythium*—there is much to be said in support of the supposition.

Peronosporeæ are a group of endophytic parasites—about 100 species—of great importance as comprising the agents of the vine mildew (*Plasmopara*), potato disease (*Phytophthora*), onion mildew (*Peronospora*), and several other epidemic diseases. The mycelium usually sends haustoria into the cells of the host, and puts out sharply marked conidiophores through the stomata, the branches of which abstrict numerous "conidia"; these either germinate directly, or their contents break up into zoospores, which escape and, after swarming for some time, germinate and infect the host-plant. This behaviour of the "conidia," sometimes as true conidial spores, sometimes as zoosporangia, may occur in one and the same species (*Cystopus candidus*, *Phytophthora infestans*), and reminds us of the similar phenomena in *Pythium*; in other cases the direct germination is characteristic for genera—e.g., *Bremia*, *Peronospora*—while others emit zoospores—e.g., *Plasmopara*, &c. In *Cystopus* the "conidia" are abstricted in basipetal chain-like series from the ends of hyphæ, which come to the surface in tufts and break through the epidermis as white pustule-like groups. Each conidium contains numerous nuclei, which do not fuse. The Peronosporineæ form oogonia, with one oosphere and pollinodia on the older mycelium, as in *Pythium*, and in some (*Phytophthora omnivora*) the fertilizing tube passes its protoplasm into the oosphere; in others no fertilization occurs (parthenogenesis), and in *Phytophthora infestans* the power of forming oogonia seems to have been lost altogether. Wager has shown that in *Cystopus* the pollinodium, which contains several nuclei, passes a nucleus into the oosphere, which unites with one of the hundred or more nuclei in the latter; the other nuclei pass to the periphery and take no part in the process. In the ripe oospore thirty-two nuclei are formed by repeated division. Magnus states that *Peronospora parasitica*, while unable to infect the older tissues of *Capsella*, is able to enter the hypertrophied cushions of these tissues infected by *Cystopus candidus*.

Monoblepharidineæ comprise three species resembling Saprolegnia, but the oogonium opens and exposes the one oosphere. The antheridial branch also opens and sets free a few amœboid spermatozoids, each with one flagellum. The spermatozoid creeps on the outside of the oogonium, enters the orifice, and fertilizes the oosphere. Resemblances between *Monoblepharis* and *Œdogonium* are interesting, as pointing to another possible origin of Fungi from Algæ.

Chytridineæ.—These parasitic and minute, chiefly aquatic, forms may be looked upon as degenerate Oomycetes, since a sexual process and feeble unicellular mycelium occur in some; or they may be regarded as series of primitive forms leading up to higher members. There is no means of deciding the question. Some authorities include them in Oomycetes, but on the whole their simple structure, minute size, usually uniciliate zoospores, and their negative characters justify their retention as a separate group. It contains less than 200 species, chiefly parasitic on or in Algæ and other water-plants or animals, of various kinds, or in other Fungi, seedlings, pollen, and higher plants. They are often devoid of hyphæ, or put forth fine protoplasmic filaments into the cells of their hosts. After absorbing the cell-contents of the latter, which it does in a few hours or days, the fungus puts out a sporangium, the contents of which break up into numerous minute swarm-spores, usually one-ciliate, rarely two-ciliate. Any one of these soon comes to rest on a host-cell, and either pierces it and empties its contents into its cavity, where the further development occurs (*Olpidium*), or merely sends in delicate protoplasmic filaments (*Rhizophydium*) or a short hyphal tube of, at most, two or three cells, which acts as a haustorium, the further development taking place outside the cell-wall of the host (*Chytridium*). In some cases resting spores are formed inside the host (*Chytridium*), and give rise to zoosporangia on germination. In a few species a sexual process is described, consisting in the conjugation of similar cells (*Zygochytrium*) or the union of two dissimilar ones (*Polyphagus*). In the development of distinct pollinodial and oogonial cells the allied Ancylistineæ show close alliances to *Pythium* and the Oomycetes. On the other hand, the uniciliate zoospores of *Polyphagus* have slightly amœboid movements, and in this and the pseudopodium-like nature of the protoplasmic processes, such forms suggest resemblances to the Myxomycetes. Opinions differ as to whether the Chytridineæ are degraded or primitive forms, and the group still needs critical revision. Many new forms will doubtless be discovered, as they are rarely collected on account of their minuteness. Some forms cause damping off of seedlings—e.g., *Olpidium Brassicæ*; others discoloured spots and even tumour-like swellings—e.g., *Synchytium Scabiosæ*, *S. Succisæ*, *Urophlyctis*, &c., on higher plants. Analogies have been pointed out between Chytridiaceæ and unicellular Algæ, such as Chlorosphæraceæ, Protococcaceæ, "Palmellaceæ," &c., some of which are parasitic, and suggestions may be entertained as to possible origin from such Algæ.

The *Zygomycetes* (*Mucorini*), of which nearly 150 species are described, have become especially important from a theoretical standpoint, since they furnish the series whence Brefeld derives the vast majority of the Fungi. They are characterized especially by the *zygospores*, but the asexual organs (*sporangia*) exhibit interesting series of changes, beginning with the typical sporangium of *Mucor* containing numerous endospores, passing to cases where, as in *Thamnidium*, these are accompanied with more numerous small sporangia (*sporangioles*) containing few spores, and thence to *Chætocladium* and *Piptocephalis*, where the sporangioles form but one spore and fall and germinate as a whole; that is to say, the monosporous sporangium has become a *conidium*, and Brefeld regards these and similar series of changes as explaining the relation of ascus to conidium in higher Fungi. According to his view, the ascus is in effect the *sporangium* with several spores, the conidium the *sporangiole* with but one spore, and that not loose but fused with the sporangiole wall. On this basis, with other interesting morphological comparisons, Brefeld erected his hypothesis that the Ascomycetes and Basidiomycetes diverge from the Zygomycetes, the former having particularly specialized the ascus (sporangial) mode of reproduction, the latter having specialized the conidial (indehiscent one-spored sporangiole) mode. In addition to sporangia and the conidial spores referred to, some Mucorini show a peculiar mode of vegetative reproduction by means of *Gemmæ* or *Chlamydospores*—*i.e.*, short segments of the hyphæ become stored with fatty reserves and act as spores. The gemmæ formed on submerged Mucors may bud like a yeast, and even bring about alcoholic fermentation in a saccharine solution.

The classification of the Mucorini depends on the prevalence and characters of the conidia, and of the sporangia and zygospores—*e.g.*, the presence or absence of a *columella* in the former, the formation of an investment round the latter. Most genera are saprophytes, but some—*Chætocladium*, *Piptocephalis*—are parasites on other Mucorini, and one or two are associated casually with the rotting of tomatoes and other fruits, bulbs, &c., the fleshy parts of which are rapidly destroyed if once the hyphæ gain entrance. Even more important is the question of mycosis in man and other animals, referred to species of *Mucor*, and recently investigated by Lucet and Costantin. Klebs's demonstration that transpiration is the important factor in determining the formation of sporangia, while zygote-development depends on totally different conditions, is valuable, as are also his other researches on *Sporodinia* and *Mucor*.

B. Eumycetes.—With the exception of Brefeld's re-grouping of the lower forms into Hemi-asci and Hemibasidii (Mesomycetes), it will be noticed that very little alteration has been brought about in the classification of the main groups.

I. Mesomycetes.

Hemi-asci.—This name was proposed by Brefeld to include a number of forms which in his opinion exhibit the transition from sporangium-bearing Phycomycetes to the true Ascomycetes. They are all small Fungi with a septate mycelium and no trace of sexual reproduction, the spores being developed in sporangia which resemble asci in most respects, but differ in being somewhat indefinite as regards the number of spores produced, and in form, size, and position. The group comprises a somewhat heterogeneous collection of types, and severe criticism may be passed on the retention of such genera as *Ascoidea*, *Protomyces*, *Thelebolus*, and (by some authors) *Saccharomyces*, &c., in one circle of alliance; the difficulties are evaded in part by Schroeter's device of separating *Saccharomycetes* and constituting a new group (Protoascineæ) of them and a few other forms. In *Ascoidea* and *Protomyces* the ascus-like sporangia are exposed (Exo-hemiasci), but in *Thelebolus* they are covered in by a web of hyphæ (Carpo-hemiasci).

Hemi-basidii, Ustilagineæ.—The Bunts and Smuts which damage our grain and fodder plants comprise about 400 species of internal parasites, found in all countries on herbaceous plants, and especially on Monocotyledons. They are remarkable for their dark spores developed in gall-like excrescences on the leaves, stems, &c., or in the fruits of the host. The discovery of the yeast-conidia of these Fungi, and their thorough investigation by Brefeld, have thrown new lights on the group, as also have the results elucidating the nature of the ordinary dark spores—Smuts, Bunt, &c.—which by their mode of origin and development are *Chlamydospores*. When the latter germinate a slender "promycelium" is put out; in *Ustilago* and its allies this is transversely septate, and bears lateral conidia (sporidia); in *Tilletia* and its allies non-septate, and bears a terminal tuft of conidia (sporidia). Brefeld regards the promycelium as a kind of *basidium*, bearing lateral or terminal conidia (comparable to *basidiospores*), but since the number of basidiospores is not fixed, and the basidium has not yet assumed very definite morphological characters, Brefeld terms the group *Hemi-basidii*, and regards them as a sort of half-way stage in the evolution of the true Basidiomycetes from Phycomycetes, the *Tilletia* type leading to the true basidium (Autobasidium), the *Ustilago* type to that of the Protobasidiomycetes, with lateral spores. The yeast-conidia, which bud off from the conidia or their resulting mycelium when sown in nutrient solutions, are developed in successive crops by budding exactly as in the yeast plant, but they cannot ferment sugar solutions. It is the rapid spread of these yeast-conidia in manure and soil waters which makes it so difficult to get rid of Smuts, &c., in the fields, and they, like the ordinary conidia, readily infect the seedling wheat, oats, barley, or other cereals. Infection in these cases can only occur in the seedling at the place where root and shoot meet, and the infecting hypha having entered the plant goes on living in it and growing up with it as if it had no parasitic action at all. When the flowers form, however, the mycelium sends hyphæ into the young ovaries and rapidly replaces the stores of sugar and starch, &c., which would have gone to make the grain, by the soot-like mass of spores so well known as *Smut*, &c. These spores adhere to the grain, and unless destroyed, by "steeping" or other treatment, are sown with it, and again produce sporidia and yeast-conidia which infect the seedlings. In other species the infection occurs elsewhere, the chief condition apparently being that the vulnerable tissue must be in the embryonic state.

II. Mycomycetes.

Ascomycetes.—Here the main groups are retained much as in older classifications, but an additional group, not regarded in Brefeld's scheme, the *Laboulbeniaceæ*, must be added owing to the importance they have attained in Thaxter's hands.

The *Exoasci* are usually regarded as comprising about 100 species of small Fungi, the mycelium of which is obsolete or septate and often breaks up into single cells, with a pronounced tendency to sprouting (yeast-forms). The asci are formed directly on the mycelium or by the direct conversion of the isolated cells, and are therefore fully exposed and devoid of any investment. They form the simplest of the Ascomycetes, the Endomycetes, comprising the true yeasts and their allies, being mostly ferment-Fungi with isolated four-spored asci, and the Taphrineæ, about fifty species of chiefly parasitic forms, having an endophytic mycelium, which develops eight-spored asci in layers breaking through the epidermis of the host-plant. Many of these Taphrineæ are important parasites—*e.g.*, Pocket plums and Witches' Brooms on Birches, &c., are due to their action. *Exoascus* and *Ascocorticium* present interesting parallels to *Exobasidium* and *Corticium* among the Basidiomycetes, the former having asci where the latter have basidia. Schroeter places the Endomycetes in a group by themselves (*Protoascineæ*) and the Taphrineæ in another, *Protodiscineæ*. Perhaps the term Proto-ascomycetes might be employed for both.

Saccharomyces, the genus into which the true yeasts which ferment various sugars and form endogenous spores are put, has attained an importance of late even beyond that to which it was brought by Pasteur's researches on alcoholic fermentation, chiefly owing to the exact results of the investigations of Hansen, who first applied the methods of pure cultures to the study of these organisms, and showed that many of the inconsistencies hitherto existing in the literature were due to the coexistence in the cultures of several species or races of yeasts morphologically almost indistinguishable, but physiologically very different. About fifty species of *Saccharomyces* are described more or less completely, but since many of these cannot be distinguished by the microscope, and some have been found to develop physiological races or varieties under special conditions of growth, the limits are still far too ill-defined for complete botanical treatment of the genus. A typical yeast is able to develop new cells by budding when submerged in a saccharine solution, and to ferment the sugar—*i.e.*, so to break up its molecules that, apart from small quantities used for its own substance, masses of it out of all proportion to the mass of yeast used become resolved into other bodies, such as carbon dioxide and alcohol, the process requiring little or no oxygen. Brefeld regards the budding process as the formation of *conidia*. Under other conditions, of which the temperature is an important one, the nucleus in the yeast-cell divides, and each daughter-nucleus again, and four *spores* are formed in the mother cell, a process obviously comparable to the typical development of ascospores in an ascus. Under yet other conditions the quiescent yeast-cells floating on the surface of the fermented liquor grow out into elongated sausage-shaped or cylindrical cells and branching cell-series, which mat together into mycelium-like *veils*. At the bottom of the fermented liquor the cells often obtain fatty contents and thick walls, and behave as resting cells (*chlamydospores*). The characters employed by experts for determining a species of yeast are the sum of its peculiarities as regards form and size; the shapes, colours, consistency, &c., of the colonies grown on certain definite media; the optimum temperature for spore-formation, and for the development of the *veils*, and the behaviour as regards the various sugars.

The following summary of some of the principal characteristics of half-a-dozen species will serve to show how such peculiarities can be utilized for systematic purposes:—

Species.	Optimum Temperature for		Characters of			Sugars Fermented and Products, &c.
	Spores.	Veils.	Fermentation.	Cells.	Spores.	
S. cerevisceæ I. . .	30°	20°–28°	High	Rounded	Globoid	Invert maltose and saccharose and form alcohol 4–6 vol. per cent.
S. Pastorianus I. .	27°–5°	26°–28°	Low	Rounded	Globoid	
S. ellipsoideus . .	25°	33°–34°	Low	Rounded	Globoid	
S. anomalus . .	28°–31°	?	High	Elliptical	Hat shaped	Ditto, and evolves fragrant ether.
S. Ludwigii . .	30°–31°	?	?	Elongated	Globoid	Will not invert maltose.
S. membranæfaciens	30°	?	High	Elongated	Globoid	Inverts neither maltose nor saccharose.

Two questions of great theoretical importance have been raised over and over again in connexion with yeasts, namely, (1) the morphological one as to whether yeasts are merely degraded forms of higher Fungi, as would seem implied by their tendency to form elongated, hypha-like cells in the veils, and their development of "ascospores" as well as by the wide occurrence of yeast-like "sprouting forms" in other Fungi (e.g., *Mucor*, Exoasci, Ustilagineæ, higher Ascomycetes and Basidiomycetes); and (2) the question as to the physiological nature and meaning of fermentation. With regard to the first question no satisfactory proof has as yet been given that Saccharomycetes are derivable by culture from any higher form, the recent statements to that effect not having been confirmed on re-examination by Klöcker and Schionning. At the same time there are strong grounds for insisting on the resemblances between *Endomyces*, a hyphal fungus bearing yeast-like asci, and such a form as *Saccharomyces anomalus*. Concerning the second question, the most recent investigations by E. Buchner show that by means of prolonged grinding, and the use of very high pressures, a something sufficiently soluble in, or miscible with, water to pass through fine filters can be obtained which causes sugar to break up into carbon dioxide and alcohol in the absence of living yeast-cells, and this has been confirmed by Green. The question whether this extracted body, which Buchner calls *Zymase*, is a true enzyme, or merely finely particulate protoplasm, has been much debated. The strongest arguments in favour of its enzyme nature are its extreme diffusibility or solubility in water, its passage through filters, and the statements that it can be dried and kept for short periods, and still retain its powers of exciting alcoholic fermentation on again distributing in water, and that it will act in presence of chloroform. In considering the bearing of these facts on the theory of fermentation proposed by Pasteur, and now so widely adopted, it must not be forgotten that although Buchner's discovery disposes of the view that alcoholic fermentation is a vital phenomenon inseparable from the presence of living yeast-cells, it does not preclude the reply that the alleged enzyme is a product of the living protoplasm, if not an integral part of it.

Whether *Schizo-saccharomyces*, a yeast which divides into two cells, which then fuse and produce spores, and *Zygo-saccharomyces*, a form in which the sporogenous cells conjugate before spore-formation, are true Saccharomycetes is still an open question. In any case, the behaviour of these genera reopens the question of the autonomy of the group.

Gymnoasceæ, which Fischer proposes to group with Aspergillaceæ, Onygenaceæ, and the truffle-like Elaphomycetes, &c., as a separate group, termed *Plectascineæ* in reference to the occurrence of the asci on irregular branches scattered throughout the interior of the very loose tissue, are kept as a separate group of about twenty species by Brefeld. They are remarkable for the loose investment of the ascigerous branches, and *Ctenomyces* for its habitat—old feathers.

The *Perisporiaceæ*, including the somewhat heterogeneous Erysipheæ, Perisporeæ, and Tuberaceæ, number probably about 1000 species. The interesting points regarding the sexuality of Erysipheæ are discussed elsewhere. Tuberaceæ comprises the underground truffles, some of which are symbiotic with the roots of trees, on which they form *Mycorhiza*. *Eurotium* (*Aspergillus*) has become still more classical since Klebs gave us a study of the conditions necessary for the development of its reproductive organs. *Onygena*, a remarkable horn-destroying fungus which long defied cultivation, has been shown by Marshall Ward to require the action of the digestive juices in an animal's stomach in order that the spores may germinate, and its life-history is now worked out. *Penicillium*, the common mould, which has played for the plant-physiologist the part that the frog does for the animal physiologist, has been shown to grow on the most unlikely poisonous substances —*e.g.*, solutions containing arsenic, copper, sulphuric acid, &c.— and has been found to form very different enzymes. It is an active agent in the destruction of wood, as shown by Marshall Ward. The significance of the "sexual organs" described by Brefeld and De Bary in this and in *Eurotium* still requires elucidation. *Aspergillus Oryzæ* plays an important part in saccharifying the starch of rice, maize, &c., by means of the abundant diastase it excretes, and, in symbiosis with a yeast which ferments the sugar thus formed, has long been used by the Japanese in the preparation of the alcoholic liquor, *saké*. The process has now been successfully introduced into European commerce. The Gymnoasceæ, Perisporiaceæ, and Pyrenomycetes are classed as Angiocarpous by Brefeld to emphasize the fact that their asci are developed in permanently closed fructifications (Cleistocarps), or in such as only open by an orifice above (Perithecia).

The *Discomycetes* in the wider sense, including the Hysteriaceæ, Phacidiaceæ, Helvellaceæ, &c., comprise not fewer than 4000, and probably nearer 5000 species, of which the well-known *Peziza*-form is the type, though extreme forms of Hysteriaceæ on the one hand and of Helvellaceæ on the other depart far from it in shape, &c.

Woronin's continued and beautiful work on *Sclerotinia* has led to much important information as to the parasitism of this group of Pezizæ. The conidia are fragrant, and carried by bees to the stigma of a bilberry; here they germinate with the pollen, and the hyphæ race the pollen-tubes down the style, and infest the ovules, where they develop sclerotia and mummify the fruits. From the sclerotium the Peziza-form develops. The conidia have remarkable disjunctors. One species is *heterœcious*, the only case known of heterœcism outside the Uredineæ. The Discomycetes and their immediate allies are termed Hemiangiocarpous, because however much their fructifications are closed at first, they ultimately open and expose the layers of asci (Apothecia).

Laboulbeniaceæ are a group of about 150 species of Fungi found on insects, especially beetles, and principally known in America from the researches of Thaxter. The plant is a small, dark brown, erect structure (receptacle) of a few cells, and 1–10 mm. high, attached to the insect by the lowermost end (foot), and easily mistaken for a hair or similar appendage of the insect. The receptacle ends above in *appendages*, each consisting of one or a few cells, some of which are the *male organs*, others the *female organs*, and others again may be barren *hairs*. The male organ (*antheridium*) consists of a few cells, the terminal one of which either abstricts from its end, or emits from its interior the non-motile *antherozoids*, reminding us of those of the Florideæ. The female organ is essentially a flask-shaped structure; the neck of the flask growing out as the *trichogyne*, and the belly composed of an axial *carpogenic cell* surrounded by investing cells, and with one cell (*trichophoric*) between it and the trichogyne. These three elements—trichogyne, trichophoric cell, and carpogenic cell—are regarded as the procarp. The antherozoids have been shown by Thaxter to fuse with the trichogyne, after which the axial cell below (*carpogenic cell*) undergoes divisions, and ultimately forms *asci* containing *ascospores*, while cells investing this form a *perithecium*, the whole structure reminding us essentially of the fructification of a Pyrenomycete. Many modifications in details occur, and the plants may be diœcious. No injury is done to the infested insects, and the importance of the type turns on the resemblances between the mode of fertilization referred to and that of the Red Seaweeds.

Basidiomycetes.—The principal advances in this group concern the discovery of accessory organs of reproduction—conidia and chlamydospores—and the important work on the Protobasidiomycetes, both initiated by Brefeld and his co-workers.

Uredineæ, of which nearly 2000 species are described, are intercellular parasites on higher plants, and so generally of some shade of orange-yellow or rusty-red, owing to oily cell-contents of such colours, that they are termed Rust Fungi, a designation the more apt since the myriads of spores dust off like iron-rust. Of the five different kinds of spores—Uredospores, Teleutospores, Sporidia, Æcidiospores, and Spermatia—the Teleutospore is the most constant, and the divisions into genera are based chiefly on its characters. It may consist of one, two, three, or more cells variously grouped, may germinate forthwith or only after a resting period, have specific markings on the walls, and so forth. The subdivisions of the larger genera depend on the coexistence of the Uredo- or Æcidium-form, or both, with the Teleutospores, and on their behaviour. The Teleutospores put forth on germination a promycelium, which is transversely septate and bears lateral conidia (sporidia), and so obviously resemble *Ustilago* in these respects that Brefeld names them accordingly—a chlamydospore putting forth a basidium which bears basidiospores. The close resemblances to the corresponding organs in Auriculariеæ have long been noticed, whence some authors regard Uredineæ as true protobasidiomycetes; their parasitism and other peculiarities of habit, and the frequent co-existence of other specialized chlamydospores (Uredo, Æcidium) and conidia (Spermatia) sufficiently distinguish them. The remarkable phenomenon of *Heterœcism*—*i.e.*, the development of one or more forms (Uredo- and Teleuto-spores) on one host, and others (Æcidium and Spermatia) on another host distantly related—is now known in about fifty species of several genera, of which the following are examples:—

Species.	Teleutspores on	Æcidium on
Coleosporium Senecionis	*Pinus*	*Senecio*
Melampsora Betulina	*Betula*	*Larix*
Calyptospora Gœppertiana	*Vaccinium*	*Abies*
Gymnosporium Sabinæ	*Juniperus*	*Pyrus*
Uromyces Pisi	*Pisum*, &c.	*Euphorbia*
Puccinia graminis	*Triticum*, &c.	*Berberis*
P. rubigo-vera	*Triticum*, &c.	*Anchusa*
P. coronata	*Avena*	*Rhamnus*
P. Phalaridis	*Digraphis*	*Arum*
P. Caricis	*Carex*	*Urtica*
Cronartium ribicolum	*Ribes*	*Pinus*
Chrysomyxa Rhododendri	*Rhododendron*	*Picea*

In some of these the Teleutospores are accompanied or preceded by Uredospores, in others not, and similarly the Æcidia may or may not have accompanying spermogonia. Further, some species may attack several or even many different genera and species of the same natural order—e.g., *Uromyces Pisi* on various Vicieæ, *Puccinia graminis* on several Gramineæ—while others seem rigidly confined to one host. But the most remarkable phenomenon is the specialized parasitism of particular races or varieties of some species of *Puccinia*, &c., a complex subject which may be illustrated as follows:—Under the designation Wheat Rust it was formerly assumed that one species of *Puccinia* (*P. graminis*) was indicated. We now know that two or three species, differing in the morphological characters and life-history, were comprised under that name, one only of which is the species *P. graminis*. The extensive researches of Eriksson have shown, however, that this species occurs on about a hundred different grasses, but, although no visible differences can be detected between these, if we try to infect oat or wheat with the spores from the fungus on barley the results are negative, though they succeed on rye; similarly the one on wheat will not infect oat, rye, or barley, and that on oat refuses to infect wheat, rye, or barley, and so on with others. Yet all these forms (races, varieties) are the same species, and their Teleutospores infect the barberry and produce on it the Æcidium-form. The explanation offered is that these are so many specialized or adapted races, so attuned to the particular conditions of life offered by the tissues of a given host-species, or group of such, that the spores evolved in this environment cannot adapt themselves to the conditions presented by another set of host species.

The *Protobasidiomycetes* comprise, in addition to the Uredineæ, about 150 species, of which *Tremella* and *Auricularia* are the principal types, and the union of the groups into one sub-class is based on the long recognized resemblances between the promycelium of Uredineæ and the protobasidium of Auricularieæ. The very remarkable genus *Pilacre* also comes here, and is regarded by Brefeld as the prototype of the angiocarpous Gastromycetes.

The *Autobasidiomycetes* comprise the Hymenomycetes and Gastromycetes of older systematists, and with approximately the same delimitations except that the smaller subdivisions of the Gastromycetes are more sharply marked and raised to higher positions by Fischer, the authority on this group.

In the *Hymenomycetes*, of which 10,000 to 11,000 species are known, several forms have now been cultivated from spore to spore in pure cultures, and no trace of sexual organs has been discovered; the cystidia have quite other functions, as Brefeld showed in *Coprinus*. In many genera the young mycelia form oidia, and in some (*Nyctalis, Fistulina, Polyporus*) well developed chlamydospores and conidia are found, and even conidiophores of special forms—e.g., *Botrytis*-like—occur. Sclerotia are also common, in some cases of large size, and the histological differentiation of tissues is often remarkable. Many Agarics and Polyporei are serious timber-destroying Fungi, even parasitic, or attacking the roots and stems of conifers, &c.—e.g., *Armillaria mellea, Polyporus annosus*, &c.—as Hartig first showed. *Merulius* is the fungus of the "dry-rot" proper, but several others attack and destroy standing and fallen timber, as well as works of construction. For the interesting and important modes of action of these wood-destroying Fungi, the reader must consult the special works.

Physiology.—The physiology of the Fungi comes under the head of that of plants generally, and the works of Pfeffer, Sachs, Vines, Darwin, and Klebs may be consulted for details. Space is here permitted only for general reference to certain phenomena peculiar to these plants, the life-actions of which are restricted and specialized by their peculiar dependence on organic supplies of carbon and nitrogen, so that most Fungi resemble the colourless cells of higher plants in their nutrition. Like these they require water, small but indispensable quantities of salts of potassium, magnesium, sulphur, and phosphorus, and supplies of carbonaceous and nitrogenous materials in different stages of complexity in the different cases. Like these, also, they respire oxygen, and are independent of light; and their various powers of growth, secretion, and general metabolism, irritability, and response to external factors show similar specific variations in both cases. It is quite a mistake to suppose that, apart from the chlorophyll function, the physiology of the fungus-cell is fundamentally different from that of ordinary plant-cells. Nevertheless, certain biological phenomena in Fungi are especially pronounced, and of these the following require particular notice.

Sexuality.—Until a short time ago all botanists were in agreement that while the Phycomycetes exhibited an undoubted sexual process—conjugation of similar organs resulting in the zygospore of Mucorini, &c., and the fertilization of the oosphere in its oogonium by the contents of a much smaller pollinodium in the Oosporeæ—the higher Fungi showed no traces of such except in the small group of Erysipheæ, where De Bary had shown the existence of an act of fertilization in *Sphærotheca* and its allies and in certain other Ascomycetes and Lichens: in these latter Stahl and others had described processes which were accepted with more or less reserve as sexual, but in which the organs concerned differed essentially from those in the Erysipheæ. In spite of numerous investigations, resulting in several suggestions not borne out by facts, no trace of sexual organs or of a sexual process could be discovered in the great group of the Basidiomycetes, nor in the Uredineæ, Ustilagineæ, and the vast mass of higher Ascomycetes, and since closer observation showed that even in the Oosporeæ, where both the morphological structures and physiological processes interpreted as sexual appear in their most convincing manner, a gradual reduction or abortion of the sexual process and organs can be traced, the conclusion was gained that as we ascend the scale of the Fungi the sexual process is gradually lost, and that these organisms have come to replace it by other physiological processes, possibly nutritive, and connected with the large accessions of energy obtained in their highly elaborated food-materials. This conclusion was carried to extremes by Brefeld and the morphological school of which he was the head; they denied the accuracy of the observations which ascribed sexual organs to the Ascomycetes, and pointed out that whereas De Bary had never been able to see a transmission of the contents of the so-called male organ of *Sphærotheca*, &c., to the contents of the so-called female organ, the structures interpreted as sexual were capable of another interpretation—viz., as being merely barren branches commencing to envelope the young ascogonium. Meanwhile, a criterion of the sexual process had been discovered, principally owing to Strasburger's work. It was found that the essential event is the fusion of two nuclei, and that however closely the fusion of two cells or two masses of protoplasm may simulate a sexual union, it is not such unless this essential event is consummated. As this was, of course, not shown to occur, the doubts gained ground as failure after failure to find sexuality was reported. With improvements in method, renewed attempts to penetrate the details led to the proof that the sexual process in the typical Oomycetes—*Peronospora, Cystopus*, &c.—is complete in cases where it was claimed to be so by De Bary and his school, as well as in some other members of the Phycomycetes and allies—*Polyphagus, Basidiobolus*—and Wager especially has convinced us that the conclusions drawn by De Bary from less complete data were essentially sound. In 1883 Eidam described a simple fusion of the ends of two hyphæ as resulting directly in the formation of the ascus in *Eremascus*, and in 1892 Lagerheim brought forward an equally simple case in *Dipodascus*; and, quite recently, Barker has shown that even so simple an Ascomycete as a yeast may conjugate previous to the development of spores. These examples lend support to the contention that a sexual process occurs in *Penicillium, Eurotium*, and *Erysipheæ*. In 1895 the accuracy of De Bary's work on *Sphærotheca* was confirmed by Harper's demonstration, that not only does the antheridium fuse with the oogonium, but that two nuclei are found in the latter after the union, and that these two nuclei conjugate to produce an oospore. At this stage Harper's work would appear to support De Bary's conclusions at every point, but he went farther, and showed that when the fertilized oospore of *Sphærotheca* develops it puts out an ascogonial filament, destined to form the ascus, and that here again two nuclei occur and conjugate in the cell which is to be the future ascus. From the product of their fusion, the nuclei of the ascopores then develop by repeated divisions.

Meanwhile Dangeard and his fellow-workers had brought forward a new and startling view of the sexuality of the higher Fungi. These observers practically confirmed the fusion of nuclei and the truly sexual nature of the process in Phycomycetes, though the different behaviour of the several, sometimes numerous, nuclei observed in the oosphere and antheridial tube, &c., of these multinucleate plants exhibit many peculiarities, for a description of which the literature, and especially Wager's works, must be consulted. In the Ascomycetes, however, Dangeard finds that each cell which is to become an ascus contains two nuclei, which fuse and then divide up to form the spores. This is affirmed for *Exoascus*, *Peziza*, *Aspergillus*, *Sphærotheca*, and other genera. Moreover, Dangeard and his followers find the same thing in Ustilagineæ; each young spore has two nuclei which fuse before it becomes a resting spore, whereas no such "sexual process" occurs in the yeast-conidia. In Uredineæ also each young Æcidiospore, Uredospore, and Teleutospore is initiated by the fusion of two nuclei. Similarly in the Basidiomycetes, each basidium at first contains two nuclei, and these fuse and their product gives rise by division to the nuclei passed into the basidiospores, and since this was found in many examples from Hymenomycetes and Protobasidiomycetes, Dangeard concludes it is universal in the group, and that the higher Fungi are not devoid of sexuality but that this process here consists in conjugation of nuclei in the initials of the principal sporogenous cells, asci and basidia respectively. Only by further research can the matter be cleared up. Meanwhile it stands somewhat as follows: In Phycomycetes there is an undoubted sexual process, where well developed sexual organs are recognizable and fusion of male and female nuclei occurs. The differences in detail concern the number and behaviour of the extra nuclei concerned, and the morphological differentiation of the sexual organs. In the group itself the process would seem to disappear, at any rate under certain conditions (*e.g.*, in Saprolegnieæ), in which, as Klebs has shown, both sexual and asexual reproduction are very sensitive to changes in the environment. In the Uredineæ, Ustilagineæ, Protobasidiomycetes, Basidiomycetes, and the vast majority of Ascomycetes, no organs capable of interpretation as morphologically differentiated sexual organs can be discovered, in spite of numerous and repeated attempts to find them; but within the initial cells which will become resting spores (Ustilagineæ), Æcidiospores, Uredospores, or Teleutospores (Uredineæ), Asci (Ascomycetes) or Basidia (Basidiomycetes), nuclear fusions occur of such a nature that they remind us forcibly of a sexual process. Within the group Ascomycetes at least three types of morphologically differentiated sexual organs and sexual processes have been described in addition to the foregoing, viz., direct conjugation of the tips of similar hyphal branches (*Eremascus*) leading to the direct formation of an ascus from the product of fusion; the fertilization of an oosphere in its oogonium by the contents of an antheridial branch (*Sphærotheca*) leading to the development of the product of fusion into an ascogonial apparatus, and the much more complex case of *Pyronema confluens*, which Harper has recently re-investigated, confirming De Bary's results and extending them in a most remarkable manner, and, finally, the case of *Collema*, and the *Laboulbeniaceæ*, where an ascogenous apparatus is initiated by the formation of a trichogyne borne on a group of cells below (the female sexual organ) and minute spermatia (male organs) abstricted or emitted by certain other branches, the sexual process being consummated by the fusion of the contents of the spermatium with the trichogyne and their transmission to the cells below. The details of this process have not been traced in the latter Fungi, but Bauer's work on the Collemaceæ and Oltmann's on the similar organs in Florideæ render it impossible to overlook the possibilities here involved. Whether Dangeard's contention that his nuclear fusions are the true sexual process in all cases, and that Harper, Stahl, Thaxter, and others have fallen into error in interpreting their observations, is to be accepted, or whether these nuclear fusions are only secondary phenomena, as has been contended by those who compare them to the fusion of nuclei in the embryo sac of the Phanerogams, cannot as yet be decided, and the whole problem, together with numerous subsidiary matters of homology consequent on its decision, remains for the present a burning question in Mycology. It is not improbable that these nuclear fusions in sporogenous cells merely indicate that nuclear masses are in all cases mutually attractive in a high degree during a certain, extremely sensitive, phase of their existence: if this is so, the phenomenon may be one of nutrition—or, even, parasitism—and our ideas as to the sexual significance of such fusions may have to be modified.

Parasitism.—Some Fungi, though able to live as saprophytes, occasionally enter the body of living plants, and are thus termed facultative parasites. The occasion may be a wound (*e.g.*, *Nectria*, *Dasyscypha*, &c.), or the enfeeblement of the tissues of the host, or invigoration of the Fungus, the mycelium of which then becomes strong enough to overcome the host's resistance (*Botrytis*). Many Fungi, however, cannot complete their life-history apart from the host-plant. Such *obligate* parasites may be *Epiphytic* (*Erysipheæ*), the mycelium remaining on the outside and at most merely sending *haustoria* into the epidermal cells, or *Endophytic* (*Uredineæ*, *Ustilagineæ*, &c.), when the mycelium is entirely inside the organs of the host. An epiphytic Fungus is not necessarily a parasite however, as many saprophytes (*Moulds*, &c.) germinate and develop a loose mycelium on living leaves, but only enter and destroy the tissues after the leaf has fallen; in some cases, however, these saprophytic epiphytes can do harm by intercepting light and air from the leaf (*Fumago*, &c.), and such cases make it difficult to draw the line between saprophytism and parasitism. Endophytic parasites may be *intracellular*, when the Fungus or its mycelium plunges into the cells and destroys their contents directly (*Olpidium*, *Lagenidium*, *Sclerotinia*, &c.), but they are far more frequently *intercellular*, at any rate while young, the mycelium growing in the lacunæ between the cells (*Peronospora*, *Uredineæ*) into which it may send short (*Cystopus*), or long and branched (*Peronospora Calotheca*) haustoria, or it extends in the middle lamella (*Ustilago*), or even in the solid substance of the cell-wall (*Botrytis*). No sharp lines can be drawn however, since many mycelia are intercellular at first and subsequently become intracellular (*Ustilagineæ*), and the various stages doubtless depend on the degrees of resistance which the host tissues are able to offer. Similar gradations are observed in the direct effect of the parasite on the host, which may be *local* (*Hemileia*) when the mycelium never extends far from the point of infection, or *general* (*Phytophthora*) when it runs throughout the plant. Destructive parasites rapidly ruin the whole plant-body (*Pythium*), whereas restrained parasites only tax the host slightly, and ill effects may not be visible for a long time, or only when the Fungus is epidemic (*Rhytisma*). A parasite may be restricted during a long incubation-period however, and rampant and destructive later (*Ustilago*). The latter fact, as well as the extraordinary fastidiousness, so to speak, of parasites in their choice of hosts or of organs for attack, point to reactions on the part of the host plant, as well as capacities on that of the parasite, which may be partly explained in the light of what we now know regarding enzymes and chemotropism. Some parasites attack many hosts and almost any tissue or organ (*Botrytis cinerea*), others are restricted to one family (*Cystopus candidus*) or genus (*Phytophthora infestans*) or even species (*Melampsora Padi*), and it is customary to speak of root-parasites, leaf-parasites, &c., in expression of the fact that a given parasite occurs only on such organs—e.g., *Dematophora necatrix* on roots, *Calyptospora Gœppertiana* on stems, *Ustilago Scabiosæ* in anthers, *Claviceps purpurea* in ovaries, &c. Associated with these relations are the specializations which parasites show in regard to the age of the host. Many parasites can enter a seedling, but are unable to attack the same host when older—e.g., *Pythium*, *Ustilago*, *Phytophthora omnivora*.

Chemotropism.—Taken in conjunction with Pfeffer's beautiful discovery that certain chemicals exert a distinct attractive influence on Fungus hyphæ (*chemotropism*), and the results of Miyoshi's experimental application of it, the phenomena of enzyme-secretion throw considerable light on the processes of infection and parasitism of Fungi. Pfeffer showed that certain substances in definite concentrations cause the tips of hyphæ to turn towards them; other substances, though not innutritious, repel them, as also do nutritious bodies if too highly concentrated. Marshall Ward showed that the hyphæ of *Botrytis* pierce the cell-walls of a lily by secreting a cytase and dissolving a hole through the membrane. Miyoshi then demonstrated that if *Botrytis* is sown in a lamella of gelatine, and this lamella is superposed on another similar one to which a chemotropic substance is added, the tips of the hyphæ at once turn from the former and enter the latter. If a thin cellulose membrane is interposed between the lamellæ, the hyphæ nevertheless turn chemotropically from the one lamella to the other and pierce the cellulose membrane in the process. The hyphæ will also dissolve their way through a lamella of collodion, paraffin, parchment paper, elder-pith, or even cork or the wing of a fly, to do which it must excrete very different enzymes. If the membrane is of some impermeable substance, like gold-leaf, the hyphæ cannot dissolve its way through, but the tip finds the most minute pore and traverses the barrier by means of it, as it does a stoma on a leaf. We may hence conclude that a parasitic hypha pierces some plants or their stomata and refuses to enter others, because in the former case there are chemotropically attractive substances present which are absent from the latter, or are there replaced by repellent substances.

Symbiosis.—The remarkable case of life in common first observed in Lichens, where a Fungus and an Alga unite to form a compound organism—the Lichen—totally different from either, has now been proved to be universal in these plants, and Lichens are in all cases merely Algæ enmeshed in the interwoven hyphæ of Fungi. Furthermore, the species of Algæ have been determined, and Lichens artificially synthesized by sowing the Alga and the Fungus together and watching the latter enslave the former. The Fungus concerned is usually an Ascomycete (Ascolichenes), but several Basidiolichenes are now known in which it is a Basidiomycete. This dualism, where the one constituent (Alga) furnishes carbohydrates, and the other (Fungus) ensures a supply of mineral matters, shade, and moisture, has been termed *Symbiosis*. Since then numerous other cases of Symbiosis have been demonstrated. Many trees are found to have their smaller roots invaded by Fungi and deformed by their action, but so far from these being injurious, experiments go to show that this Mycorhiza (fungus-root) is necessary for the well-being of the tree. This is also the case with numerous other plants of moors and woodlands—*e.g.*, Ericaceæ, Pyrolaceæ, Gentianaceæ, Orchidaceæ, Ferns, &c. Recent experiments have shown that the difficulties of getting Orchid seeds to germinate are due to the absence of the necessary Fungus, which must be in readiness to infect the young seedling immediately it emerges from the seed. The well-known failures with rhododendrons, heaths, &c., in ordinary garden soils are also explained by the need of the fungus-infected peat for their roots. The rôle of the Fungus appears to be to supply materials from the leaf-mould around, in forms which ordinary root-hairs are incapable of providing for the plant; in return the latter supports the Fungus at slight expense from its abundant stores of reserve materials. Numerous other cases of Symbiosis have been discovered among the Fungi of fermentation, of which those between *Aspergillus* and yeast in saké manufacture, and between yeasts and bacteria in kephir and in the ginger-beer plant are best worked out. For cases of Symbiosis see article BACTERIOLOGY.

AUTHORITIES.—**General.**—ENGLER and PRANTL. *Die Natürlichen Pflanzenfamilien*, i. Theil, 1892 onwards.—ZOPF. *Die Pilze.* Breslau, 1890.—VON TAFEL. *Vergleichende Morphologie der Pilze.* Jena, 1892. **Distribution, &c.**—COOKE. *Introduction to the Study of Fungi.* London, 1895.—FELIX in *Zeitschr. d. deutsch. Geologisch. Gesellsch.* 1894–96.—STAUB. *Sitzungs ber d. bot. Sec. d. Kgl. Ungarischen natur. wiss. Gesellsch. zu Budapest.* 1897. **Anatomy, &c.**—BOMMER. "Sclerotes et Cordons Mycéliens," *Mém. de l'Acad. Roy. de Belg.* 1894.—MANGIN. "Observ. sur la Membrane des Mucorinées," *Journ. de Bot.* 1899.—ZIMMERMANN. *Die Morph. und Physiologie des Pflanz Zellkernes.* Jena, 1896. —WISSELINGH. "Microchem. Unters. über die Zellwände d. Fungi," *Pringsh. Jahrb.*, B. 31, p. 619. 1898.—WAGER. "The Nucleus of the Yeast Plant," *Ann. Bot.*, vol. xii. 1898.—ISTVÁNFFYI. "Unters. über die Phys. Anat. der Pilze," *Prings. Jahrb.* 1896. **Spore Distribution.**—FULTON. "Dispersal of the Spores of Fungi by Insects," *Ann. Bot.* 1889. **Spores and Sporophores.**—ZOPF. *Die Pilze.* Also the works of Von Tafel and Brefeld. **Classification.**—VAN TIEGHEM. *Journ. de Bot.*, p. 77. 1893. And the works of Brefeld, Engler and Prantl, Von Tafel, and Saccardo already cited. **Phycomycetes.**—WAGER. "On the Fertilization of Peronospora parasitica," *Ann. Bot.*, vol. xiv. 1900.—KLEBS. *Die Bedingungen der Fortpflanzung*, &c. Jena, 1896. And "Zur Physiologie der Fortpflanzung," &c., *Pringsh. Jahrb.* 1898–1900.—THAXTER. "New or Peculiar Aquatic Fungi. I. *Monoblepharis*," *Bot. Gaz.*, vol. xx. p. 433. 1895.—LAGERHEIM. "Unters. über die Monoblepharideen," *Bot. Zeit.*, B. 58, p. 218. 1900. **Hemi-asci.** BREFELD and VON TAFEL *l.c.*, also SCHROETER in Engler and Prantl, *l.c.* **Yeasts.**—JÖRGENSEN. *The Micro-organisms of Fermentation*, Engl. Ed. 1899.—BARKER in *Ann. Bot.*, vol. xiv. p. 215, and *Proc. R. S.*, 1901. **Ustilagineæ.**—PLOWRIGHT. *British Uredineæ and Ustilagineæ.* London, 1889.—MASSEE. *British Fungi* (Phycomycetes and Ustilagineæ). London, 1891.—BREFELD. "Unters. aus dem Gesammtgeb. der Mykol.," H. xi. and xii. **Ascomycetes.**—FISCHER and LINDAU in Engler and Prantl, *l.c.*—MARSHALL WARD. "Onygena equina, a Horn-destroying Fungus," *Phil. Trans.*, vol. 191, p. 269. 1899.—DAWSON. "On the Biology of Poronia punctata," *Ann. Bot.*, vol. xiv. p. 245. 1900.—HARPER. "Cell-division in Sporangia and Asci," *Ann. Bot.*, vol. xiii. p. 467. 1899. —BARKER. "A Fragrant Mycoderma Yeast," *Ann. Bot.*, vol. xiv. p. 215. 1900.—THAXTER. "Contributions towards a monograph of the Laboulbeniaceæ," *Mem. American Acad. of Arts and Sc.*, vol. xii. p. 190. 1896.—**Uredineæ.**—ERIKSSON and HENNING. *Die Getreideroste.* Stockholm, 1896. And ERIKSSON. *Botan. Gaz.*, vol. xxv. p. 26, with literature. 1898.—MARSHALL WARD. "The Bromes and their Rust-fungus," *Ann. Bot.*, vol. xv. 1901.—**Protobasidiomycetes.**—MÖLLER. *Botanische Mittheilungen aus den Tropen*, Heft 8. Jena, 1895.—MASSEE. "On the Origin of the Basidiomycetes," *Journ. Linn. Soc.*, vol. xxxiv. p. 438. 1900. —**Basidiomycetes.**—HENNING in Engler and Prantl, *l.c.*—MASSEE. *British Fungus Flora*, 4 vols. London, 1892–95.—HARTIG. *Die Zersetzungserscheinungen des Holzes.*—MARSHALL WARD. *Timber and Some of its Diseases.* London, 1889. "On the Biology of *Stereum hirsutum*," *Phil. Trans.*, vol. 189, p. 123. 1898.—**Sexuality.**—MARSHALL WARD. "The Sexuality of the Fungi," *Quart. Journ. Microsc. Sc.*, vol. 24. 1884.—WAGER. "The Sexuality of the Fungi," *Ann. Bot.*, vol. xiii. p. 575, with literature. 1899.—HARPER. "Sexual Reproduction in *Pyronema confluens*," *Ann. Bot.*, vol. xiv. p. 321. 1900.—DANGEARD. "La Reproduction sexuelle des Champignons," *Le Botaniste*, 7e Serie, p. 89. May 1900.—KLEBS. "Zur Physiol. der Fortpflanzung einiger Pilze," iii., *Pringsh. Jahrb.*, vol. 35. 1900.—**Fermentation.** —JÖRGENSEN. *The Micro-organisms of Fermentation*, English Ed. 1899.—GREEN. *The Soluble Ferments and Fermentation.* Cambridge, 1899.—PFEFFER. *Physiology of Plants.* Oxford, 1900.—BUCHNER. *Gährung ohne Hefezellen*, see *Bot. Zeit.*, vol. lviii. p. 181, for literature. 1898.—OPPENHEIMER. *Ferments and their Actions.* 1901. **Parasitism.**—MARSHALL WARD. "On Some Relations between Host and Parasite, &c." (Croonian Lecture), *Proc. Roy. Soc.*, vol. xlvii. p. 394. 1890. "A Lily Disease," *Ann. Bot.*, vol. ii. p. 320. 1888. "Address to the Botanical Section," *Brit. Assoc. Report.* 1897.—**Symbiosis.**

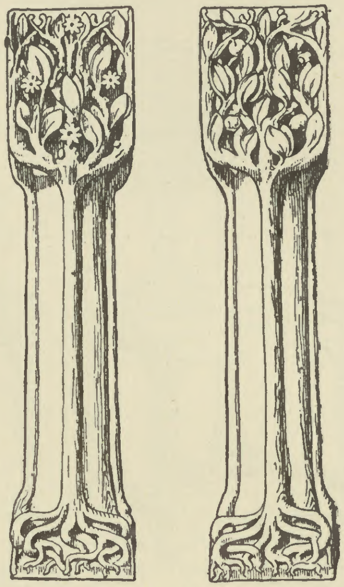
—Marshall Ward. "The Ginger-beer Plant," *Phil. Trans.*, p. 125. 1892. "Symbiosis," *Ann. Bot.*, vol. xiii. p. 549. 1899.—Stahl. "Der Sinn der Mykorrhizenbildung," *Pringsh. Jahrb.*, vol. xxxiv. p. 539. 1900.—Bernard. "On some Difficult Cases of Germination," *Gardeners' Chronicle*, June 23, 1900.—Also numerous papers in *Ann. Bot.*, 1887 onwards; *Transactions British Mycological Society*, 1897 onwards; *Gardeners' Chronicle*, *Nature*, and *Proceedings of Linnean and Royal Societies*.

(H. M. W.)

Furnes, a town of Belgium, in the province of West Flanders, 27 miles south-west of Bruges, near the French frontier, the central point of a system of canals to Nieuport, Dunkirk, Bergues, and Ypres, with a station on the line from Dixmude to Dunkirk. It has tanyards and a factory for linen goods. Population (1897), 5636.

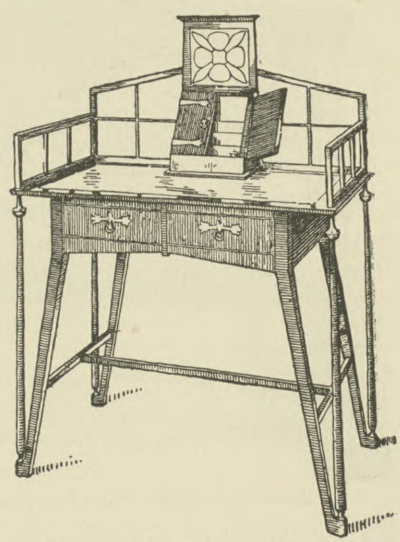
Furness, Horace Howard (1833——), American Shakespearean scholar, was born in Philadelphia, 2nd November 1833, being the son of William Henry Furness, minister of the First Unitarian Church in that city, a powerful preacher and writer. He graduated at Harvard in 1854, and was admitted to the bar in 1859, but soon devoted himself to the study of Shakespeare. He accumulated a collection of illustrative material of great richness and extent, and brought out in 1871 the first volume of a new Variorum edition, designed to represent and summarize the conclusions of the best authorities in all languages—textual, critical, and annotative. Twelve volumes had appeared by the year 1900, as follows: *Romeo and Juliet*, 1871; *Macbeth*, 1873; *Hamlet*, 2 vols., 1877; *King Lear*, 1880; *Othello*, 1886; *The Merchant of Venice*, 1888; *As You Like It*, 1890; *The Tempest*, 1892; *A Midsummer Night's Dream*, 1895; *The Winter's Tale*, 1898; *Much Ado about Nothing*, 1899. The edition has been generally accepted as a thorough and scholarly piece of work; its chief fault is that, beginning with *Othello* (1886), the editor used the First Folio text as his basis, while in others he makes the text of the Cambridge (Globe) editors his foundation.

Furniture.—A decided effort to inaugurate a recognized style in furniture has been made during the last few years, and with the advent of the Paris Exhibition of the year 1900 this effort was called the "New Style," a name first given in France, several years ago, to the work of a number of Paris furniture makers who migrated to Nancy, and who profess to be free from all old traditions, and only to seek inspiration from Nature. How far Nature is likely to inspire an art so essentially utilitarian as cabinet-making is not at once apparent. It is generally admitted that the pioneers of the new style of original thought, as devoted to useful art, were William Morris and his friends about 1860. (See Morris, William, and Arts and Crafts.) That some of the works of Morris and his school were too quaint to become types of the furniture of the future is true enough. But some of the pieces were admirable both for design and execution, and worthy to inspire, as they have inspired, subsequent designers in furniture both in England and on the Continent. The Arts and Crafts Society, founded in 1880 by Walter Crane and others, has carried on the work of producing and exhibiting all kinds of "Art allied to Industry," and has fostered originality of design in furniture, and exercised great influence on artists and artist workmen throughout Europe, where many similar associations have been founded. In the Arts and Crafts Exhibition of 1899 were some chairs designed by C. E. Voysey, which may be noted as having frames of thick square uprights, tapering at the back to high points. By the same artist was a wooden mantel-piece, also of heavy workmanship. The mantel-shelf, instead of the architectonic cornice with its various members, was of one piece, with slight carving on its ogee surface, upheld by two masses of wood bulging towards their bases. Again, two wooden column supports of a mantel-piece by W. Aumonier were of a novel style; the capitals were groups of leaves and tendrils forming squares, and undercut so that the shaft could be seen through the capital; a base was formed by carved roots round the bole. The Guild of Handicraft have also carried out some furniture designs of merit by C. R. Ashbee, notably some writing cabinets. The arrangement of them is that of the old-fashioned bureau, the workmanship is very good, and a pretty and useful feature consists in the place contrived in the upper part of the cabinet for an electric lamp.



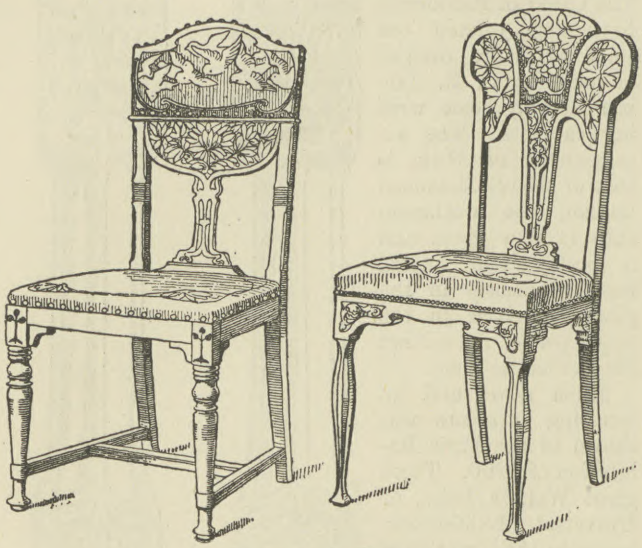
Carved Wood Columns, by W. Aumonier.

Much novel and interesting furniture was shown in the Paris Exhibition of 1900. These great World's Fairs, or Universal Exhibitions, began in 1851, and have borne good fruit, not only in encouraging competition to show the best work in all industries, but also in stimulating the establishment of state museums, where the best models of art designs, both ancient and modern, are permanently on view. The South Kensington Museum in London followed the Exhibition of 1851; the Austrian Museum for Art, &c., was founded after the Exhibition of 1863; and in other countries the same useful results followed. The Paris Exhibition was the most extensive of all, and the furniture there, both English and foreign, could be studied as the outcome of all that was newest in design, material, and execution in the world of art and industry. The display of English furniture in Paris was in itself sufficient to prove that the English cabinet-makers are most to be praised for what may be called the general excellence and suitability of their furniture. No doubt the remarkable exhibition of furniture of the Chippendale and Sheraton period at Bethnal Green in 1896 partly accounts for the continued influence of their patterns and traditions on English furniture.



Writing-Desk, by Henry, London.

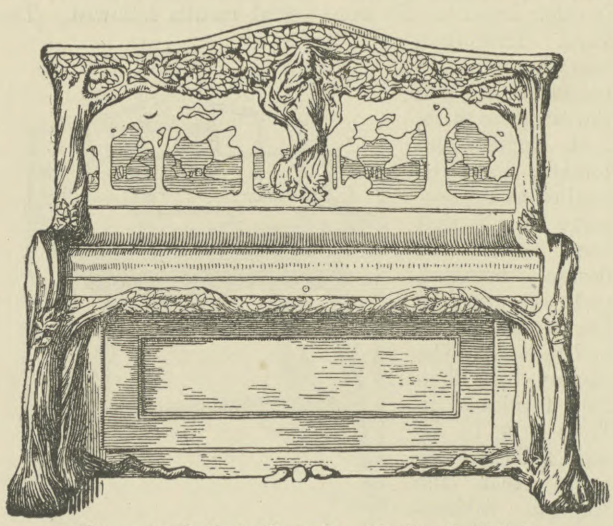
British manufacturers do not err by losing sight of constructive utility in order to experiment with fanciful decoration, and their work is, for the most part, solid and good. The four or five principal English firms who have shown examples of modern interiors have worthily carried out the traditions of former times: no attempt at mere quaintness spoils the furniture, and the novelties shown of material and workmanship do not detract from the feeling of repose and comfort, which must be considered an essential. The error most common in reproducing set



Chairs, by G. Hulbe.

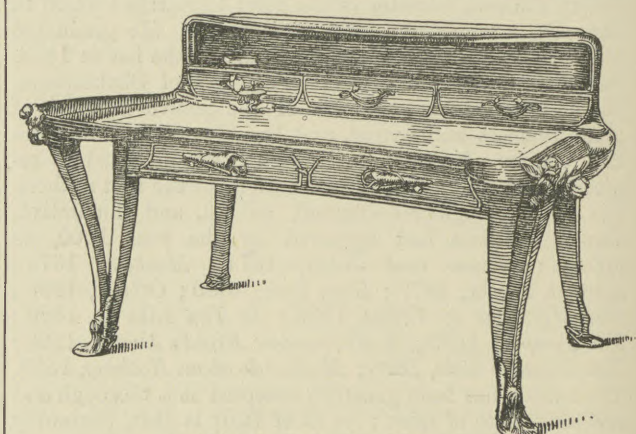
pieces, such as sideboards, cabinets, &c., from old types, is the disposition to "improve," *i.e.*, add to the carving or other decoration; as a rule, this has a questionable effect.

The French makers of the new style of furniture seem in some instances to have a positive distaste for straight lines. They delight in strange curves, usually sweeping curves with sudden twists. Wardrobes and china closets



Piano, by Baldwin Piano Co., Cincinnati, U.S.A.

are pyramidal, chairs and seats have raking legs, table-legs are fortified with bronze, &c. One cabinet is made to represent a leaf-clad arbour, with tree-trunks, branches, and boughs entwined to the life. A pianoforte in the American section of the Exhibition was no less extreme an instance of the new taste, a tree trunk being carved along the front of its bed. Such an instrument as a pianoforte is entirely artificial; the very wood of it is taken from the choicest part of the tree, dried and prepared with the utmost care. How is this symbolized by a stem to imitate nature, however well sculptured? It is obvious that an interior furnished in this manner must be lacking every desirable qualification for home life. A piece of furniture is not a painting; it has a use, and the use must be kept in sight throughout. The naturalism of the Nancy workers extends to the working of the metal; the ormoulu lines of flower and leaf-work are fastened along the edge of cabinets and wardrobes, and then carried up to the tops, where they bend over and form a sort of buttress to support a shelf. In chair frames the craftsmen bind all parts of the seat, as if a kind of strap were necessary round a decaying object. As lightness is a merit in chairs, brass bars and straps ought not to be necessary to their security. The marquetry work of this modern school is also purely realistic, and the attempt is made, notably by Gallé of Nancy, by various coloured woods to represent



Desk, by Majorelles, Nancy.

nature in colours, a questionable use of that form of decoration when applied to furniture intended for use. A typical work by Majorelles of Nancy, a desk, is much better; the lines give an impression of strength and solidity, and the metal work, handles, &c., although representing water-lilies and their leaves in successful imitation, are arranged with some reference to the uses of the object they decorate. A peculiarity of some of the tables of the New Style is the assumed insufficiency of four or any number short of eight legs. The top boards spread over at the corners, and wherever that occurs an extra leg, sometimes curved, springs from the foot of the corner leg and stretches over to support this extension.

In many of the pieces of furniture, in the Arts and Crafts and other Exhibitions in England and abroad, there has been an effort to make furniture of old types as unlike old furniture as possible, either by a simplicity, sometimes amounting to rudeness of construction, or by exaggeration of some feature of the design. (J. H. P.)

Furnivall, Frederick James (1825——), English philologist and editor, was born at Egham, 4th February 1825, being the son of a surgeon. He was called to the bar in 1849, but his attention was soon diverted to philological studies and social problems. He gave Frederick Denison Maurice valuable assistance in founding the Working Men's College, and for half a century indefatigably promoted the study of early English literature, partly by his own work as editor, and still more efficaciously by the agency of the numerous learned societies of which he was both founder and director, especially the Early English Text Society (1864), which has been of inestimable service in promoting the study of early English. He also established and conducted the Chaucer, Ballad, New Shakspere, and Wyclif Societies; and at a later period societies for the special study of Browning and Shelley. As an editor he published the *Percy Ballads* and many other ancient English books; but his most important labours have been devoted to Chaucer, whose study he has greatly assisted by his "Six-Text" edition of the *Canterbury Tales.* He laboured much for the Philological Society, and was one of the original promoters of its great English Dictionary. The completion of his half century of labour was acknowledged in 1900 by a handsome testimonial, including the preparation of a volume of philological essays by various writers specially dedicated to him. Dr Furnivall has views of his own on phonetic spelling, which have not obtained general acceptance.

Fürth, a town of Bavaria, Germany, district Middle Franconia, 5 miles by rail north-west of Nüremberg. It is the seat of several large industries, such as brewing, the production of chromo-lithographs and picture-books, the manufacture of mirror and mirror-frames, bronze and gold-leaf wares, pencils, toys, haberdashery, optical instruments, silver-work, turnery, chicory, machinery, fancy boxes and cases, &c., and an extensive trade is carried on in these goods, and in hops, metals, wool, groceries, coals, &c. Population (1885), 35,455; (1900), 53,874.

Fusilier.—A fusilier was a soldier armed with a fusil. In the early years of the 16th century there appeared a small-arm with a lock in which the spark to ignite the charge was obtained by the percussion of a flint and steel. A specimen exists as old as 1500–20. It was called a snaphance (Dutch, *snap-haan* = snap-cock), a term applied indifferently to the lock and the weapon. The snaphance must have been well known in England in 1594, for it is mentioned in Lilly's *Mother Bombie,* Act ii. scene 1. After a chequered existence of nearly a century and a half, an improved model of the snaphance (which would now be called "snaphance, Mark II.") was produced about 1670, and drove the old fire-lock and wheel-lock completely out of the field. This arm the French called *fusil,* and the English afterwards christened it Brown Bess. The French raised a regiment of fusiliers in 1671, and in 1685 England raised the (7th) Royal Fusiliers.

Fusion.—The term Fusion is generally applied to the melting of a solid substance, or the change of state of aggregation from the solid to the liquid. The term "liquefaction" is frequently employed in the same sense, but is often restricted to the condensation of a gas or vapour. The converse process of *Freezing* or *Solidification,* the change from the liquid to the solid state, is subject to the same laws, and must be considered together with fusion. The *Solution* of a solid in a foreign liquid, and the deposition of *Crystallization* of a solid from a solution, are so closely related to the fusion of a pure substance, that it will also be necessary to consider some of the analogies which they present.

1. *General Phenomena.*—There are two chief varieties of the process of fusion, namely, Crystalline and Amorphous, which are in many ways distinct, although it is possible to find intermediate cases which partake of the characteristics of both. The melting of ice may be taken as a typical case of crystalline fusion. The passage from rigid solid to mobile liquid occurs at a definite surface without any intermediate stage or plastic condition. The change takes place at a definite temperature, the *Fusing* or *Freezing Point* (abbreviated F.P.), and requires the addition of a definite quantity of heat to the solid, which is called the *Latent Heat of Fusion.* There is also in general an abrupt change of volume at the moment of fusion, which amounts in the case of ice to a contraction of 9 per cent. Typical cases of amorphous solidification are those of silica, glass, plastic sulphur, pitch, alcohol, and many organic liquids. In this type the liquid gradually becomes more and more viscous as the temperature falls, and ultimately attains the rigidity characteristic of a solid, without any definite freezing-point or latent heat. The condition of the substance remains uniform throughout, if its temperature is uniform; there is no separation into the two distinct phases of solid and liquid, and there is no sudden change of volume at any temperature.

In the case of crystalline fusion it is necessary to distinguish two cases, the Homogeneous and the Heterogeneous. In the first case, the composition of the solid and liquid phases are the same, and the temperature remains constant during the whole process of fusion. In the second case, the solid and liquid phases differ in composition; that of the liquid phase changes continuously, and the temperature does not remain constant during the fusion. The first case comprises the fusion of pure substances, and that of eutectics, or cryohydrates; the second is the general case of an alloy or a solution. These have been very fully studied and their phenomena greatly elucidated in recent years.

There is also a sub-variety of amorphous fusion, which may be styled *Colloid* or *Gelatinous,* and may be illustrated by the behaviour of solutions of water in gelatine. Many of these jellies melt at a fairly definite temperature on heating, and coagulate or set at a definite temperature on cooling. But in some cases the process is not reversible, and there is generally marked hysteresis, the temperature of setting and other phenomena depending on the rate of cooling. This case has not yet been fully worked out; but it appears probable that in many cases the jelly possesses a spongy framework of solid, holding liquid in its meshes or interstices. It might be regarded as a case of "heterogeneous" amorphous fusion, in which the liquid separates into two phases of different composition, one of which solidifies before the other. The two phases cannot, as a rule, be distinguished optically, but it is generally possible to squeeze out some of the liquid phase when the jelly has set, which proves that the substance is not really homogeneous. In very complicated mixtures, such as acid lavas or slags containing a large proportion of silica, amorphous and crystalline solidification may occur together. In this case the crystals separate first during the process of cooling, the mother liquor increases gradually in viscosity, and finally sets as an amorphous ground-mass or matrix, in which crystals of different kinds and sizes, formed at different stages of the cooling, remain embedded. The formation of crystals in an amorphous solid after it has set is also of frequent occurrence. It is termed *Devitrification,* but is a very slow process unless the solid is in a plastic state.

2. *Homogeneous Crystalline Fusion.*—The fusion of a solid of this type is characterized most clearly by the perfect constancy of temperature during the process. In fact, the law of constant temperature, which is generally stated as the first of the so-called "laws of fusion," does not strictly apply except to this case. The constancy of the F.P. of a pure substance is so characteristic that change of the F.P. is often one of the most convenient tests of the presence of foreign material. In the case of substances like ice, which melt at a low temperature and are easily obtained in large quantities in a state of purity, the point of fusion may be very accurately determined by observing the temperature of an intimate mixture of the solid and liquid while slowly melting as it absorbs heat from surrounding bodies. But in the majority of cases it is more convenient to observe the freezing-point as the liquid is cooled. By this method it is possible to ensure perfect uniformity of temperature throughout the mass by

stirring the liquid continuously during the process of freezing, whereas it is difficult to ensure uniformity of temperature in melting a solid however gradually the heat is supplied, unless the solid can be mixed with the liquid. It is also possible to observe the F.P. in other ways, as by noting the temperature at the moment of the breaking of a wire, of the stoppage of a stirrer, or of the maximum rate of change of volume, but these methods are generally less certain in their indications than the point of greatest constancy of temperature in the case of homogeneous crystalline solids.

3. *Superfusion, Supersaturation.* — It is generally possible to cool a liquid several degrees below its normal freezing-point without a separation of crystals, especially if it is protected from agitation, which would assist the molecules to rearrange themselves. A liquid in this state is said to be "undercooled" or "superfused." The phenomenon is even more familiar in the case of solutions (*e.g.*, sodium sulphate or acetate) which may remain in the "metastable" or "supersaturated" condition for an indefinite time if protected from dust, &c. The introduction into the liquid under these conditions of the smallest fragment of the crystal, with respect to which the solution is supersaturated, will produce immediate crystallization, which will continue until the temperature is raised to the saturation point by the liberation of the latent heat of fusion. The constancy of temperature at the normal freezing-point is due to the equilibrium of exchange existing between the liquid and solid. Unless both solid and liquid are present, there is no condition of equilibrium, and the temperature is indeterminate. The corresponding case of a superheated solid, existing in metastable equilibrium at a temperature above its normal fusing-point, might theoretically occur, but has not as yet been observed.

4. *Effect of Pressure on the F.P.*—The effect of pressure on the fusing-point depends on the change of volume during fusion. Substances which expand on *freezing*, like ice, have their freezing-points lowered by increase of pressure; substances which expand on *fusing*, like wax, have their melting-points raised by pressure. In each case the effect of pressure is to retard increase of volume. This effect was first predicted by James Thomson on the analogy of the effect of pressure on the boiling-point, and was numerically verified by Lord Kelvin in the case of ice, and later by Bunsen in the case of paraffin and spermaceti. The equation by which the change of the F.P. is calculated may be proved by a simple application of the Carnot cycle, exactly as in the case of vapour and liquid. (See THERMODYNAMICS, § 4.) If L be the latent heat of fusion in mechanical units, v' the volume of unit mass of the solid, and v'' that of the liquid, the work done in an elementary Carnot cycle of range $d\theta$ will be $dp(v''-v')$, if dp is the increase of pressure required to produce a change $d\theta$ in the F.P. Since the ratio of the work-difference or cycle-area to the heat-transferred L must be equal to $d\theta/\theta$, we have the relation

$$d\theta/dp=\theta(v''-v')/L \quad . \quad . \quad . \quad . \quad (1).$$

The sign of $d\theta$, the change of the F.P., is the same as that of the change of volume $(v''-v')$. Since the change of volume seldom exceeds 0·1 c.c. per gramme, the change of the F.P. per atmosphere is so small, that it is not as a rule necessary to take account of variations of atmospheric pressure in observing a freezing-point. A variation of 1 cm. in the height of the barometer would correspond to a change of ·0001° C. only in the F.P. of ice. This is far beyond the limits of accuracy of most observations. Although the effect of pressure is so small, it produces, as is well known, remarkable results in the motion of glaciers, the moulding and regelation of ice, and many other phenomena. It has also been employed to explain the apparent inversion of the order of crystallization in rocks like granite, in which the arrangement of the crystals indicates that the quartz matrix solidified subsequently to the crystals of felspar, mica, or hornblende embedded in it, although the quartz has a higher melting-point. It is contended that under enormous pressure the freezing-points of the more fusible constituents might be raised above that of the quartz, if the latter is less affected by pressure. Thus Bunsen found the F.P. of paraffin wax 1·4° C. below that of spermaceti at atmospheric pressure. At 100 atmospheres the two melted at the same temperature. At higher pressures the paraffin would solidify first. The effect of pressure on the silicates, however, is much smaller, and it is not so easy to explain a change of several hundred degrees in the F.P. It seems more likely in this particular case that the order of crystallization depends on the action of superheated water or steam at high temperatures and pressures, which is well known to exert a highly solvent and metamorphic action on silicates.

5. *Variation of Latent Heat.*—Person in 1847 endeavoured to show by the application of the first law of thermodynamics that the increase of the latent heat per degree should be equal to the difference $(s''-s')$ between the specific heats of the liquid and solid. If, for instance, water at 0° C. were first frozen and then cooled to $-t$° C., the heat abstracted per gramme would be $(L'+s't)$ calories. But if the water were first cooled to $-t$° C., and then frozen at $-t$° C., by abstracting heat L'', the heat abstracted would be $L''+s''t$. Assuming that the heat abstracted should be the same in the two cases, we evidently obtain $L'-L''=(s''-s')t$. This theory has been approximately verified by Petterson, by observing the freezing of a liquid cooled below its normal F.P. (*Jour. Chem. Soc.* 24, p. 151). But his method does not represent the true variation of the latent heat with temperature, since the freezing, in the case of a superfused liquid, really takes place at the normal freezing-point. A quantity of heat $s''t$ is abstracted in cooling to $-t$, $(L'-s''t)$ in raising to 0° and freezing at 0°, and $s't$ in cooling the ice to $-t$. The latent heat L'' at $-t$ does not really enter into the experiment. In order to make the liquid freeze at a different temperature, it is necessary to subject it to pressure, and the effect of the pressure on the latent heat cannot be neglected. The entropy of a liquid ϕ'' at its F.P. reckoned from any convenient zero ϕ_0 in the solid state may be represented by the expression

$$\phi''-\phi_0=\int s'd\theta/\theta+L/\theta \quad . \quad . \quad . \quad . \quad (2).$$

Since $\theta d\phi''/d\theta=s''$, we obtain by differentiation the relation

$$dL/d\theta=s''-s'+L/\theta \quad . \quad . \quad . \quad . \quad (3),$$

which is exactly similar to the equation for the specific heat of a vapour maintained in the saturated condition. If we suppose that the specific heats s' and s'' of the solid and liquid at equilibrium pressure are nearly the same as those ordinarily observed at constant pressure, the relation (3) differs from that of Person only by the addition of the term L/θ. Since s'' is greater than s' in all cases hitherto investigated, and L/θ is necessarily positive, it is clear that the latent heat of fusion must increase with rise of temperature, or diminish with fall of temperature. It is possible to imagine the F.P. so lowered by pressure (positive or negative) that the latent heat should vanish, in which case we should probably obtain a continuous passage from the liquid to the solid state similar to that which occurs in the case of amorphous substances. According to equation (3), the rate of change of the latent heat of water is approximately 0·80 calorie per degree at 0° C. (as compared with 0·50, Person), if we assume $s''=1$, and $s'=0·5$. Putting $(s''-s')=0·5$ in equation (2), we find $L=0$ at -160° C. approximately, but no stress can be laid on this estimate, as the variation of $(s''-s')$ is so uncertain.

6. *Freezing of Solutions and Alloys.*—The phenomena of freezing of heterogeneous crystalline mixtures may be illustrated by the case of aqueous solutions and of metallic solutions or alloys, which have been most widely studied. The usual effect of an impurity, such as salt or sugar in solution in water, is to lower the freezing-point, so that no crystallization occurs until the temperature has fallen below the normal F.P. of the pure solvent, the depression of F.P. being nearly proportional to the concentration of the solution. When freezing begins, the solvent generally separates out from the solution in the pure state. This separation of the solvent involves an increase in the strength of the remaining solution, so that the temperature does not remain constant during the freezing, but continues to fall as more of the solvent is separated. There is a perfectly definite relation between temperature and concentration at each stage of the process, which may be represented in the form of a curve as AC in Fig. 1, called the *Freezing-Point Curve.* The equilibrium temperature, at the surface of contact between the solid and liquid, depends only on the composition of the liquid phase and not at all on the quantity of solid present. The abscissa of the F.P. curve represents the composition of that portion of the original solution which remains liquid at any temperature. If instead of starting with a dilute solution we start with a "*saturated*" solution of the solid in the solvent at any point D on the diagram, the dissolved substance or "*solute*" generally separates out as the solution is cooled, and the concentration diminishes

with fall of temperature in a definite relation, as indicated by the curve CB, which is called the *Solubility Curve*. Though often called by different names, the two curves AC and CB are essentially of a similar nature. To take the case of an aqueous solution of salt as an example, along CB the solution is saturated with respect to salt, along AC the solution is saturated with respect to ice. When the point C is reached along either curve, the solution is saturated with respect to both salt and ice.

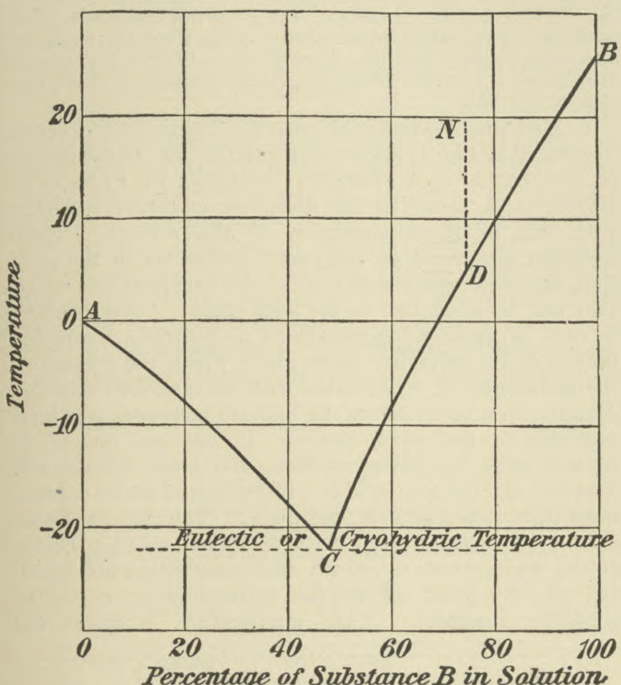


Fig. 1.—F.P. or Solubility Curve: simple case.

The concentration cannot vary further, and the temperature remains constant, while the salt and ice crystallize out together, maintaining the exact proportions in which they exist in the solution. The resulting solid was termed a *Cryohydrate* by Guthrie, but it is really an intimate mixture of two kinds of crystals, and not a chemical compound or hydrate containing the constituents in chemically equivalent proportions. The lowest temperature attainable by means of a *Freezing Mixture* is the temperature of the F.P. of the corresponding cryohydrate. In a mixture of salt and ice with the least trace of water a saturated brine is quickly formed, which dissolves the ice and falls rapidly in temperature, owing to the absorption of the latent heat of fusion. So long as both ice and salt are present, if the mixture is well stirred, the solution must necessarily become saturated with respect to both ice and salt, and this can only occur at the cryohydric temperature, at which the two curves of solubility intersect.

The curves in Fig. 1 also illustrate the simplest type of freezing-point curve in the case of alloys of two metals A and B which do not form mixed crystals or chemical compounds. The alloy corresponding to the cryohydrate, possessing the lowest melting-point, is called the *Eutectic Alloy*, as it is most easily cast and worked. It generally possesses a very fine-grained structure, but is not a chemical compound. (See Alloys.)

To obtain a complete F.P. curve even for a binary alloy is a laborious and complicated process, but the information contained in such a curve is often very valuable. It is necessary to operate with a number of different alloys of suitably chosen composition, and to observe the freezing-points of each separately. Each alloy should also be analysed after the process if there is any risk of its composition having been altered by oxidation or otherwise. The freezing-points are generally best determined by observing the gradual cooling of a considerable mass, which is well stirred so long as it remains liquid. The curve of cooling may most conveniently be recorded, either photographically, using a thermocouple and galvanometer, as in the method of Sir W. Roberts-Austen, or with pen and ink, if a platinum thermometer is available, according to the method put in practice by Heycock and Neville. A typical set of curves obtained in this manner are shown in Fig. 2. When the pure metal A in cooling reaches its F.P. the temperature suddenly becomes stationary, and remains accurately constant for a considerable period. Often it falls slightly below the F.P. owing to

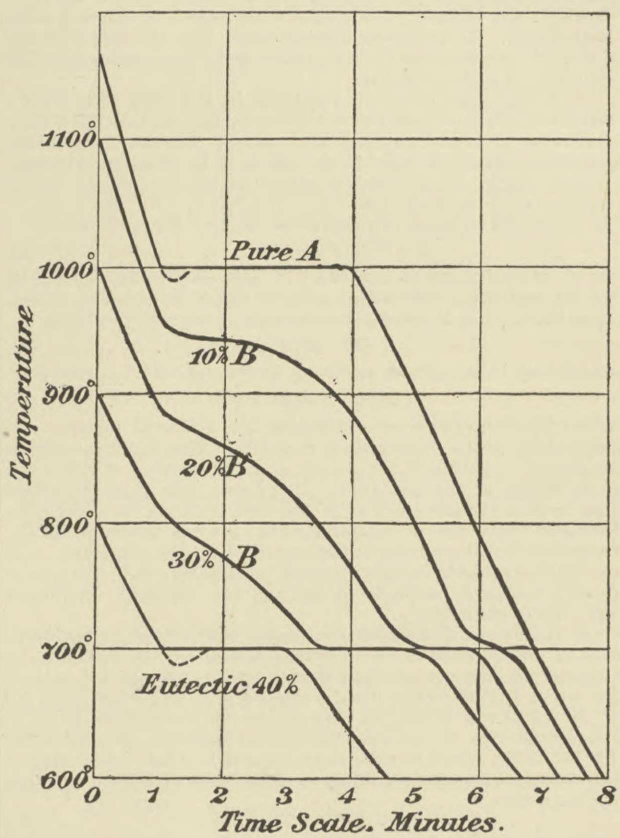


Fig. 2.—Cooling Curves of Alloys: typical case.

superfusion, but rises to the F.P. and remains constant as soon as freezing begins. The second curve shows the cooling of A with 10 per cent. of another metal B added. The freezing begins at a lower temperature with the separation of pure A. The temperature no longer remains constant during freezing, but falls more and more rapidly as the proportion of B in the liquid increases. When the eutectic temperature is reached there is a second F.P. or arrest at which the whole of the remaining liquid solidifies. With 20 per cent. of B the first F.P. is further lowered, and the temperature falls faster. The eutectic F.P. is of longer duration, but still at the same temperature. For an alloy of the composition of the eutectic itself there is no arrest until the eutectic temperature is reached, at which the whole solidifies without change of temperature. There is a great advantage in recording these curves automatically, as the primary arrest is often very slight, and difficult to observe in any other way.

7. *Change of Solubility with Temperature.*—The lowering of the F.P. of a solution with increase of concentration, as shown by the

F.P. or solubility curves, may be explained and calculated by equation (1) in terms of the "*osmotic pressure*" of the dissolved substance by analogy with the effect of mechanical pressure. It is possible in salt solutions to strain out the salt mechanically by a suitable filter or "semi-permeable membrane," which permits the water to pass, but retains the salt. To separate one gramme of salt requires the performance of work PV against the osmotic pressure P, where V is the corresponding diminution in the volume of the solution. In dilute solutions, to which alone the calculation can be satisfactorily applied, the volume V is the reciprocal of the concentration C of the solution in grammes per unit volume, and the osmotic pressure P is equal to that of an equal number of molecules of gas in the same space, and may be deduced from the usual equation of a gas,

$$P = R\theta/VM = R\theta C/M \quad . \quad . \quad . \quad . \quad (4),$$

where M is the molecular weight of the salt in solution, θ the absolute temperature, and R a constant which has the value 8·32 joules, or nearly 2 calories, per degree C. It is necessary to consider two cases, corresponding to the curves CB and AB in Fig. 1, in which the solution is saturated with respect to salt and water respectively. To facilitate description we take the case of a salt dissolved in water, but similar results apply to solutions in other liquids, and alloys of metals.

(*a*) If unit mass of salt is separated in the solid state from a saturated solution of salt (curve CB) by forcing out through a semi-permeable membrane against the osmotic pressure P the corresponding volume of water V in which it is dissolved, the heat evolved is the latent heat of saturated solution of the salt Q together with the work done PV. Writing $(Q+PV)$ for L, and V for $(v''-v')$ in equation (1), and substituting P for p, we obtain

$$Q + PV = V\theta dP/d\theta \quad . \quad . \quad . \quad . \quad (5),$$

which is equivalent to equation (1), and may be established by similar reasoning. Substituting for P and V in terms of C from equation (4), if Q is measured in calories, $R=2$, and we obtain

$$QC = 2\theta^2 dC/d\theta \quad . \quad . \quad . \quad . \quad (6),$$

which may be integrated, *assuming Q constant*, with the result

$$2 \log_e C''/C' = Q/\theta' - Q/\theta'' \quad . \quad . \quad . \quad (7),$$

where C', C'' are the concentrations of the saturated solution corresponding to the temperatures θ' and θ''. This equation may be employed to calculate the latent heat of solution Q from two observations of the solubility. It follows from these equations that Q is of the same sign as $dC/d\theta$, that is to say, the solubility increases with rise of temperature if heat is absorbed in the formation of the saturated solution, which is the usual case. If, on the other hand, heat is liberated on solution, as in the case of caustic potash or sulphate of calcium, the solubility diminishes with rise of temperature.

(*b*) In the case of a solution saturated with respect to ice (curve AB), if one gramme of water having a volume v is separated by freezing, we obtain a precisely similar equation to (5), but with L the latent heat of fusion of water instead of Q, and v instead of V. If the solution is dilute, we may neglect the external work Pv in comparison with L, and also the heat of dilution, and may write P/t for $dP/d\theta$, where t is the depression of the F.P. below that of the pure solvent. Substituting for P in terms of V from equation (4), we obtain

$$t = 2\theta^2 v/LVM = 2\theta^2 w/LWM \quad . \quad . \quad . \quad (8),$$

where W is the weight of water and w that of salt in a given volume of solution. If M grammes of salt are dissolved in 100 of water, $w=M$, and $W=100$. The depression of the F.P. in this case is called by van t' Hoff the "Molecular Depression of the F.P." and is given by the simple formula

$$t = {\cdot}02\theta^2/L \quad . \quad . \quad . \quad . \quad . \quad (9).$$

Equation (8) may be used to calculate L or M, if either is known, from observations of t, θ, and w/W. The results obtained are sufficiently approximate to be of use in many cases in spite of the rather liberal assumptions and approximations effected in the course of the reasoning. In any case the equations give a simple theoretical basis with which to compare experimental data in order to estimate the order of error involved in the assumptions. We may thus estimate the variation of the osmotic pressure from the value given by the gaseous equation, as the concentration of the solution or the molecular dissociation changes. The most uncertain factor in the formula is the molecular weight M, since the molecule in solution may be quite different from that denoted by the chemical formula of the solid. In many cases the molecule of a metal in dilute solution in another metal is either monatomic, or forms a compound molecule with the solvent containing one atom of the dissolved metal, in which case the molecular depression is given by putting the atomic weight for M. In other cases, as Cu, Hg, Zn, in solution in cadmium, the depression of the F.P. per atom, according to Heycock and Neville, is only half as great, which would imply a diatomic molecule. Similarly As and Au in Cd appear to be triatomic, and Sn in Pb tetratomic. Intermediate cases may occur in which different molecules exist together in equilibrium in proportions which vary according to the temperature and concentration. The most familiar case is that of an electrolyte, in which the molecule of the dissolved substance is partly dissociated into ions. In such cases the degree of dissociation may be estimated by observing the depression of the F.P., but the results obtained cannot always be reconciled with those deduced by other methods, such as measurement of electrical conductivity, and there are many difficulties which await satisfactory interpretation.

Exactly similar relations to (8) and (9) apply to changes of boiling-point or vapour pressure produced by substances in solution (see VAPORIZATION), the laws of which are very closely connected with the corresponding phenomena of fusion; but the consideration of the vapour phase may generally be omitted in dealing with the fusion of mixtures where the vapour pressure of either constituent is small.

8. *Hydrates.*—The simple case of a freezing-point curve, illustrated in Fig. 1, is generally modified by the occurrence of compounds of a character analogous to hydrates of soluble salts, in which the dissolved substance combines with one or more molecules of the solvent. These hydrates may exist as compound molecules in the solution, but their composition cannot be demonstrated unless they can be separated in the solid state. Corresponding to each crystalline hydrate there is generally a separate branch of the solubility curve along which the crystals of the hydrate are in equilibrium with the saturated solution. At any given temperature the hydrate possessing the least solubility is the most stable. If two are present in contact with the same solution, the more soluble will dissolve, and the less soluble will be formed at its expense until the conversion is complete. The two hydrates cannot be in equilibrium with the same solution except at the temperature at which their solubilities are equal, *i.e.*, at the point where the corresponding curves of solubility intersect. This temperature is called the

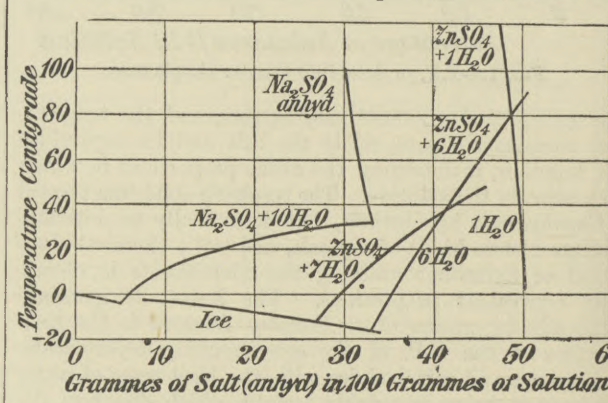


FIG. 3.—Solubility Curves of Hydrates.

"*Transition Point.*" In the case of $ZnSO_4$, as shown in Fig. 3, the heptahydrate, with seven molecules of water, is the least soluble hydrate at ordinary temperatures, and is generally deposited from saturated solutions. Above 39° C., however, the hexahydrate, with six molecules, is less soluble, and a rapid conversion of the hepta- into the hexahydrate occurs if the former is heated above the transition point. The solubility of the hexahydrate is greater than that of the heptahydrate below 39°, but increases more slowly with rise of temperature. At about 80° C. the hexahydrate gives place to the monohydrate, which dissolves in water with evolution of heat, and diminishes in solubility with rise of temperature. If intermediate hydrates exist, as is possible, they are more soluble, and cannot be isolated. Both the mono- and hexahydrates are capable of existing in supersaturated equilibrium at ordinary temperatures far below their transition points, provided that the less soluble hydrate is not present in the crystalline form. The solubility curves can therefore be traced, as in Fig. 3, over an extended range of temperature. The equilibrium of each hydrate with the solvent, considered separately, would present a diagram of two branches similar to Fig. 1, but as a rule only a small portion of each curve can be realized, and the complete solubility curve, as experimentally determined, is composed of a number of separate pieces corresponding to the ranges of minimum solubility of different hydrates. Failure to recognize this, coupled with the fact that in strong and viscous solutions the state of equilibrium is but slowly attained, is the probable explanation of the remarkable discrepancies existing in many recorded data of solubility.

9. *Metallic Compounds.*—The F.P. curves of metallic solutions or alloys, which are often very complicated, are most easily understood by the analogy which the crystalline compounds formed in the process of solidification bear to the familiar aqueous hydrates. For instance, the F.P. curve of solutions of sodium in mercury (Fig. 4) presents seven or more branches, each of which probably corresponds to the separation of a compound of the nature of a hydrate, except the terminal branches AB, HHg, which correspond to the separation of pure Na and pure Hg respectively. The summit F corresponds to the

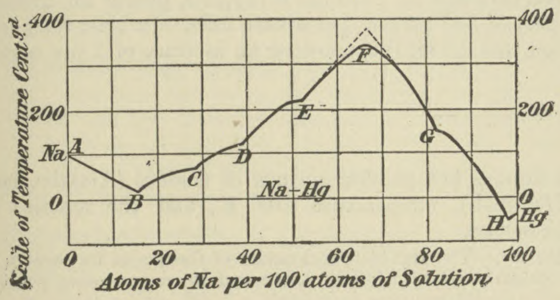


Fig. 4.—Freezing-point Curve of Alloys of Na and Hg.

compound $NaHg_2$, the F.P. of which, at 350° C., is much higher than that of either constituent.

In cases like this, where a well-marked compound is formed, the portion of the curve between the summit corresponding to the compound and the melting-point of the pure metal, as between the points F and Hg in the F.P. curve of NaHg, often bears a close resemblance to the simple case represented in Fig. 1. But there is a characteristic difference to be noted. On the analogy of the ideal case we should expect to find the two branches on either side of a summit like F meeting at a well-defined angle, as indicated by the dotted lines, and not showing continuous curvature. The slope of the curve on one side of the summit should be that corresponding to the depression of the F.P. of the compound F by Na in dilute solution, as calculated by formula (8), the slope on the other side that corresponding to dilute solutions of Hg in F. The experimental evidence goes, however, to show that in most cases these summits are rounded, and not sharp. This would indicate, according to Neville and Le Chatelier, that the compound is partly dissociated at its melting-point. The observed point of fusion corresponding to the summit of the curve is depressed below the ideal point of fusion by the presence of dissociated atoms of the components. It is highly probable that in many cases these loose chemical compounds, like some aqueous hydrates, are partly dissociated before the true point of fusion is reached.

10. *Formation of Mixed Crystals.*—An important exception to the general type already described, in which the addition of a dissolved substance *lowers* the F.P. of the solvent, is presented by the formation of mixed crystals, or "solid solutions," in which the solvent and solute occur mixed in varying proportions. This isomorphous replacement of one substance by another, in the same crystal with little or no change of form, has long been known and studied in the case of minerals and salts, but the relations between composition and melting-point have seldom been investigated, and much still remains obscure. In this case the process of freezing does not necessitate the performance of work of separation of the constituents of the solution, the F.P. is not necessarily depressed, and the effect cannot be calculated by the usual formula for dilute solutions. One of the simplest types of F.P. curve which may result from the occurrence of mixed crystals, is illustrated by the case of alloys of gold and silver, or gold and platinum, in which the F.P. curve is nearly a straight line joining the freezing-points of the constituents. The equilibrium between the solid and liquid, in both of which the two metals are capable of mixing in all proportions, bears in this case an obvious and close analogy to the equilibrium between a mixed liquid (*e.g.*, alcohol and water) and its vapour. In the latter case, as is well known, the vapour will contain a larger proportion of the more volatile constituent. Similarly in the case of the formation of mixed crystals, the liquid should contain a larger proportion of the more *fusible* constituent than the solid with which it is in equilibrium. The composition of the crystals which are being deposited at any moment will, therefore, necessarily change as solidification proceeds, following the change in the composition of the liquid, and the temperature will fall until the last portions of the liquid to solidify will consist chiefly of the more fusible constituent, at the F.P. of which the solidification will be complete. If, however, as seems to be frequently the case, the composition of the solid and liquid phases do not greatly differ from each other, the greater part of the solidification will occur within a comparatively small range of temperature, and the initial F.P. of the alloy will be well marked. It is possible in this case to draw a second curve representing the composition of the *solid* phase which is in equilibrium with the liquid at any temperature. This curve will not represent the average composition of the crystals, but that of the outer coating only which is in equilibrium with the liquid at the moment. Roozeboom (*Zeit. Phys. Chem.*, xxx. p. 385) has attempted to classify some of the possible cases which may occur in the formation of mixed crystals on the basis of Gibbs's thermodynamic potential, the general properties of which may be qualitatively deduced from a consideration of observed phenomena. But although this method may enable us to classify different types, and even to predict results in a qualitative manner, it does not admit of numerical calculation similar to equation (8), as the Gibbs's function itself is of a purely abstract nature, and its form is unknown. There is no doubt that the formation of mixed crystals may explain many apparent anomalies in the study of F.P. curves. The whole subject has been most fruitful of results in recent years, and appears full of promise for the future. For further details in this particular branch the reader may consult a report by Neville (*Brit. Assoc. Rep.*, 1900), which contains numerous references to original papers by Roberts-Austen, Le Chatelier, Roozeboom, and others.

(H. L. C.)

Fustel de Coulanges, Numa Denis (1830–1889), French historian, was born at Paris, 18th March 1830, being of Breton descent. After studying at the École Normale he was sent to the French school at Athens in 1853, and after his return filled various educational offices until, in 1860, he was appointed professor of history at the university of Strasburg. After the conquest of Strasburg by Germany he returned to Paris, and filled a professorship at the École Normale. In 1878 a professorship of mediæval history was created for him, which, except for a brief period during which he was director of the École Normale, he held until his death on 12th September 1889. His principal works are *La Cité Antique* (1862) and *Histoire des institutions politiques de l'ancienne France* (1875). In the former, which went through a great number of editions, he traces the influence of religion in moulding antique institutions, especially those of prehistoric times; in the latter, founded on a course of lectures originally delivered to the Empress Eugénie, he investigates the effect of the Roman and Frankish conquests upon Gaulish society, which he considers to have been less than usually supposed. The continuation of the work was interrupted by the author's death; but the various sections, which had been thoroughly revised by him, were republished as separate books. The eulogium of Fustel de Coulanges has been pronounced by MM. Albert Sorel, Paul Guiraud, and Jules Simon, whose oration has been reproduced in his *Notices et Portraits*. (R. G.)

Fyzabad, or FAIZABAD, a city, district, and division of British India, in Oudh. The city is on the left bank of the river Gogra, 78 miles by rail east of Lucknow. Population (1881), 71,405; (1891), 78,921; (1901), 74,076. The municipal income in 1897–98 was Rs. 72,678. The registered death-rate in 1897 was 57 per thousand. The cantonments accommodate a battery of artillery, and a European and a native infantry regiment. There is a Government college. The DISTRICT has an area of 1728 miles. Population (1881), 1,081,419; (1891), 1,216,959, giving an average density of 704 persons per square mile; (1901), 1,298,086, showing an increase of 7 per cent. The land revenue and rates were Rs. 13,16,315; the incidence of assessment being R. 1–1–1 per acre; the cultivated area in 1896–97 was 623,677 acres, of which 313,834 were irrigated from wells and tanks; the number of police was 3196; the number of vernacular schools in 1896–97 was 68, with 4003 pupils; the registered death-rate in 1897 was 31·67 per thousand. There are six printing-presses, two of which are owned by English firms; 77 indigo factories, employing 8781 persons, with an out-turn valued at Rs. 5,65,000. The district is traversed throughout its length by the line of the Oudh and Rohilkhand railway from Lucknow to Jaunpur, 66 miles in all, with eight stations. Tanda, with a population in 1891 of 19,724, is the largest producer of cotton goods in Oudh. The DIVISION OF FYZABAD has an area of 12,177 square miles, and had a population in 1881 of 6,062,140, and in 1891 of 6,794,272, giving an average density of 557 persons per square mile. In 1901 the population was 6,904,315, showing an increase of 2 per cent.

Gablonz (Bohemian or Czech, *Jablonec*), the chief town of a district in Bohemia, Austria. It possesses several new technical and special schools and a large hospital. It is the chief seat of the glass pearl and imitation jewellery manufacture, and has also an important textile industry, and produces large quantities of papier-mâché and other paper goods, hardware, &c. Gablonz has increased its population by 345 per cent. since 1857, a rate of progress only surpassed in Bohemia by Prague, Pilsen, and Aussig. Population (1890), 14,653; (1900), 21,086.

Gabrovo, a town in the department of Selvi, in the principality of Bulgaria. It is picturesquely situated at the foot of the Balkans near the famous Shipka pass, on the Jantra, an affluent of the Danube, 22 miles south-west of Trnovo. The Jantra in its course through the town breaks into several streams, and is crossed by six bridges. At one point a great rock divides it into two streams and forms a double cascade. Owing to its fine supply of water-power the town has become an important centre of the cloth industry. Cord spinning is also carried on, and there are several tanneries. The population is almost entirely Christian, and there is a large nunnery. The first modern school of Bulgaria, founded in the town in 1835, has become a higher-class school. Population about 8000.

Gadag, or GARAG, a town of British India, in the Dharwar district of Bombay, 43 miles east of Dharwar town. It is an important railway junction on the Southern Mahratta system, with a growing trade in raw cotton, and also in the weaving of cotton and silk. There are fourteen factories for ginning and pressing cotton. Population about 24,000.

Gadara, now Umm Keis, altitude 1194 feet, one of the cities of the Syrian Decapolis, a strong fortress, and the political centre of a small district, Gadaris, which possibly extended to the Sea of Galilee. The extensive ruins are now being rapidly destroyed by the natives. In the Yarmúk valley, about 2½ miles north of the town, are the famous hot sulphur springs of Gadara (Amatha, now el-Hammah), temperature 110° F., and the remains of bath-houses.

History.—The first historical notice of Gadara is its capture by Antiochus the Great; but its name and its commanding position in a fertile district seem to indicate a much earlier existence. It was given by Augustus (30 B.C.) to Herod the Great, at whose death it was re-annexed to Syria. In the Middle Ages it was called Kedar by the Crusaders, and Jadar by the Arabs, a name preserved in the modern Jedúr Umm Keis. Gadara was a Greek city; its coins bear Greek legends, and the inscriptions that have been found on its site are Greek. Its governing and wealthy classes were probably of Greek origin, whilst the people, urban and rural, were Hellenized and Judaized Aramaeans. The community was Hellenistically organized, with a democratic senate at its head, and, whilst dependent on Syria, and acknowledging the supremacy of Rome, it managed its own internal affairs. The city used the era of Pompey (64 B.C.). Gadara, though not mentioned in the Bible, is referred to in the expression "the country of the Gadarenes" (R.V., Matt. viii. 28); but the reading is uncertain, and the scene of the miracle was probably on the eastern shore of the lake.

See SCHÜRER. *History of the Jewish People in the Time of Christ.* English translation, Division II. vol. i. p. 100.—SCHUMACHER. *Northern Ajlûn.* P. E. Fund.—BAEDEKER. *Handbook to Palestine.*—WARREN. "Gadara," in HASTINGS's *Dict. of the Bible.*—WILSON, in *Recovery of Jerusalem* (P. E. Fund, 1882); "Gadara," in SMITH's *Dict. of the Bible.* (C. W. W.)

Gade, Niels Wilhelm (1817–1890), Danish composer, was born at Copenhagen, 22nd February 1817, his father being a musical instrument maker. At first intended for his father's trade, his bent for a musician's career, made evident by the ease and skill with which he learnt to play upon a number of instruments, was not to be denied. Yet, though he became proficient on the violin under Wexschall, and in the elements of theory under Weyse and Berggreen, he was to a great extent self-taught. His opportunities of hearing and playing in the great masterpieces were many, since he was a member of the court band. In 1841 his opus 1—the still popular *Nachklänge aus Ossian* overture—gained the local musical society's prize, the judges being Spohr and Schneider; and it also attracted the notice of the king to Gade, who received a stipend which enabled him to go to Leipzig and Italy.

In 1844 he conducted the Gewandhaus concerts in Leipzig during Mendelssohn's absence, and at the latter's death Gade became chief conductor. In 1848, on the outbreak of the Holstein war, Gade returned to Copenhagen, where he was appointed organist and conductor of the Musik-Verein, a society which prospered exceedingly under him. He succeeded Gläser as court conductor in 1861, and was pensioned by the Government in 1876—the year in which he visited Birmingham to conduct his *Crusaders*. This work, and the *Frühlingsfantasie*, the *Erlkönigs Tochter*, *Frühlingsbotschaft*, and *Psyche* (written for Birmingham in 1882), have enjoyed a wide popularity. Indeed, they represent the strength and the weakness of Gade's musical ability quite as well as any of his eight symphonies (the best of which are the first and fourth, while the fifth has an obbligato pianoforte part). Gade was distinctly a romanticist, but his music rarely glows with the warmth one finds in Grieg or Sinding, or even J. P. E. Hartmann, Gade's father-in-law. It is highly polished and beautifully finished, lyrical rather than dramatic and effective. But it rarely stirs one's deeper self. Much of the pianoforte music, the "Aquarellen," the "Spring Flowers," for instance, enjoyed a considerable vogue, as did the "Novelletten" trio; but Gade's only opera, *Mariotta*, never passed beyond the confines of the Copenhagen Opera House. Gade died at his birthplace, 21st December 1890. (R. H. L.)

Gainesville, capital of Cooke county, Texas, U.S.A., near the Red river, on the Gulf, Colorado, and Sante Fé, and the Missouri, Kansas, and Texas railways, at an altitude of 730 feet. Population (1880), 2667; (1890), 6594; (1900), 7874, of whom 269 were foreign-born and 1201 negroes.

Gainsborough, a market-town in the Gainsborough parliamentary division of Lincolnshire, England, on the Trent, 145 miles north of London. There are three parish churches, a Roman Catholic church, and various Nonconformist chapels. Recent erections include an Albert Hall, new town hall, and a Church of England Institute. There are agricultural implement and engineering works. Area of urban district, 2118 acres; population (1881), 10,873; (1901), 17,660. Area of civil parish, 3446 acres.

Gaisford, Thomas (1779–1855), English classical scholar, was born at Iford, Wiltshire, on the 22nd of December 1779. Proceeding to Oxford in 1797, he became successively student and tutor of Christ Church, and was in 1811 appointed regius professor of Greek at the University. Taking orders, he held (1815–47) the college living of Westwell, in Oxfordshire, and other ecclesiastical preferments simultaneously with his professorship. In 1831 he was appointed Dean of Christ Church, and presided over the destinies of his college until his death on the 2nd of June 1855. As curator of the Bodleian and principal delegate of the University Press he was instrumental in securing the co-operation of distinguished European scholars as collators, notably Bekker and Dindorf. Gaisford was a recondite and critical Greek scholar, of European reputation. Among his numerous contributions to Greek literature may be mentioned, Hephæstion's *Encheiridion* (Oxford, 1810); *Poetæ Græci Minores* (*ibid.*, 1814–20), *Herodotus, cum notis variorum* (*ibid.*, 1824), *Suidas* (*ibid.*, 1834), *Etymologicum Magnum* (*ibid.*, 1848). In 1856 the Gaisford prize, for Greek composition, was founded at Oxford to perpetuate his memory.

Galapagos Islands, an archipelago of five larger and ten smaller islands, situated in the Pacific Ocean, exactly under the equator, from 500 to 600 miles west of Ecuador, to which country they belong. The name is derived from *galapago*, a tortoise, on account of the giant species, the characteristic feature of its fauna.

The origin, distribution, and development of the biological conditions of islands so distinctly oceanic as the Galapagos have given its chief importance to this volcanic archipelago since it was visited in the *Beagle* by Darwin. Of the seven species of these giant reptiles known to science (although at the discovery of the islands there were probably fifteen) all are indigenous, and each is confined to its own islet. There also occurs a peculiar genus of lizards with two species, the one marine, the other terrestrial. The majority of the birds are of endemic species peculiar to different islets—and their number is greater than was believed—while more than half belong to peculiar genera. More than half of the flora is unknown elsewhere. A convict settlement still exists on Chatham, but no longer on Charles Island; there are nearly 300 inhabitants, living in low thatched or iron roofed huts, under the supervision of a police commissioner and other officials. A Spaniard, with large estates on which sugar was grown and refined for the Guayaquil market, was in 1901 the sole employer of labour on the island. Charles Island, the most valuable of the group, is being cultivated by a small colony under an American. On many of the islets numerous tropical fruits are to be found growing wild, but they are no doubt escapes from cultivation, just as the large herds of wild cattle, horses, donkeys, pigs, goats, and dogs—the last large and fierce—which occur so abundantly on most of the islands have escaped from domestication. The shores of the larger islands are fringed with a dense barrier of mangroves, backed by an often impenetrable thicket of tropical undergrowth, which, as the ridges are ascended, give place to taller trees and deep green bushes which are covered with orchids and trailing moss (*orchilla*), and from which creepers hang down interlacing the vegetation.

Since 1860 several visits have been paid to the group by scientific investigators—by Dr Habel in 1868; Messrs Baur and Adams, and the naturalists of the *Albatross*, between 1888 and 1891; and in 1897–98 by Mr Charles Harris, whose journey was specially undertaken at the instance of the Hon. Walter Rothschild of Tring. Very complete collections have therefore, as a result of these expeditions, been brought together; but their examination does not materially change the facts upon which the conclusions arrived at by Darwin—from the evidence of the birds and plants—were based; but he "no doubt would have paid more attention to [the evidence afforded by Land-tortoises], if he had been in possession of facts with which we are acquainted now" (*Günther*). These were that the group "has never been nearer the mainland [of America] than it is now, nor have its members been at any time closer together"; and that the character of the flora and fauna is the result of species straggling over from the mainland, at long intervals of time, to the different islets, where in their isolation they have gradually varied in different degrees and ways from their ancestors. Equally indecisive is the further exploration as to evidence for the opinion held by other naturalists that the endemic species of the different islands have resulted from subsidences, through volcanic action, which have reduced one large island mass into a number of islets, wherein the separated species became differentiated during their isolation. The presence of these giant reptiles on the group, each species on its own islet, is still the chief fact on which a former land connexion with the continent of America may be sustained. "Nearly all authorities agree that it is not probable that they have crossed the wide sea between the Galapagos Islands and the American continent, although, while they are helpless and quite unable to swim, they can float on the water. If their ancestors had been carried out to sea once or twice by a flood and safely drifted as far as the Galapagos Islands" (*Wallace*), "they must have been numerous on the continent" (*Rothschild and Hartert*). No remains, and of course no living species, of these tortoises are known to exist or have existed on the mainland. Rothschild and Hartert seem to think that "it is more natural to assume the disappearance of a great stock of animals, the remains of which have survived, . . . than to assume the disappearance in comparatively recent times (*i.e.*, in the Eocene period or later) of enormous land masses." Past elevations of land (and doubtless equally great subsidences) have, we know, taken place in South America since the Eocene, and on a somewhat similar distribution of giant tortoises in the Mascarene region has long been based the conclusion that extensive areas of land have subsided in the Indian Ocean. "But so much we may claim at present, that Dr Baur's theory of the origin of the Galapagos fauna, when applied to the problem offered by the tortoises in the Indian Ocean, is actually . . . supported by geological and biological facts" (*Günther*). The Galapagos Islands continue to be of some commercial importance to the Government of Ecuador, on account of the guano and the orchilla moss found on them and exported to Europe. Except on Charles Island, where settlement existed longest, little or no influence of the presence of man is evident in the group; still, the running wild of dogs, cats, and especially goats as regards the vegetation, must in the course of a comparatively short period greatly modify the biological condition of the islets.

AUTHORITIES.—SCLATER and SALVIN. "Characters of New Species collected by Dr Habel in the Galapagos Islands," *Proc. Zool. Soc. London*, 1870, pp. 322–327.—THEODOR WOLF. *Ein Besuch der Galapagos Inseln.* Heidelberg, 1879.—W. L. and P. L. SCLATER. *The Geography of Mammals.* London, 1899.—RIDGWAY. "Birds of the Galapagos Archipelago," *Proc. U.S. Nat. Mus.*, vol. xix. pp. 459–670 (1897).—BAUR. "New Observations on the Origin of the Galapagos Islands," *Amer. Nat.*, 1897, pp. 661–680, 864–896.—AGASSIZ. "The Galapagos Islands," *Bull. Mus. Comp. Zool.*, vol. xxiii. pp. 56–75.—GÜNTHER. *Proc. Linn. Soc. London* (President's Address), Oct. 1898, pp. 14–29 (with Bibliography from 1875 to 1898 on Gigantic Land-tortoises).—ROTHSCHILD and HARTERT. "Review of the Ornithology of the Galapagos Islands," *Novitates Zoologicæ*, vi. pp. 85–205. (H. O. F.)

Galashiels, a parliamentary burgh and manufacturing town, situated since 1891 wholly in Selkirkshire, Scotland, on the river Gala, 40 miles south-south-west of Edinburgh by rail. There are now 16 woollen mills and 2 hosiery factories, 2 iron foundries, 2 engineering works, 3 dye-works, and a boot factory. Recent erections include 2 United Free churches, St Paul's parish church, a cottage hospital, and Gala public school. There is a free library, and waterworks have been completed. Population (1881), 15,330; (1901), 13,598.

Galatia.—I. *Galatia Proper*, a large inland district of Asia Minor, which was occupied by Gauls in the 3rd century B.C. Their position was that of a military aristocracy dwelling amongst an inferior race. Some of them settled down in the towns, but for the most part they lived in fortified villages and led a pastoral life. As the military powers of the Gauls declined, they began to mix with the Phrygian natives and adopt their religion; but they long retained much of the Gallic character, and their language was still in use in the 4th century of our era. In the 1st century, when St Paul made his missionary journeys, though the townsmen spoke Greek, the rural population was little affected by Greek civilization. But after the foundation of Constantinople the Hellenization of the country was more rapid. Galatia included a great portion of the viláyet of Angora. (See ANGORA.) It is a pastoral, agricultural country, and consists of a series of larger or smaller plains lying between bare desolate hills. Its scenery is monotonous; it is almost devoid of trees, except on its northern frontier; its cities are far apart, and its climate—a long severe winter and short hot summer—is trying.

II. The *Roman Province* was constituted 25 B.C. It consisted of parts of Lycaonia, Phrygia, with Iconium, Derbe, Lystra, Isaura, and Western Pisidia, to the borders of Pamphylia. The province was enlarged by the addition of the Paphlagonian territories of Deiotarus (who had been called king of Galatia by the Romans, and who died in 40 B.C.), 5 B.C.; Sebastopolis, 2 B.C.; Comana, A.D. 35; Pontus, A.D. 63; and Cappadocia and Armenia Minor, A.D. 72. About 106 Trajan reduced the province by taking away Armenia Minor, Cappadocia, and Pontus, and in 137 the southern and central parts of Lycaonia were attached to Cilicia. Under Diocletian's reorganization, about 297, Galatia became a province of the Diocesis Pontica, and in 413 this was divided into Galatia Prima and Galatia Salutaris. The question whether the "churches of Galatia," to which St Paul addressed his Epistle, were situated in South Galatia or in North Galatia, has been discussed by Professor W. M. Ramsay, who rightly maintains that they were the churches planted in Derbe, Lystra, Iconium, and Antioch. (See GALATIANS.)

AUTHORITIES.—RAMSAY. *Hist. Com. on St Paul's Epistle to the Galatians*, 1899. *St Paul the Traveller.* London, 1898.—PERROT et GUILLAUME. *Expn. archéologique de la Galatie.* Paris, 1862. —HUMANN and PUCHSTEIN. *Reisen in Kleinasien.* Berlin, 1890. —CROWFOOT and ANDERSON. "Expn. in Galatia," in *Journal of Hellenic Society*, xix. 1899. (C. W. W.)

Galatians.—It can no longer be said that "Galatia is never used in the New Testament, except in its older colloquial sense as equivalent to 'Gallogræcia,' or 'Eastern Gaul.'" It is now generally recognized that in 1 Peter i. Galatia is used for the whole Roman province of that name, which in the apostolic age included far more than Gallogræcia. But we are here concerned to consider where "the churches of Galatia" were to which St Paul's Epistle, generally known as the Epistle to the Galatians, was addressed. The contents of the Epistle make it clear that "the churches of Galatia" were of St Paul's own founding. We naturally turn then to the Acts of the Apostles, to inquire whether there is any mention of these churches there. We do not find the word Γαλατία anywhere in the Acts, but twice the adjective Γαλατικός is used (xvi. 6, xviii. 23). It has been generally thought until recent years that the first of these two passages gives the occasion of the founding of the churches of Galatia, a revisit to which is spoken of in the other passage. A careful examination of the passage xvi. 6 ff. has convinced the writer of this article that this view is no longer tenable. His reasons are given at length in the Norrisian Essay for 1898 (*Destination and Date of the Epistle to the Galatians*).

It is the habit of the author of the Acts of the Apostles, when he is telling of St Paul's missionary work in cities before unvisited by him, to give details of the effect of his preaching and of the events of his stay in those cities. Now we observe that in Acts xvi. 6 there is no detailed account of the Apostle's missionary work, so that, if it be the case that we have here the occasion of the planting of "the churches of Galatia," the general rule observed by the author of the Acts here finds its exception. We read: "But they went through [διῆλθον] the Phrygo-Galatian region [τὴν Φρυγίαν καὶ Γαλατικὴν χώραν], forbidden [*or* being forbidden] by the Holy Ghost to preach the word in Asia." If by "the Phrygo-Galatian region" is intended missionary ground new to the Apostle, we have a very brief record of the founding of churches. There is an entire absence of detail. After the Apostle had revisited the churches founded by him on his first missionary journey, the churches of Derbe, Lystra, Iconium, and Antioch (all of which were in the *Roman province* of Galatia), he would naturally pass on to Asia. But Asia was forbidden him as ground for missionary work. We might then understand Acts xvi. 6 to mean that the travellers went through the Phrygo-Galatian region *because* they were forbidden by the Holy Ghost to preach the word in Asia. "The Phrygo-Galatian region" would then be new ground, and might include Galatia proper or Gallogræcia. This is the interpretation of the participial clause given by supporters of the North-Galatian theory, as distinguished from the advocates of the South-Galatian theory, who hold that "the churches of Galatia" addressed by St Paul in his Epistle were the churches of Derbe, Lystra, Iconium, and Antioch, these being, as has been already said, in the province of Galatia. A serious objection to the North-Galatian interpretation of Acts xvi. 6, is that the preaching to those to whom the Epistle was written becomes due to a prohibition imposed by the Holy Ghost against speaking the word in Asia, whereas in the Epistle St Paul writes as if his first preaching had been due to some sickness or bodily infirmity (Gal. iv. 13). It is recognized by those who hold the North-Galatian theory that the route into Galatia was a very unlikely one for St Paul to take, and that his course can only be interpreted as due to some special guidance, such guidance being intended by the words of Acts xvi. 6, κωλυθέντες ὑπὸ τοῦ ἁγίου πνεύματος λαλῆσαι τὸν λόγον ἐν τῇ 'Ασίᾳ. But this cannot be reconciled satisfactorily with Gal. iv. 13. The present writer is of opinion that the proper way to interpret this κωλυθέντες participial clause is not retrospectively as giving the reason why the travellers went through the Phrygo-Galatian region, but as part of the predicate. They went through the Phrygo-Galatian region forbidden by the Holy Ghost to preach the word in Asia. The Phrygo-Galatian region is then not new ground at all, but that part of the province of Galatia which was Phrygian, where St Paul had already preached on his first missionary journey. This interpretation of the phrase "the Phrygo-Galatian region" is due to Professor W. M. Ramsay, who has steadily advocated the South-Galatian theory. In spite of opposition, the theory has been gaining adherents in Great Britain, though the opposition to it in Germany can claim some names of repute.

It has been urged as a serious objection to the South-Galatian theory that St Paul in the Epistle addresses his readers as "Galatians" (Gal. iii. 1). This appellation, it has been said, would be extremely inappropriate unless those addressed were nationally Galatians, and not only belonging to the province of Galatia. This objection has been met by Ramsay in *Studia Biblica*, vol. iv. (*The "Galatia" of St Paul and the "Galatic territory" of Acts*), and in his *Historical Commentary on the Galatians* (notes on iii. 1). And we may remark here that this argument might be turned against supporters of the North-Galatian theory, for it is not likely that a large percentage of inhabitants even of Gallogræcia were Gauls. There would be a mixture of Gaul, Phrygian, and Greek; thus Γαλαταὶ might be just as inappropriate as an appellation of the converts in Gallogræcia.

It has been well argued by Professor Ramsay that "the development and importance of the territory on the northern side of the plateau—*i.e.*, Northern Galatia and Northern Phrygia—belong to the period following after A.D. 292, and result from a transference of the centre of government, first to Nicomedia and afterwards to Constantinople. Under the earlier Roman Empire the southern side of the plateau was far more important than the northern side." This argument is worked out at length in Ramsay's *Historical Geography of Asia Minor*.

The reader who wishes to explore the subject thoroughly should study Ramsay's *The Church in the Roman Empire before A.D. 170*, and his *St Paul the Traveller and Roman Citizen*, with the other works mentioned in this article, also the articles on Galatia, &c., in Hastings's *Dictionary of the Bible*. (E. H. A.)

Galatz, a town and port of Rumania, on the left bank of the Danube, about 90 miles from Sulina on the Black Sea, and 130 miles north-east of Bucharest by rail. Its situation on the Danube between the rivers Sereth and Pruth makes it a position of mercantile importance. Great improvements have been carried out; all the main thoroughfares are paved, and the streets lighted with gas, the fine quays being lighted by electricity. Galatz ceased to be a free port in 1876. Large docks under government control have been constructed, covering an area of 88,000 square metres at low water. The depth is 5 metres at low water. The dock buildings consist of a grain warehouse with 338 silos constructed of iron and cement, having a total accommodation for about 25,000 tons of grain; a depôt for goods, several sheds for goods in transit, an engine room, and administrative offices with a room for samples. Extensive private grain storehouses are also in proximity to the docks and quays. Much of the grain trade has been absorbed by Braila, but the wood export industry has been much developed, and with the opening of the Galatz–Bêrlad railway, which brings much of the rich agricultural country of the north-west of Moldavia into direct touch with the former, Galatz will probably regain much of her ascendency. The navigation of the Sulina branch of the Danube has been greatly improved, vessels of 2500 tons being able to ascend to Galatz. There are large steam saw mills, flour mills, a brewery, soap and candle factories, oil works; a fine prison has been built, as well as extensive barracks, and military and civil hospitals. Electric tramways were started in 1900. The total imports amounted in 1898 to £2,363,595, and the total exports to £1,013,563. The average annual amount of shipping of all nations clearing from Sulina is 1500 vessels of 1,499,887 tons. Population 62,678, of whom 14,000 are Jews.

Galena, capital of Jo Daviess county, Illinois, U.S.A., on the Galena river, near the Mississippi. Three railways, the Chicago, Burlington, and Quincy, the Chicago and North-Western, and the Illinois Central, intersect here. The lead and zinc mines, to which Galena owes its existence and former prosperity, now produce but little, and the business of the city has decreased. Population (1880), 6451; (1890), 5635; (1900), 5005, of whom 918 were foreign-born.

Galena, a city of Cherokee county, Kansas, U.S.A., at the intersection of two railways, in the midst of the lead and zinc region. The development of these mines has given the city a rapid growth. Population (1890), 2496; (1900), 10,155, of whom 251 were foreign-born and 580 negroes.

Galesburg, capital of Knox county, Illinois, U.S.A., in a rich agricultural region, on a level site, at an altitude of 756 feet. It has excellent railway connexions by means of the Atchison, Topeka, and Santa Fé, the Chicago, Burlington, and Quincy, and the Fulton County Narrow Gauge railways. There are extensive manufactures of agricultural implements, carriages, waggons, &c., and the Chicago, Burlington, and Quincy Railway has yards and works here. Knox College and Lombard University, both co-educational institutions, are situated here. The former had, in 1899, 39 instructors and 413 students; the latter, 15 instructors and 116 students. Population (1880), 11,437; (1890), 15,264; (1900), 18,607, of whom 3602 were foreign-born and 738 negroes.

Galicia (German, *Galizien*; Polish, *Halicz*), a Crown land of the Cisleithan part of the Austro-Hungarian monarchy. Its population in 1880 was 5,958,907, and in 1890 was 6,607,816, equivalent to 218 inhabitants per square mile; in 1900 it was 7,295,538. The population grows solely by natural increase, there being practically no immigration, while there was a loss of 67,400 by emigration in the decade 1880–90. In 1890 the proportion of females to males was 1027 to 1000. Racially, 53·34 per cent. were Poles, 43·1 Ruthenians, the remainder being made up of Germans (3·46 per cent.) and about 500 Slovenes and Rumanians. Considered by religions, 45·38 per cent. were Roman Catholic, 42·22 per cent. Greek Catholic (mostly Ruthenians), 11·66 per cent. Jews, the remainder consisting of Protestants and Armenian Catholics. Provisional returns for 1898 gave a marriage-rate of 7·8, a birth-rate of 37·08, and a death-rate of 24·8. Of the births in 1897, 14·4 per cent. were illegitimate. The marriage, birth, and death rates are diminishing. Galicia sends 78 members to the Reichsrath, of whom 15 are returned by the new universal suffrage curia. The Diet is composed of 1 German, 133 Polish, and 17 Ruthenian members. Apart from the Polish Academy of Science, educational requirements are provided for by the Universities of Lemberg and Cracow

(2852 students), a Polytechnic (376 students), an Academy of Art, 3 theological seminaries, 30 gymnasia and *real* gymnasia, 12 academies of music, 337 commercial, agricultural, mining, and other technical and continuation schools, together with 11 intermediate and 3863 elementary schools. Only 65 per cent. of the children attend school. In 1880 the proportion of illiterates was 77·1, in 1890, 68·2 per cent.—a degree of illiteracy only exceeded in Austria by Bukovina and Dalmatia. Of the 203 periodicals and newspapers published in 1898, there were 153 in the Polish language, 25 in Ruthenian, 16 in Hebrew, 4 in German, 1 in Russian, and 4 were polyglot. More than three-fourths of the population are engaged in agriculture and forestry, and about 12 per cent. in mining, industry, and trade. Although there has been an increase in the proportion of arable land, Galicia is backward in agriculture, as in most other branches of production. It has the largest area under potatoes and legumes of any Austrian Crown land. The various classes of live stock show a moderate increase, with the exception of sheep, mules, and asses, which have greatly diminished. Its wealth of valuable timber is one of its chief resources. The principal mining products in 1897 were —coal (8 million metric centners), lignite (607,000 m.c.), petroleum (2,752,000 m.c.), and ozocerite (68,815 m.c.), in addition to smaller quantities of iron, lead, and zinc ore. The total production of salt in 1897 (34·75 per cent. of the total Austrian production) was 1,438,951 metric centners, value £739,970. Manufactures are still comparatively unimportant, with the exception of spirits, of which Galicia has 36·75 per cent. of the entire Austrian production. In 1897 there were 3082 kilometres of railway, 17·70 per cent. of the total length in Austria, 13,759 kms. of roads, and 2102 kms. of waterway, of which 1287 were only available for floating timber. There were 817 post and 351 telegraph offices, with 6168 kms. of line and 15,901 of wire.

This province enjoys a larger degree of autonomy than any other part of the empire. Indeed, owing to the absence of central control, due to the official employment of the Polish language, it may be said to be practically self-governed. Except from the standpoint of international policy—the Poles of Galicia are loyal, politically accommodating, and devoted to the dynasty—this experiment is not regarded as particularly successful. Nearly every department of the administration leaves much to be desired; the material and moral condition of the populace is unsatisfactory, and even that of the large landed proprietors, who have monopolized political power and influence, is less favourable than might fairly be expected, considering the advantages they have secured from the central Parliament. The treatment of the Ruthenians, who form nearly half the population, has excited animosity between the two races, and is considered certain to lead to difficulties if an opportunity offers; while the old feud between the peasant and the noble is as bitter as ever, and has latterly manifested itself in a dangerous form of agrarian socialism.

See SZUJSKI, *Die Polen und Ruthenen in Galizien*, Vienna, 1882; JANDAUREK, *Das Königreich Galizien*, Vienna, 1884; and histories by HOPPE, Vienna, 1793, and ENGEL, 1793. (Æ. O'N.)

Galilee. See PALESTINE.

Galilee, Sea of, the name most frequently used in the New Testament for the lake called in the O.T. the Sea of Chinnereth or Chinneroth, and, once in the N.T., the "lake of Gennesareth," a corruption of the old name, which is commonly used by Josephus and in the Targums. By St John the lake is called the "Sea of Tiberias," and this name survives in the modern Bahr Tabaríeh. In the Gospels its shores are closely connected with the Galilean ministry of Christ and the homes of most of the Apostles. The Sea of Galilee is, like the Dead Sea, a "rift" lake situated in the Jordan-ʿAraba depression. (See DEAD SEA.) It has an area of 64 square miles. The maximum depth is 145 to 150 feet. The present level is 682·5 feet below that of the sea, but deposits show that originally the lake formed part of the inland sea which filled the Jordan valley in Pleistocene times. During the rainy season the surface level rises from 2 to 4 feet. The shores are for the most part formed of fine gravel (limestone, basalt, and flint), mixed with fragments of shells. Some yards from the shore the bed of the lake is uniformly covered with a fine greyish mud. Oleanders fringe the lake, and the large papyrus grows at ʿAin et-Tin, and near the mouth of the Jordan. The heat in summer is tropical, but is relieved after noon by a strong northwest breeze, which causes a fall of 10° to 11° F. The slopes of the surrounding limestone hills, overlain here and there by basalts, which have a bare steppe-like appearance for half the year, are clothed with green in spring. The lake was once surrounded by towns with a large population, but Tiberias and Mejdel (Magdala) alone are now inhabited. The lake, in which Molyneux first took soundings in 1847, was examined in 1890 by M. Barrois. The most interesting features are—the great range of the diurnal variations of temperature at the surface, the relatively small depth of the zone (hardly 49 feet) influenced by these variations, the uniform temperature (59° F.) of the deeper zones between 65 feet and 131 feet, and the existence of at least one sub-aqueous hot spring. The water is generally used for drinking, but it is flat, slightly brackish, and not very clear. The surface is usually placid, but it is liable to be disturbed by short, sudden storms. The lake swarms with fish, which are caught with nets by a guild of fishermen, whose boats are the only representatives of the many ships and boats which plied on the lake as late as the 10th century. Fishing was a lucrative industry at an early date, and the Jews ascribed the laws regulating it to Joshua. The fish, which were classed as clean and unclean, the good and bad of the parable (Matt. xiii. 47, 48), belong to the genera *Chromis*, *Barbus*, *Capoeta*, *Discognathus*, *Nemachilus*, *Blennius*, and *Clarias*; and there is a great affinity between them and the fish of the East African lakes and streams. There are eight species of Chromis, most of which hatch their eggs and raise their young in the buccal cavities of the males. The *Chromis simonis* is popularly supposed to be the fish from which Peter took the piece of money (Matt. xvii. 27). The most remarkable fish is the *Clarias macracanthus* (Arab, *Burbur*), called coracinus by Josephus, who says that it lived in the Nile and in the spring of Capharnaum. It was found by Lortet in the springs of ʿAin Mudáwara, ʿAin et-Tin, and ʿAin Tabghah, on the lake shore where muddy, and in Lake Huleh. It is a scaleless, snake-like fish, often nearly 5 feet long, which resembles the *C. anguillaris* of Egypt. From the absence of scales it was held by the Jews to be unclean, and some commentators suppose it to be the serpent of Matt. vii. 10 and Luke xi. 11. Large numbers of grebes —great crested, eared, and little—gulls, and pelicans frequent the lake. On its shores are terrapins, crabs, and innumerable sandhoppers; and at varying depths in the lake several species of *Melania*, *Melanopsis*, *Neritina*, *Corbicula*, and *Unio* have been found.

AUTHORITIES.—MERRILL. *Galilee in the Time of Christ.*—GUÉRIN. *Galilée.*—BAEDEKER. *Handbook to Palestine.*—FREI. "Beobachtung vom See Genezareth," in *Zeitschrift d. Deutschen Pal. Vereins*, 1886.—G. A. SMITH. *Historical Geography of the Holy Land.*—LORTET. *La Syrie d'aujourd'hui*; "Poissons et reptiles du lac de Tibériade," in *Archives du Mus. d'hist. nat. de Lyon*, iii. 1883.—TRISTRAM. *Flora and Fauna of Palestine* (P. E. Fund Memoirs).—BARROIS, in *Bulletin de la Société de Géographie.* Paris, 1893.—LOCARD. *Malacologie des lacs de Tibériade, &c.* Lyon, 1883.—MOLYNEUX, in *R.G.S. Journal*, xviii. 1848.

(C. W. W.)

Galion, a city of Crawford county, Ohio, U.S.A., on the Erie and the Cleveland, Cincinnati, Chicago, and St Louis railways, at an altitude of 1167 feet. It has

"A Bohemian Woman and her Children." By L. Gallait.

railway and iron works. Population (1880), 5635; (1890), 6326; (1900), 7282—703 foreign-born.

Gallait, Louis (1810–1887), Belgian painter, was born at Tournay, in Hainaut, Belgium, 9th May 1810. He first studied in his native town under Hennequin. In 1832 his first picture, "Tribute to Cæsar," won a prize at the exhibition at Ghent. He then went to Antwerp to prosecute his studies under Mathieu Ignace Van Brée, and in the following year exhibited at the Brussels Salon "Christ Healing the Blind." This picture was purchased by subscription and placed in the cathedral at Tournay. Gallait next went to Paris, whence he sent to the Belgian Salons "Job on the Dunghill," "Montaigne Visiting Tasso in Prison"; and, in 1841, "The Abdication of Charles V.," in the Brussels Gallery. This was hailed as a triumph, and gained for the painter a European reputation. Official invitations then caused him to settle at Brussels, where he died on the 20th of November 1887. Among his greater works may be named: "The Last Honours paid to Counts Egmont and Horn by the Corporations of the Town of Brussels," now at Tournay; "The Death of Egmont," in the Berlin Gallery; the "Coronation of Baudouin, Emperor of Constantinople," painted for Versailles; "The Temptation of St Anthony," in the Palace at Brussels; "The Siege of Antioch," "Art and Liberty," a "Portrait of M. B. Dumortier," and "The Plague at Tournay," all in the Brussels Gallery. "A Gipsy Woman and Her Children" (see Plate) was painted in 1852. "M. Gallait has all the gifts that may be acquired by work, taste, judgment, and determination," wrote Théophile Gautier; his art is that of a man of tact, a skilled painter, happy in his dramatic treatment, but superficial. No doubt, this Walloon artist, following the example of the Flemings of the Renaissance and the treatment of Belgian classical painters and the French Romantic School, sincerely aimed at truth; unfortunately, misled by contemporary taste, he could not conceive of it excepting as dressed in sentimentality. As an artist employed by the State he exercised considerable influence, and for a long period he was the leader of public taste in Brussels.

Teichlin, *Louis Gallait und die Malerei in Deutschland*, 1853; J. Dujardin, *L'Art Flamand*, 1899; C. Lemonnier, *Histoire des Beaux Arts en Belgique*, 1881. (H. Fr.)

Galle, or Point de Galle, town and port of Ceylon, on the south-west coast. The opening of the Suez Canal in 1869, and the construction of a breakwater at Colombo, leading to the transfer of the mail and most of the commercial steamers to the capital port of the island, made a great difference to Galle. Although a few steamers still call to coal and take in some cargo, yet the loss of the Peninsular and Oriental and other steamer agencies reduced it to a very subordinate position; nor has the extension of the railway, 70½ miles from Colombo, and beyond Galle 26½ miles to Matara, very much improved matters. The houses occupied by Europeans in or near the town are now very few. The tea-planting industry has, however, spread to the neighbourhood, and a great deal is done in digging plumbago and in growing grass for the distillation of citronella oil. The export trade for 1899 was chiefly represented by cocoanut oil, 47,731 cwt.; plumbago, 57,549 cwt.; coir yarn, fibre, and rope, 68,930 cwt.; while of tea 348,067 ℔ were shipped. In import trade there was a declared value of about 50,000 rupees (£3400) of cotton goods in the same year. Both the export and import trade for the district, however, chiefly passes through Colombo. Population (1891), 33,853; (1901), 37,248.

Gallenga, Antonio Carlo Napoleone (1810–1895), Italian author and patriot, born at Parma on 4th November 1810, was the eldest son of a Piedmontese of good family, who served for ten years in the French army under Massena and Napoleon. He had finished his education at the University of Parma, when the French Revolution of 1830 caused a ferment in Italy. He sympathized with the movement, and within a few months was successively a conspirator, a State prisoner, a combatant, and a fugitive. For the next five years he lived a wandering life in France, Spain, and Africa. In August 1836 he embarked for New York, and three years later he proceeded to England, where he supported himself as a translator and teacher of languages. His first book, *Italy; General Views of its History and Literature*, which appeared in 1841, was well received, but was not successful financially. On the outbreak of the Italian Revolution in 1848 he at once put himself in communication with the insurgents. He filled the post of Chargé d'Affaires for Piedmont at Frankfort in 1848–49, and for the next few years he travelled incessantly between Italy and England, working for the liberation of his country. In 1854, through Cavour's influence, he was elected a deputy to the Italian Parliament. He retained his seat until 1864, passing the summer in England and fulfilling his parliamentary duties at Turin in the winter. On the outbreak of the Austro-French war of 1859 he proceeded to Lombardy as war correspondent of *The Times*. The campaign was so brief that the fighting was over before he arrived, but his connexion with *The Times* endured for twenty years. He was a forcible and picturesque writer, with a command of English remarkable for an Italian. He materially helped to establish that friendly feeling towards Italy which became traditional in England. In 1859 Gallenga purchased the Falls, at Llandogo on the Wye, as a residence, and thither he retired in 1885. He died at this house on 17th December 1895. He was twice married. Among his chief works are a *Historical Memoir of Frà Dolcino and his Times*, 1853; a *History of Piedmont*, 3 vols., 1855, Italian translation 1856; *Country Life in Piedmont*, 1858; *The Invasion of Denmark*, 2 vols., 1864; *The Pearl of the Antilles* [travels in Cuba], 1873; *Italy Revisited*, 2 vols., 1875; *Two Years of the Eastern Question*, 2 vols., 1877; *The Pope* [Pius IX.] *and the King* [Victor Emmanuel], 2 vols., 1879; *South America*, 1880; *A Summer Tour in Russia*, 1882; *Iberian Reminiscences*, 2 vols., 1883; *Episodes of my Second Life*, 1884; *Italy, Present and Future*, 2 vols., 1887. Gallenga's earlier publications appeared under the pseudonym of Luigi Mariotti. (E. I. C.)

Galleries of Art. See Art Galleries.

Gallieni, Joseph Simon (1849–——), French soldier and administrator, was born at Saint-Béat, in the department of Haute-Garonne, on 24th April 1849. He left the military academy of Saint-Cyr in July 1870 as a second lieutenant in the Marines, becoming lieutenant in 1873 and captain in 1878. He saw service in the Franco-German war, and between 1877 and 1881 took an important part in the explorations and military expeditions by which the French dominion was extended in the basin of the Upper Niger. He rendered a particularly valuable service by obtaining, in March 1881, a treaty from Ahmadu, chief of Segu, giving the French exclusive rights of commerce on the Upper Niger. For this he received the gold medal of the Société de Géographie. From 1883 to 1886 Gallieni was stationed in Martinique. On 24th June 1886 he attained the rank of lieutenant-colonel, and on 20th December was nominated governor of Haute-Fleuve (Senegal). He obtained several successes against

Ahmadu in 1887, and compelled Samory to agree to a treaty by which he abandoned the left bank of the Niger. In connexion with his service in West Africa Gallieni published two works — *Voyage au Sudan Français, 1879–1881* (Paris, 1885), and *Deux Campagnes au Sudan Français* (Paris, 1891), which, besides possessing great narrative interest, give information of considerable value in regard to the resources and topography of the country. In 1888 Gallieni was made an officer of the Legion of Honour. In 1891 he attained the rank of colonel, and from 1893 to 1895 he served in Tongking, commanding the second military division of the territory. In 1899 he published his experiences in *Trois Colonnes au Tonkin.* In September 1896 Madagascar was made a French colony, and after the unsuccessful administration of Laroche, Gallieni was appointed resident-general and commander-in-chief. By a vigorous military system he succeeded in clearing of brigands the great routes to the capital, and eventually in completing the subjugation of the island. He then turned his attention to the destruction of the political supremacy of the Hovas and the restoration of the autonomy of the other tribes. The execution of the queen's uncle, Ratsimamanga, and of Rainandrianampandry, the minister of the interior, in October 1896, and the exile of Queen Ranavalona herself in 1897, on the charge of fomenting rebellion, broke up the Hova hegemony; but the application of the tariff of French customs and other like measures were disastrous to British and American trade, and struck a serious blow at the commercial prosperity of the island.

Galliffet, Gaston Alexandre Auguste de, Marquis, Prince de Martignes (1830– ——), French general, was born in Paris on 23rd January 1830. He entered the army in 1848, was commissioned as sub-lieutenant in 1853, and served with distinction at the siege of Sebastopol in 1855 (Legion of Honour), in the Italian campaign of 1859 under General Douay, and in Algeria in 1860. He displayed great gallantry as a captain at the siege and storm of Puebla, in Mexico, in 1863, when he was severely wounded (majority and officer, Legion of Honour). He went again to Algeria in 1864, took part in expeditions against the Arabs, and became colonel in 1867, with the command of the 3rd Regiment of Chasseurs d'Afrique. In the Franco-German war of 1870–71 he commanded this regiment in the Army of the Rhine, was promoted to be general of brigade on 30th August, and commanded the three regiments of Chasseurs d'Afrique at the battle of Sedan, leading them in person in a splendid charge on the heights of Floing, and winning the admiration of his enemies. Made prisoner of war at the capitulation of Sedan, he returned to France during the siege of Paris by the French Army of Versailles, and commanded a brigade against the Communists. The severity of his methods against the Communists came to be permanently associated with his name. In 1872 he took command of the Batna subdivision of Algeria, and commanded an expedition against El Golea, surmounting great difficulties in a rapid march across the desert, and inflicting severe chastisement on the revolted tribes (commander, Legion of Honour). On the general reorganization of the army he commanded the 31st infantry brigade of the 8th Army Corps, and the department Cher. Promoted general of division in 1875, he successively commanded the 15th infantry division at Dijon, the 9th Army Corps at Tours, and in 1882 the 12th Army Corps at Limoges. In 1885 he became a member of the Supreme Council of War. He conducted the cavalry manœuvres in successive years, and attained a European reputation on all cavalry questions. Decorated with the Grand Cross of the Legion of Honour in 1887, he received a military medal for his able conduct of the autumn manœuvres in 1891, and after again commanding at the manœuvres of 1894 he retired from the active list. Afterwards he took an important part in French politics, as War Minister (22nd June 1899 to 29th May 1900) in M. Waldeck-Rousseau's Cabinet, and distinguished himself by the firmness with which he dealt with certain cases of unrest in the army.

Gallipoli, a fortified seaport town and episcopal see of the province of Lecce, Apulia, Italy, on the east side of the Gulf of Taranto, and 59 miles by rail south from Brindisi. It exports olive oil (£113,000 to £236,000 annually), wine (£185,500 in 1899), dried figs (£12,000 average), &c., to the average value of £300,000 annually (£454,500 in 1899); and imports cereals, flour, timber, and other commodities (£11,000 in 1888, £153,200 in 1899). The port was cleared by 407 vessels of 188,180 tons in 1888, and by 913 vessels of 338,670 tons in 1899. The harbour was dredged to a depth of 16¼ feet in 1884, and further improved at a later date. Population, 11,000.

Gallipoli, a seaport of Turkey, on the Thracian Chersonesus, chief town of the sanjak of the same name. Its chief industries consist of two steam flour mills, and a sardine factory which exports 15,000 to 16,000 cases (100 boxes to a case) annually. The sanjak, of which the population is 95,500, comprises four *kazas* (cantons), namely (1) Maitos, noted for its excellent cotton; (2) Keshan, lying inland north of Gallipoli, noted for its cattle-market, the district producing also grain, linseed, and canary seed; (3) Myriofyto; and (4) Sharkeui, on the coast of the Sea of Marmora, which once produced wine that was highly esteemed and was largely exported to France for blending. Heavy taxation, however, amounting to 55 per cent. of the value of the wine, broke the spirit of the viticulturists, most of whom uprooted their vines and replanted their lands with mulberry trees, making sericulture their occupation, an industry which is year by year assuming larger proportions. All this region has been depressed by a succession of bad crops, and the people oppressed by excessive taxation rigidly exacted. The country folk have been reduced to indigence, their lands, their cattle, and in many cases their household goods, having been sold by the authorities to cover arrears of taxes. (E. W*.)

Galston, a police burgh and manufacturing town of Ayrshire, Scotland, on the river Irvine, 5 miles east by south of Kilmarnock by rail. There is a blanket factory, 2 lace and muslin and 3 hosiery factories, and a paper millboard factory. There are coal mines in the vicinity. The institute contains a library and recreation rooms. A Roman Catholic church was erected in 1886 by the marquis of Bute. Galston figures frequently in Burns's poems. Population (1881), 4085; (1901), 4876.

Galt, a town in Waterloo county, Ontario, Canada, 23 miles N.N.W. of Hamilton, on the Grand river and on the Grand Trunk and Canadian Pacific railways. It has excellent water privileges, which furnish power for flour mills, and axe, machinery, paper, and other manufactories. Exports in 1899–1900 were valued at $165,913, imports at $729,931. Population (1881), 5187; (1900), 7746.

Galton, Francis (1822– ——), English anthropologist, son of S. T. Galton, of Duddeston, Warwickshire, His grandfather was the poet-naturalist Erasmus Darwin, and his cousin was the famous propounder of the doctrine of evolution. Francis Galton was born in 1822, and educated at King Edward VI.'s Grammar School, Birmingham. Electing to study medicine, he attended classes at Birmingham Hospital, and afterwards "walked" King's College, London. Graduating at Trinity College, Cambridge, in 1844, he next travelled for two years and ascended the White Nile, thus being a pioneer of the modern explorers of that part of the Dark Continent. In 1850 he made an exploration, with Dr John Anderson, of Damaraland and the Ovampo country in South-West Africa, starting from Walfisch Bay. These tracts had practically never been traversed before, and on the appearance of the published account of his journey and experiences under the title of *Narrative of an Explorer in Tropical South Africa* (1853) Galton was awarded the gold medal of the Royal Geographical Society. His *Art of Travel; or, Shifts and Contrivances in Wild Countries*, was first published in 1855. In 1861 he visited the north of Spain, and published the fruits of his observations of the country and the people in the first of a series of volumes which he edited, entitled *Vacation Tourists.* He then turned to meteorology, the result of his investigations appearing in *Meteorographica*, published in 1863. This was the first serious attempt to chart the weather on an extensive scale, and in this work also the author first established the existence and theory of anti-cyclones. Galton succeeded Admiral Fitzroy as a member of the meteorological committee of the Board of Trade, and was appointed one of the committee entrusted with the parliamentary grant for the Meteorological Office. He next devoted himself to the study of heredity, and with his researches on this subject and his anthropological investigations his name will be most closely associated. In 1869 appeared his *Hereditary Genius, its Laws and Consequences*, a work which excited much interest in scientific and medical circles. This was followed by *English Men of Science, their Nature and Nurture*, published in 1874; and *Inquiries into Human Faculty and its Development*, issued in 1883. Then followed, in the order named, *Life-History Album*, 1884; *Record of Family Faculties*, 1884 (tabular forms and directions for entering data, with a preface); *Natural Inheritance*, 1889; *Decipherment of Blurred Finger-Prints*, 1893; and *Finger-Print Directories*, 1895. Galton is also the author of several memoirs on anthropometric subjects, and on new statistical processes applicable to anthropometry, including that of composite portraiture. His writings on heredity have been especially popular. He has had a long connexion with the leading scientific societies, and in 1886 he received the gold medal of the Royal Society.

Galveston, seaport and capital of Galveston county, Texas, U.S.A., on Galveston Island, Gulf of Mexico, at the entrance to Galveston Bay. It is the fourth city of the state in population, and first in commercial importance, and it is one of the important commercial centres of the South. Six railways meet in it, and its excellent harbour has had its entrance deepened by jetties, at the expense of the United States. Through these agencies Galveston has become one of the largest cotton shipping ports of the country, shipping 900,000 bales of cotton annually. Its exports increased from $15,700,000 in 1888 to $68,428,621 in 1898, placing it second only to New Orleans among the southern ports. Of these exports 70 per cent. consisted of raw cotton. It has regular steamship lines to the ports of the Gulf, Atlantic, West Indies, and Europe. In the autumn of 1900 it was nearly destroyed by a West Indian hurricane, but was rapidly rebuilt. Its manufactures are by no means comparable with its commerce. In 1890 the capital invested was $5,122,612, employing 1932 hands and producing $5,724,545 of products. These were of great variety. The assessed valuation of real and personal property, on a basis of about two-thirds of the full value, was in 1899 $26,777,338, the net debt of the city $2,839,146, and the rate of taxation $26·30 per $1000. Population (1880), 22,248; (1890), 29,084; (1900), 37,789, of whom 6339 were foreign-born and 8291 negroes.

Galway, a maritime county of Ireland, province of Connaught, bounded on the N. by Mayo and Roscommon; on the E. by Roscommon, King's County, and Tipperary; on the W. by the Atlantic Ocean; and on the S. by Clare and Galway Bay. The area of the administrative county in 1900 was 1,463,430 acres, of which 196,365 were tillage, 755,888 were pasture, 851 fallow, 25,166 plantation, 141,925 turf bog, 54,876 marsh, 221,259 barren mountain, and 67,100 water, roads, fences, &c. The new administrative county under the Local Government (Ireland) Act, 1898, includes the parliamentary borough of Galway, and the portion of Ballinasloe formerly situated in Roscommon, but is diminished to the extent of six electoral divisions added to other counties. The population in 1881 was 242,005, and in 1891 214,712, of whom 108,283 were males and 106,429 females, divided as follows among the different religions: Roman Catholics, 208,364; Protestant Episcopalians, 5340; Presbyterians, 628; Methodists, 324; and other denominations, 56. The average number of persons to an acre in the whole county was ·14. Of the total population, 191,673 persons inhabited the rural districts, being an average of 134 persons to each square mile under crops and pasture. The population in 1901 was 192,146 (Roman Catholics, 186,870; Protestant Episcopalians, 4435; Presbyterians, 589; Methodists, 181; others, 71), being a decrease of 10·5 per cent., as compared with a decrease of 11·3 per cent. from 1881 to 1891. The following table gives the number of births, deaths, and marriages in various years:—

Year.	Births.	Deaths.	Marriages.
1881	5638	3323	708
1891	4707	3370	651
1899	4373	2755	650

The birth-rate per 1000 in 1899 was 20·7, and the death-rate 13·0; the rate of illegitimacy was ·9 per cent. of the total births. The total number of emigrants who left the county between 1st May 1851 and 31st December 1899 was 196,794, of whom 94,295 were males and 102,499 females. The chief towns in the county are Galway, Ballinasloe, and Tuam.

Education.—The following table gives the degree of education in 1891 (excluding the town of Galway):—

	Males.	Females.	Total.	Percentage.		
				R. C.	Pr. Ep.	Presb.
Read and write	51,837	47,694	99,531	55·3	91·0	94·4
Read only	8,358	8,792	17,150	9·8	4·0	2·8
Illiterate	29,065	31,364	60,429	34·9	5·0	2·8

In 1881 the percentage of illiterates among Roman Catholics was 47·5. In 1891 (including the town of Galway) the number of superior schools was 11, with 489 pupils (Roman Catholics 325, and Protestants 164), and the number of primary schools was 445, with 30,743 pupils (Roman Catholics 29,720, and Protestants 1023). The number of pupils on the rolls of the national schools on 30th September 1899 was 39,485, of whom 38,850 were Roman Catholics and 635 Protestants.

Administration.—The county is divided into four parliamentary divisions, north, south, east, and Connemara, the number of registered electors in 1900 being respectively 10,475, 8148, 8936, and 8423. The rateable value in 1900 was £472,941. By the Local Government (Ireland) Act, 1898, the fiscal and administrative duties of the grand jury were transferred to a county council, urban and rural district councils were established, and under that Act the county now comprises two urban and ten rural sanitary districts. By the same Act the county of the town of Galway was abolished.

Agriculture.—The following tables give the acreage under crops, including meadow and clover, and the amount of live stoek in 1881, 1891, 1895, and 1900. The figures for 1900 are for the new administrative county.

Year.	Wheat.	Oats.	Barley, Rye, Beans, &c.	Potatoes.	Turnips.	Other Green Crops.	Meadow and Clover.	Total.
1881	3544	54,352	6923	50,533	12,307	7066	85,345	220,070
1891	5258	42,962	4542	41,621	12,594	9313	91,220	207,510
1895	2766	42,220	4440	38,900	11,789	8135	95,186	203,436
1900	4054	36,710	3615	36,768	11,077	8986	95,155	196,365

In 1899 the total value of the cereal and other crops was estimated by the Registrar-General at £1,366,245. The number of acres under pasture in 1881 was 741,803 ; in 1891, 717,775 ; and in 1900, 755,888.

Year.	Horses and Mules.	Asses.	Cattle.	Sheep.	Pigs.	Goats.	Poultry.
1881	29,070	14,763	173,445	530,912	53,768	10,549	757,922
1891	32,828	18,373	200,188	683,560	63,125	14,623	858,609
1895	33,566	17,967	190,552	602,944	63,500	13,207	877,143
1900	28,986	18,207	198,385	653,456	69,874	13,668	924,903

The number of milch cows in 1891 was 44,852 and in 1900 45,170. It is estimated that the total value of cattle, sheep, and pigs in 1899 was £3,975,514, the third largest amount in the Irish counties. In 1900 the number of holdings not exceeding 1 aere was 1980 ; between 1 and 5, 4553 ; between 5 and 15, 11,951 ; between 15 and 30, 8762 ; between 30 and 50, 3498 ; between 50 and 100, 2410 ; between 100 and 200, 1340 ; between 200 and 500, 765 ; and above 500, 222—total, 35,481. The number of loans issued (the number of loans being the same as the number of tenants) under the Land Purchase Acts, 1885, 1891, and 1896, up to 31st March 1900, was 1529, amounting to £416,170. The number of loans for agricultural improvements sanctioned under section 31 of the Land Act, 1881, between 1882 and 1900, was 653, and the amount issued was £46,323. The total amount issued on loan for all classes of works under the Land Improvement Aets from the commencement of operations in 1847 to 31st March 1900 was £392,919.

Fisheries.—In 1899 1414 vessels, employing 4877 hands, were registered in the deep-sea and coast fishery districts of Galway and Clifden. In the same year 344 persons were employed in the salmon fishery districts of Galway and Connemara.

(W. H. Po.)

Galway, a maritime town and parliamentary borough (returning one member), capital of the above county, on the north side of Galway Bay, and on the Midland Great Western Railway. The town commissioners were abolished in 1898, and an urban district council substituted. There is an extensive line of quays, and a canal runs from the harbour to Lough Corrib and Lough Mask. In all, 193 vessels of 37,376 tons entered in 1899, and 80 of 16,798 tons cleared. The number of vessels registered in 1899 in the fishery district was 793, and the number of men and boys employed 2503. A light railway now runs from Galway to Clifden. Population (1881), 15,417 ; (1901), 13,414.

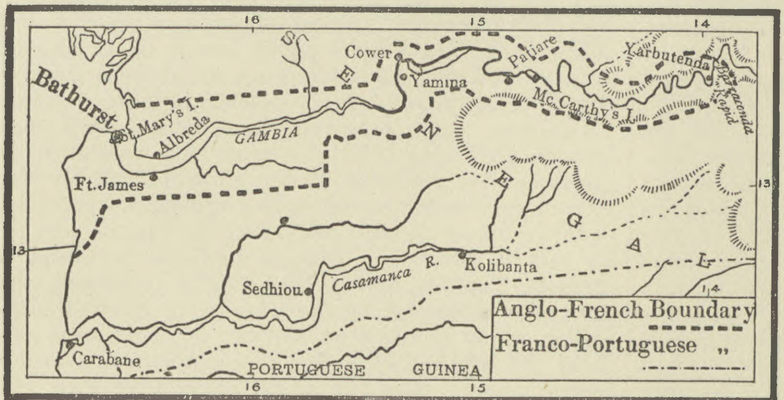
Gambetta, Léon (1838–1882), French statesman, was born at Cahors on the 3rd of April 1838. His father, a Genoese, who had established himself as a grocer and had married a Frenchwoman, is said to have been his son's prototype in vigour and fluency of speech. In his sixteenth year young Gambetta lost by an accident the sight of his left eye, which eventually had to be removed. Notwithstanding this privation, he highly distinguished himself at the public school of Cahors, and in 1857 proceeded to Paris to study law. His southern vehemence gave him great influence among the students of the Quartier Latin, and he was soon known as an inveterate enemy of the Imperial Government. He was called to the bar in 1859, but, although contributing to a Liberal review, edited by M. Challemel Lacour, did not make much way until, on the 17th of November 1868, he was selected to defend a journalist prosecuted for having promoted the erection of a monument to the representative Baudin, killed in resisting the *coup d'état* of 1851. Gambetta seized his opportunity, and assailed both the *coup d'état* and the Government with an eloquence of invective which made him immediately famous. In May 1869 he was returned to the Assembly, both by the first circumscription of Paris and by Marseilles, defeating Hippolyte Carnot for the former constituency and Thiers and Lesseps for the latter. He elected to sit for Marseilles, and lost no opportunity of attacking the Empire in the Assembly. He opposed the war with Germany, but did not refuse to vote supplies when it was determined upon. When the news of the disaster at Sedan reached Paris, Gambetta led the agitation which substituted the Republic for the

Léon Gambetta.
(From a photograph by Carjat et Cie., Paris.)

Empire, and was one of the members of the new Government of National Defence. He advised his colleagues to leave Paris and conduct the Government from some provincial city. This advice was rejected from dread of another revolution in Paris, and a delegation to organize resistance in the provinces was despatched to Tours, but when this was seen to be inefficient Gambetta himself (7th October) quitted Paris in a balloon, and upon arriving at Tours took the supreme direction of affairs as Minister of the Interior and of War. Aided by M. de Freycinet, a young officer of engineers, as his assistant secretary of war, he displayed prodigies of energy and intelligence. He speedily organized an army, which might possibly have effected the relief of Paris if Metz had held out, but the treacherous surrender of Bazaine brought the army of the Crown Prince into the field, and success was impossible. After the defeats of the French near Orleans early in December the seat of government had to be transferred to Bordeaux, and when Paris surrendered at the end of January, Gambetta, though resisting and protesting, was compelled to submit to the capitulation concluded with Prince Bismarck. He immediately resigned his office. Elected by nine departments to the National Assembly meeting at Bordeaux, he chose to sit for Strasburg, which by the terms of the treaty about to be submitted to the Assembly for ratification was to be ceded to Prussia, and when the treaty was adopted he resigned in protest and retired to Spain. It is difficult to determine whether patriotism or political calculation had more influence on his conduct. He returned to France in June, was elected by three departments in July, and commenced an agitation for the definitive establishment of the Republic. In 1871 he established a journal, *La République Française*, which soon became the most influential in France. His orations at public meetings were more effective than those delivered in the Assembly, especially that made at Bordeaux on his return, and that at Grenoble on 26th November 1872, in which he spoke of political power having passed to *les nouvelles couches sociales*. When Thiers fell from power in May 1873, and a Royalist was placed at the head of the Government in the person of Marshal MacMahon, Gambetta gave proof that the demagogue had ripened into the statesman. He unceasingly urged his friends to a moderate course, and by his tact and parliamentary dexterity, no less than by his eloquence, was mainly instrumental in the voting of the Constitution in February 1875. This policy he continued during the early days of the now consolidated Republic, and gave it the appropriate name of "Opportunism." It was not until 4th May 1877, when the peril from reactionary intrigues was notorious, and the clerical party had begun a campaign for the restoration of the temporal power of the Pope, that he delivered his famous speech denouncing "Clericalism" as "the enemy." On 16th May Marshal MacMahon, in order to support the clerical reactionaries, perpetrated his parliamentary *coup d'état*, and on 15th August Gambetta, in a speech at Lille, gave him the alternative *se soumettre ou se démettre*. This was during the great electoral contest, the result of which left MacMahon, equally unwilling to resign or to provoke civil war, no choice but to dismiss his advisers and form a moderate Republican ministry under the premiership of M. Dufaure. When the resignation of the Dufaure Cabinet brought about the abdication of Marshal MacMahon, Gambetta did not become a candidate for the Presidency, but allowed this to devolve upon M. Grévy; nor did he attempt to form a ministry, but accepted the office of President of the Chamber of Deputies (January 1879). This position, which he filled with much ability, did not prevent his occasionally descending from the presidential chair to make speeches, one of which, advocating an amnesty to the Communards, was especially memorable. He evidently thought that the time was not ripe for asserting his own claims to direct the policy of the Republic, and seemed inclined to observe a neutral attitude as far as possible; but events hurried him on, and early in 1881 he placed himself at the head of a movement for restoring *scrutin de liste*, or the system by which deputies are returned by the entire department which they represent, so that each elector votes for several representatives at once, in place of *scrutin d'arrondissement*, the system of small constituencies, giving one member to each district and one vote to each elector. A bill to re-establish *scrutin de liste* was passed by the Assembly on 19th May 1881, but rejected by the Senate on 19th June. The Ferry Cabinet then in office was unable to retain its ground, and Gambetta was unwillingly entrusted by M. Grévy with the formation of a ministry in November 1881 — known as *Le Grand Ministère*. He now experienced the Nemesis of his over-cautious system of abstinence from office for fear of compromising his popularity. Every one suspected him of aiming at a dictatorship; attacks, not the less formidable for their injustice, were directed against him from all sides, and his Cabinet fell ingloriously in February 1882, after an existence of only sixty-six days. Had he remained in office the face of the world might now have been different, for his declarations leave no doubt that he would have cultivated the British alliance and co-operated with Great Britain in Egypt. It is only surprising that, feeling as he did, he should not have protested against the desertion of Great Britain by the Freycinet administration. His fortunes were presenting a most interesting problem when, on 31st December 1882, at his house in Ville d'Avray, near Sèvres, he came to a violent end, by a shot from a pistol, in circumstances which have never been fully explained. France awoke to a sense of her obligation to him, and his public funeral on the 6th of January 1883 evoked one of the most overwhelming displays of national sentiment ever witnessed on a similar occasion.

Gambetta is the only politician produced by France between 1870 and 1900 who merits the reputation of greatness. He rendered France three inestimable services: by preserving her self-respect through the gallantry of the resistance he organized during the German war, by his tact in persuading extreme partisans to accept a Moderate Republic, and by his energy in overcoming the usurpation attempted by the advisers of Marshal MacMahon. Had he remained in power he might have rendered yet another by giving a sound direction to her foreign policy. His fall, which could have been but temporary, was not so much owing to popular ingratitude as to a serious fault of his own, his want of loyalty to his colleagues, whom he systematically used for his own purposes, until at length he found himself distrusted and isolated. His death, however, at the early age of forty-four, cut short a career which had given promise of greater things than have been accomplished by any of those who tried to maintain his traditions. In many respects he strikingly resembles Danton, but he was too humane and good-natured to have participated in a Reign of Terror. (R. G.)

Gambia, the most northerly of the British West African dependencies. The total area of the colony and Protectorate is 3550 square miles, but before the delimitation of the frontier in 1891, in accordance with the Anglo-French agreement of 1889, the outside districts which now form the Protectorate constituted a wholly undefined sphere of influence, and the settlements (including St Mary's Island, British Combo, the Ceded Mile, McCarthy's Island, and other islets) had an area of about 69 square miles. The general effect of the delimitation was to recognize as British a narrow strip of land extending for about 6 miles on each side of the river to a distance of about 250 miles from the sea. The land outside these limits and beyond the Barraconda rapid is recognized as French. The breadth of the colony near the coast is somewhat greater. Gambia, as its name implies, derives its character and value from the river, which is navigable throughout the colony, while large ocean-going ships can always cross the bar at its mouth and enter the port of Bathurst (population about 6000). Steamers already run to McCarthy's Island, and the line will be continued to Yarbutenda (243 miles from Bathurst). The banks of the river, for about 100 miles from its mouth, are fringed with mangrove swamps, behind which are plains densely covered with grass and interspersed with clumps of timber. Beyond this point the banks become steep and thickly wooded, the valley of the river from McCarthy's Island to Barraconda being enclosed by low rocky hills of volcanic character, surrounded by park-like scenery. Since 1888 the Gambia has been a separate Crown colony, with a governor, still termed administrator, and an executive and legislative council. The executive council includes one nominated member, and the legislative two unofficial members. The Protectorate is divided into seventeen districts, each placed under a head chief, supervised by travelling commissioners. The population of the settlements was returned in 1898 as 14,300, having remained nearly stationary since 1881. The population of the Protectorate has been estimated at about 200,000. The native tribes are almost exclusively negro: Mandingoes, Jolofs, Jolas, &c. The Europeans in the settlements number about sixty. Education is in a very backward



B. V. Darbishire & O. J. R. Howarth, *Engl. Miles.* 0 60 *Oxford, 1901.*

SKETCH MAP OF GAMBIA.

condition, in spite of mission schools supported by Government. Mahommedanism is reported to be increasing, "and with it temperance and decency." The climate of Bathurst is fairly healthy during the dry season. The temperature is subject to great variations, the thermometer sometimes varying from 68° to 98° on the same day. It is always warmer by 20° or more up the river than near the sea coast. The mean temperature at Bathurst at noon in the shade is from 72° to 82°. The average rainfall is about 50 inches, but, with the exception of a few showers in May and June, there is no rain excepting between July and October. The dry east wind, known as the "harmattan," blows from December to March. The agricultural resources of the colony remain undeveloped. Land can be hired for 2d. an acre per annum for twenty-one years, and there is stated to be an opening for capital in the cultivation of sisal hemp, &c. A botanical station was opened in 1894, but as yet has led to little results. Ground nuts (*Arachis hypogœa*) are the staple product, and account for more than four-fifths of the total exports. They go mainly to Marseilles, where the oil derived from them is sold as olive. In 1899 the exports amounted to 34,353 tons of the value of £210,005, as against about 20,000 tons of the value of about £127,000 in 1897. Next to ground nuts, but at a long interval, the most important product is india-rubber. Beeswax, palm kernels, and hides are also exported in small quantities. The principal imports are cotton goods, kola nuts (from Sierra Leone), tobacco, and spirits. The revenue for 1899 amounted to nearly £47,000. Over £36,000 was derived from custom duties, of which over £11,000 was from ground nuts. There is no public debt, and there was in 1899 an available surplus of more than £43,000. The cost of the Protectorate is covered by direct taxation. A hut tax has encountered no opposition from the natives.

See C. P. LUCAS. *Historical Geography of the British Colonies.* Vol. iii. *West Africa*, 2nd ed. 1900.—A. F. MOCKLER-FERRYMAN. *Imperial Africa.* Vol. i. *British West Africa.* 1898.—*Colonial Reports, Annual.*

(H. E. EG)

Game Laws.—There have not been any changes since 1879 in the laws affecting winged game, except the alteration of the close season for partridges in Ireland, which is now from 1st February to 31st August, and the passing of a temporary Act, still annually continued, for the protection of that occasional summer visitor, the sand-grouse. The Wild Birds' Protection Acts have not in any district been used to alter the close time for game birds. A measure of protection against the inconsiderate preservation of game has been given by a decision of the High Court, that persons who overstock with game lands over which they have sporting rights are liable for damage thereby caused to the crops of the occupiers.

In 1880 the Ground Game Act was passed, at the instance of Sir William Harcourt, "in the interests of good husbandry, and for the better security of capital and labour invested by occupiers of land in the cultivation of the soil." With these objects the Act gives to the occupier of the land (whether he be also owner or not, and whether his occupation be under lease or only under an agreement for a lease), as incident to and inseparable from his occupation, the right to kill and take hares and rabbits on the land. The right of the occupier is indefeasible, and he cannot divest himself of it by contract with his landlord, or even by letting his sporting rights over the land; but, where the terms of occupation do not otherwise provide, the landlord, as the lessee of the sporting rights, or persons having right of chase or free warren, may take ground game *concurrently* with the occupier. The mode of exercise of the right is subject to certain limitations. Traps must not be set except in rabbit burrows, nor may poison be used. Firearms may not be used at night as defined in the Night Poaching Act, nor may they be used at any time except (1) by the occupier himself, and (2) with his authority by some *one* other person. But the occupier may authorize the taking or capture of hares and rabbits by other means by members of his own household resident on the land, persons in his ordinary service on the land, and persons *bonâ fide* employed for reward in taking and destroying ground game. The authority must be in writing, and must be produced on demand to persons who have a concurrent right to take the game, or an authorized agent. No game licence is necessary, and the occupier may sell the hares and rabbits taken.

There is no close time for hares or rabbits in England or Scotland, except Sundays and Christmas Day. In Ireland there is a close time from 20th April to 12th August. But hares and leverets killed in the United Kingdom may not be sold in March, April, May, June, or July; and occupiers of moorland and unenclosed land which is not arable (except detached portions not exceeding 25 acres) may exercise their right to take ground game only from 11th December to 31st March. The terms for which licences to kill game are issued were altered in 1883, and they are now of four kinds:—

Those taken out after 31st July:—			
To expire on the next 31st July . . .	£3	0	0
To expire on the next 31st October . .	2	0	0
Those taken out after 1st November:—			
To expire on the next 31st July . . .	2	0	0
Those taken out for any continuous period of fourteen days specified in the licence . .	1	0	0

The necessity of licences to deal in game was in 1893 extended to game killed abroad, but the penalties for selling in close time do not extend to such game. Since

1894 the authority of justices of the peace to grant game-dealers' licences has been transferred to borough or district councils in places outside London. The terms on which they may be granted have not been changed, but have been construed so as to preclude their grant to large stores in London which have also a licence for the sale of beer.

See OKE's *Game Laws*, 4th ed., by Willis Bund, 1897.—WARRY. *The Game Laws of England*, 1897.—MARCHANT and WATKINS. *The Wild Birds' Protection Acts*, 1897. (W. F. C.)

Gaming.—There was no new legislation between 1879 and 1902 for the punishment of gaming except the Betting and Loans (Infants) Act, 1892, passed at the instance of Lord Herschell, which makes persons guilty of misdemeanour who, with a view to profit, send to any one whom they know to be an infant a document inviting him to enter into a betting or wagering transaction. The Act was intended to protect lads at school and college from temptation by bookmakers. The powers of making bye-laws for the peace, order, and good government of their districts, possessed by municipal boroughs—and since 1888 by County Councils—and extended in 1899 to the new London boroughs, have in certain cases been exercised by making bye-laws forbidding any person to "frequent or use any street or other public place, on behalf either of himself or any other person, for the purpose of book-making, or betting, or wagering, or agreeing to bet or wager with any person, or paying, or receiving, or settling bets." This and similar bye-laws have been held valid. The police and the Anti-Gambling League have during the last few years shown great activity in the enforcement of the Acts against betting and gaming. Some results of this activity have been to add baccarat banque and *chemin de fer* to the list of unlawful games, and to establish that a man cannot be convicted of keeping a common gaming-house because on a single occasion he invites friends in to play an unlawful game; and also to apply to persons found in gaming-houses the provisions of the old Act of Hen. VIII. by binding them over not to frequent such places. A further result has been to produce a large crop of decisions on the Betting Act of 1853, showing a considerable divergence of judicial opinion. The House of Lords has held that the Tattersall's enclosure or betting ring on a race-course is not a "place" within the statute; and members of a *bonâ fide* club who bet with each other in the club are not subject to the penalties of the Act. But the word "place" has been held to include a public-house bar, an archway, a small plot of waste ground, and a book-maker's stand, and even a book-maker's big umbrella, and it is difficult to extract from the judges any clear indication of the nature of the "places" to which the Act applies. The Act is construed as applying only to ready-money betting when the stake is deposited with the book-maker, and only to places used for betting with persons physically resorting thereto; so that bets by letter, telegram, or telephone do not fall within its penalties. The arm of the law has been found long enough to punish as thieves "welshers," who receive and make off with deposits or bets which they never mean to pay if they lose.

The construction put by the judges on § 18 of the Gaming Act, 1845, which avoids contracts made by way of gaming and wagering, enabled turf commission agents to recover from their principals bets made and paid for them. But the Gaming Act, 1892, rendered null and void any promise, express or implied, to pay any person any sum of money paid by him under, or in respect of, any contract or agreement rendered null and void by the Gaming Act, 1845, or to pay any sum of money by way of commission, fee, reward, or otherwise in respect of any such contract or agreement, or of any services in relation thereto or in connexion therewith. By the combined effect of these two enactments, the recovery by the winner of bets or of stakes on games is absolutely barred; but persons who have deposited money to abide the event of a wager are not debarred from crying off and recovering their stake before the event is decided, or even after the decision of the event and before the stake is paid over to the winner;[1] and a man who pays a bet for a friend or customer has now no legal means of recovering the money, unless indeed some actual deceit was used to induce him to pay in ignorance that it was a bet. But a person who has received a bet on account of another can still, it would seem, be compelled to pay it over, and the business of a betting man is treated as so far lawful that income-tax is charged on its profits, and actions between parties in such a business for the taking of partnership accounts have been seriously entertained by Chancery judges.

The effect of these enactments on speculative dealings in shares or other commodities calls for special consideration. It seems to be correct to define a wagering contract as one in which two persons, having opposite opinions touching the issue of an event (past or future), of which they are uncertain, mutually agree that on the determination of the event one shall win, and the other shall pay over a sum of money, or other stake, neither party having any other interest in the event than the sum or stake to be won or lost. This definition does not strike at contracts in "futures," under which the contractors are bound to give or take delivery at a date fixed of commodities not in existence at a date of the contract. Nor are such contracts rendered void because they are entered into for purposes of speculation; in fact, their legality is expressly recognized by the Sale of Goods Act of 1893. And contracts to buy or sell stocks and shares are not void because entered into by way of speculation and not for purposes of investment. But a transaction in any commodity, though in form commercial, falls within the Gaming Acts if in substance the transaction is a mere wager on the price of the commodity at a date fixed by the contract. It does not matter whether the dealing is in stocks or in cotton, nor whether it is entered into on the Stock Exchange, or on any produce exchange, or elsewhere; nor is it conclusive in favour of the validity of the bargain that it purports to bind the parties to take or deliver the article dealt in. The courts are entitled to examine into the true nature of the transaction; and where the substantial intention of the parties is merely to gamble in differences, the fact that it is carried out by a series of contracts, regular and valid in form, will not be sufficient to exclude the application of the Gaming Acts.

In very many cases transactions with "outside stock-brokers" or "bucket shops" have been held to be mere wagers, although the contracts purported to give options to demand delivery or acceptance of the stocks dealt with; and the cover deposited by the "client" has been treated as a mere security for performance of the bargain, and recoverable if sued for in time, *i.e.*, before it is used for the purpose for which it is deposited. There was not up to 1902 any authoritative decision as to the application of the Gaming Act 1892 to transactions on the London Stock Exchange through a stockbroker who is a member of "the House"; but the same principle appears to be applicable where the facts of the particular deal clearly indicate that the intention was to make a mere time bargain, or to pay or receive differences only. In the event of the bankruptcy of a person involved in speculations, the bankruptcy officials exclude from proof against the estate all claims founded on any dealing in the nature of a wager; and on the same principle the bankrupt's trustee cannot recover sums won by the bankrupt by gaming transactions.

In the *United States*, many of the states make gaming

[1] So held, *Burge* v. *Ashley*, 1900; 1 Q.B. 744, May 1900.

a penal offence when the bet is upon an election, or a horse-race, or a game of hazard. Betting contracts and securities given upon a bet are often made void, and this may destroy a gaming note in the hands of an innocent purchaser for value. The subject lies outside of the province of the Federal Government.

AUTHORITIES.—COLDRIDGE and HAWKSFORD. *The Law of Gambling*, 1895.—STUTFIELD. *Betting*, 3rd ed. 1892.—BRODHURST. *The Stock Exchange*, 1897. (W. F. C.)

Gandia, a Mediterranean port of Spain, in the province of Valencia. It is a station on the Madrid-Alicante railway. There are some modern public buildings — schools, a theatre, and several parish churches—besides the palace of the dukes of Osuna and a Jesuit convent. The principal local industries are manufactures of leather, silks, velvet, and ribbons. In 1898, 348 vessels of 142,175 tons entered. The value of the imports, chiefly coal, guano, timber, and flour, was £147,464; of the exports, mainly oranges, tomatoes, wine, raisins, onions, and cloth, £346,471. The greater part of the exports, except cloth and tomatoes, went to England. Population about 10,000.

Gando. See NIGERIA.

Ganjam, a district of British India, in the extreme north-east of the Madras Presidency. It has an area of 6037 square miles. The population in 1891 was 1,896,803, being 226 persons per square mile. In the hill tracts alone the density is only 88 per square mile; for the rest of the district it rises to 325. In 1901 the population was 2,011,488, showing an increase of 6 per cent. The total amount of land revenue and rates is returned as Rs. 18,45,758, the incidence of assessment per acre being Rs. 2–2–2 in *ryotwari* and R. 0–3–8 in *zamindari* lands; the number of police is 1134. In 1897–98, out of a total cultivated area of 479,108 acres 239,443 were irrigated (115,757 from government canals). There are two large systems of government irrigation in the district: (1) the Rushikulya project, upon which Rs. 46,44,423 has been spent, and which showed a deficit in 1897–98 of Rs. 1,42,119; and (2) the Ganjam minor rivers system, on which Rs. 44,846 has been spent, and which shows a profit of Rs. 6,513, or 15 per cent. The principal crops are rice, other food grains, pulse, oil seeds, and a little sugar-cane and cotton. Salt is evaporated, as a government monopoly, along the coast. Sugar is refined, according to German methods, at Aska, where rum also is produced. A considerable trade is conducted at the ports of Gopalpur and Calingapatam, which are only open roadsteads. In 1897–98 the total sea-borne trade was valued at Rs. 30,55,430, of which more than half was coasting trade. The district is traversed throughout by the East Coast railway, which was opened from Madras to Calcutta in 1900. There are colleges at Berhampur and Parlakimedi. In 1896–97 the number of schools was 1763, attended by 39,389 pupils. There are eight printing-presses and several libraries, reading-rooms, and literary institutes. The registered death-rate in 1897 was 50·1 per thousand.

Gap, Canal of, or CANAL DU DRAC, a very important French irrigation channel derived from the Drac in the upper Champsaur Valley, at an altitude of 3838 feet. It is thence carried partly by aqueducts to the Puy de Manse, through which a tunnel 3916 yards in length leads it from the basin of the Isère to that of the Durance, its course of 10 miles involving the construction of ninety-eight artificial works. Here, at the water-tower, in the valley of the Luye, at a point only about 96 feet lower than its origin, it divides into two branches, the Charance and the Rochette. The former, taking nearly four-fifths of the total volume of water, or 685 gallons per second, goes west, south-west, and south for a length of 16 miles, and the latter, taking little more than one-fifth of the total, or 195 gallons per second, goes east, south-west, south, and west for about 17 miles. Both branches then give origin to secondary canals, and these again to smaller ones, making a total length of about 445 miles. The area affected by this system of canals is 18,600 acres, of which 16,500 acres are capable of irrigation, but of this only about one-fourth is actually irrigated. Full utilization of the work has been hindered by want of capital and labour; nevertheless, the extent to which it has been developed has resulted in great improvements in the district, and extension of the cultivable area. The work was commenced in 1864; in 1880 irrigation began to be applied, and in 1888 the work was completed.

Gapan, a town in the southern part of the province of Nueva Ecija, Luzon, Philippine Islands. It lies at the centre of a rich tobacco-producing region, and the forests in its vicinity contain the finest of hardwoods. Its climate is comparatively cool and healthful. The principal languages spoken are Tagalog and Ilocano. Population, 20,000.

Gard, a department in the south of France, bordering on the Mediterranean, and watered by the Rhône, the Gard, and the Hérault.

Area, 2270 square miles. From 417,099 in 1886 the population increased to 418,470 in 1901. Births in 1899, 8813, of which 268 illegitimate; deaths, 9315; marriages, 3164. There were in 1896 1020 schools, with 55,000 pupils. Three per cent. of the population is illiterate. Out of 1,037,879 acres composing the area of the department under cultivation in 1896, 494,229 acres were plough-land and 130,970 acres in vineyards. The cereals yielded in 1899 a value of less than £500,000. The production of the vines, on the other hand, exceeded the value of £2,532,000. Gard takes the first rank among the departments of France for the production of the mulberry, which in 1899 yielded a value of £132,000, a figure, however, slightly exceeded by the produce of Ardèche in that year, and of silk-worm cocoons, which amounted in 1898 to 35,826 cwts., a figure slightly in excess of the production of Ardèche. The live stock in 1899 numbered 20,670 horses, 14,480 asses, 8290 cattle, 404,500 sheep, 43,970 pigs, and 27,850 goats. The mining industry produced in 1898 1,974,000 metric tons of coal and lignite, of the value of £1,036,000, and 113,000 tons of iron, lead, and manganese, valued at £192,000. The salt-pans yielded in 1898 81,000 metric tons of salt, of the value of £56,000. Metallurgy is in a very advanced state in the arrondissement of Alais, its total production in 1898 amounting to 58,000 metric tons of cast-iron, 5000 tons of iron, and 40,000 tons of steel. The other industries, textile and paper manufactures, are less developed. Nîmes, the capital, has a population of 80,355 (1901).

Garda, a lake of North Italy, partly in Lombardy, partly in Venetia, partly in Tirol. According to Martinelli, the lake has an area of 143 square miles, a depth of 1135 feet, and it lies at an altitude of 213 feet above sea-level. The mean surface temperature is 66° Fahr. Between 60 and 100 feet in depth the temperature decreases rapidly from 64° to 55°, and from the latter level down to the bottom decreases gradually to 45·9°. There are meteorological observatories at Riva, Salò, and Desenzano. The west shore from Gargnano to Salò is known as the Riviera Benacense, and is reputed to be the warmest district of North Italy.

Gardiner, a city of Kennebec county, Maine, U.S.A., on the western bank of the Kennebec river, 6 miles below Augusta, on the Maine Central Railroad. The city rises somewhat steeply from the river, is laid out with much regularity, with the business streets paved. It has excellent water power in the Cobosseecontee river, which flows through it to the Kennebec, and this has given rise to large and varied manufactures, including several lumber mills. Gardiner has also a brisk business in ice, which is cut mainly from the Kennebec, and shipped to Boston, New York, and southern cities. Population

(1880), 4439; (1890), 5491; (1900), 5501, of whom 537 were foreign-born.

Gardiner, Samuel Rawson (1829–1902), English historian, son of Rawson Boddam Gardiner, was born near Alresford, Hants, 4th March 1829. He was educated at Winchester and Christ Church, Oxford, where he obtained a first class in *literæ humaniores*. He was subsequently elected to fellowships at All Souls (1884) and Merton (1892). For some years he was professor of modern history at King's College, London, and devoted his life to historical work. He is the historian of the Puritan revolution, and has written its history in a series of volumes, originally published under different titles, beginning with the accession of James I.; the seventeenth, the third volume of the *History of the Commonwealth and Protectorate*, appeared in 1901, and two more were meant to complete the whole work, ending with the Restoration. The series is *History of England from the Accession of James I. to the Outbreak of the Civil War, 1603–1642*, 10 vols.; *History of the Great Civil War, 1642–1649*, 4 vols.; and *History of the Commonwealth and Protectorate, 1649–1660*. His treatment is exhaustive and philosophical, taking in, along with political and constitutional history, the changes in religion, thought, and sentiment during his period, their causes and their tendencies. Of the original authorities on which his work is founded many of great value exist only in manuscript, and his researches in public and private collections of manuscripts at home, and in the archives of Simancas, Venice, Rome, Brussels, and Paris, were indefatigable and fruitful. His accuracy is universally acknowledged. He was perhaps drawn to the Puritan period by the fact of his descent from Cromwell and Ireton, but he has certainly written of it with no other purpose than to set forth the truth. In his judgments of men and their actions he is unbiassed, and his appreciations of character exhibit a remarkable fineness of perception and a broad sympathy. Among many proofs of these qualities it will be enough to refer to what he says of the characters of James I., Bacon, Laud, Strafford, and Cromwell. On constitutional matters he writes with an insight to be attained only by the study of political philosophy, discussing in a masterly fashion the dreams of idealists and the schemes of government proposed by statesmen. Throughout his work he gives a prominent place to everything which illustrates human progress in moral and religious as well as political conceptions, and specially to the rise and development of the idea of religious toleration, finding his authorities not only in the words and actions of men of mark, but in the writings of more or less obscure pamphleteers, whose essays indicate currents in the tide of public opinion. His record of the relations between England and other States proves his thorough knowledge of contemporary European history, and is rendered specially valuable by his researches among manuscript sources which have enabled him to expound for the first time some intricate pieces of diplomacy.

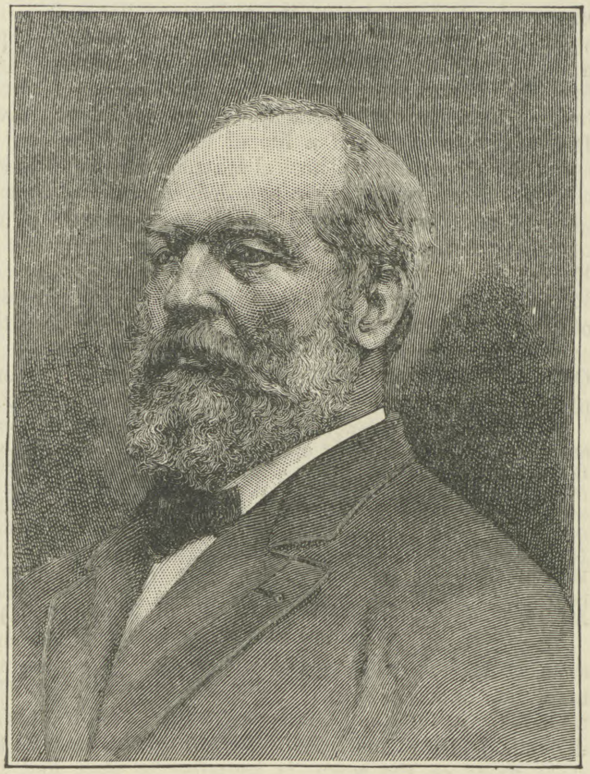
Gardiner's work is long and minute; the fifty-seven years which it covers are a period of exceptional importance in many directions, and the actions and characters of the principal persons in it demand careful analysis. He is perhaps apt to attach an exaggerated importance to some of the authorities which he was the first to bring to light, to see a general tendency in what may only be the expression of an individual eccentricity, to rely too much on ambassadors' reports which may have been written for some special end, to enter too fully into the details of diplomatic correspondence. In any case the length of his work is not the result of verbiage or repetitions. His style is clear, absolutely unadorned, and somewhat lacking in force; he appeals constantly to the intellect rather than to the emotions, and is seldom picturesque, though in describing a few famous scenes, such as the execution of Charles I., he writes with pathos and dignity. The minuteness of his narrative detracts from its interest; though his arrangement is generally good, here and there the reader finds the thread of a subject broken by the intrusion of incidents not immediately connected with it, and does not pick it up again without an effort. And Gardiner has the defects of his supreme qualities, of his fairness and critical ability as a judge of character; his work lacks enthusiasm, and leaves the reader cold and unmoved. Yet, apart from its sterling excellence, it is not without beauties, for it is marked by loftiness of thought, a love of purity and truth, and refinement in taste and feeling. He wrote other books, mostly on the same period, but his great history is that by which his name will live. It is a worthy result of a life of unremitting labour, a splendid monument of historical scholarship. His position as a historian was formally acknowledged: in 1862 he was given a civil list pension of £150 per annum, "in recognition of his valuable contributions to the history of England"; he was honorary D.C.L. of Oxford, LL.D. of Edinburgh, and Ph.D. of Göttingen, and honorary student of Christ Church, Oxford; and in 1894 he declined the appointment of regius professor of modern history at Oxford, lest its duties should interfere with the accomplishment of his history. He died 24th February 1902.

Among the more noteworthy of Mr Gardiner's separate works are: *Prince Charles and the Spanish Marriage*, 2 vols., London, 1869; *Constitutional Documents of the Puritan Revolution, 1625–1660*, 1st ed., Oxford, 1889, 2nd ed., Oxford, 1899; *Oliver Cromwell*, London, 1901; *What Gunpowder Plot Was*, London, 1897; *Outline of English History*, 1st ed., London, 1887, 2nd ed., London, 1896; and *Student's History of England*, 2 vols., 1st ed., London, 1890–91, 2nd ed., London, 1891–92. He edited collections of papers for the Camden Society, and also the *English Historical Review*. (W. Hu.)

Gardner, a town of Worcester county, Massachusetts, U.S.A., at an altitude of 1034 feet. It is on the main line and a branch of the Fitchburg Railroad. The town has an area of 23 square miles of hill country, diversified with ponds. The principal village, bearing the same name as the town, is irregular in plan, and has extensive manufactures, largely of chairs, for which it is widely known. Population of the town (1880), 4988; (1890), 8424; (1900), 10,813, of whom 3449 were foreign-born and 53 coloured.

Garfield, James Abram (1831–1881), twentieth President of the United States, was born 19th November 1831, in a log cabin in the little frontier town of Orange, Cuyahoga county, in Ohio. His early years were spent in the performance of such labour as fell to the lot of every farmer's son in the new states, and in the acquisition of such education as could be had in the district schools held for a few weeks each winter. But life on a farm was not to his liking, and at sixteen he left home and set off to make a living in some other way. A book of stories of adventure on the sea, which he read over and over again when a boy, had filled him with a longing for a seafaring life. He decided, therefore, to become a sailor, and tramping across the country to Cleveland, he sought employment from the captain of a lake schooner. But the captain drove him from the deck, and, wandering on in search of work, he fell in with a canal boatman who engaged him. During some months young Garfield served as bowsman, deck-hand, and driver of a canal boat. An attack of the ague sent him home, and on recovery, having resolved to attend a high school and fit himself to become a teacher, he passed the next four years in a hard struggle with poverty and in an earnest effort to secure an education. He worked as a teacher, a carpenter, and a farmer; studied Greek and Latin, and finally entered Williams College. On graduation, in 1856, Garfield became professor of ancient languages and literature in Hiram College, Ohio, and had risen to the presidency of the institution when the Civil War opened and he joined the army.

Meanwhile his entrance into political life had been made. In the early days of the Republican party, when the shameful scenes of the Kansas struggle were exciting the whole country, and during the campaigns of 1857 and 1858, he became known as an effective speaker and ardent



James Abram Garfield.

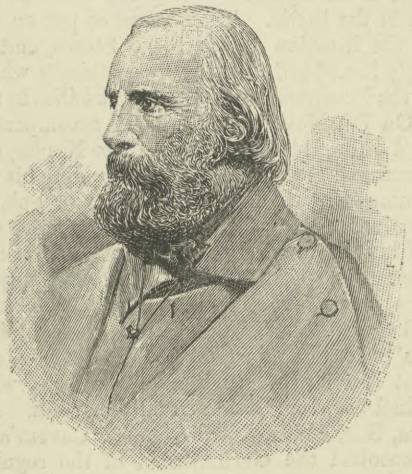
anti-slavery man. His reward for these services was election to the Ohio Senate as the member from Portage and Summit counties. When the cotton states seceded, Garfield appeared as a warm supporter of vigorous measures. He was one of the six Ohio senators who voted against the proposed amendment to the Federal Constitution forbidding Congress ever again to legislate on the subject of slavery in the States; he upheld the right of the Government to coerce seceded states; defended the "Million War Bill"; and when the call came for 75,000 troops he moved that Ohio furnish 20,000 soldiers and three million of dollars as her share. He at once offered his services to the governor, and became lieutenant-colonel and then colonel of the 42nd Ohio Volunteers. He served in Kentucky; was with Grant at Pittsburg Landing; was under Rosecrans in the Army of the Cumberland, and was his chief of staff; fought at Chickamauga, and was made a major-general of volunteers for gallantry in that great fight. In 1862 he was elected a member of Congress from the Ashtabula district of Ohio, and took his seat in the House of Representatives in December 1863. In Congress he joined the Radical wing of the Republican party, advocated the confiscation of rebel property, approved and defended the Wade-Davis manifesto denouncing the tameness of Lincoln, and was soon recognized as a hard worker and ready speaker. Capacity for work brought him places on important committees, and his ability as a speaker enabled him to achieve distinction on the floor of the House and to rise to leadership. Between 1863 and 1873 Garfield delivered speeches of importance on "The Constitutional Amendment to Abolish Slavery," "The Freedman's Bureau," "The Reconstruction of Rebel States," "The Public Debt and Specie Payment," "Reconstruction," "The Currency," "Taxation of United States Bonds," "Enforcing the 14th Amendment," "National Aid to Education," and "The Right to Originate Revenue Bills." The year 1874 was one of disaster to the Republican party. The greenback issue, the troubles growing out of reconstruction in the South, the Credit Mobilier and the "Salary Grab," disgusted thousands of independent voters and sent a wave of Democracy over the country. A Republican Convention in his district demanded his resignation and denounced his support of the hated measures, and re-election seemed impossible. But he defended himself in two pamphlets, "Increase of Salaries" and "Review of the Transactions of the Credit Mobilier Company," made a village-to-village canvass, and was victorious. In 1876 Garfield for the eighth time was again chosen to represent his district; and when, in 1877, James G. Blaine was made a senator from Maine, the leadership of the House of Representatives passed to Garfield, and he became the Republican candidate for Speaker. But the Democrats had a majority in the House, and he was defeated. Mr Hayes, the new President, having chosen John Sherman to be his Secretary of the Treasury, an effort was now made to send Garfield to the United States Senate in Sherman's place. But the President needed his services in the House, and he was not elected to the Senate until 1880.

The time had now come (1880) when the Republican party must nominate a candidate for the Presidency. General Grant had served two terms (1869–77), and by the unwritten law of custom ought not to be given another. But the "bosses" of the Republican party in three great states—New York, Pennsylvania, and Illinois—were determined that Grant should be renominated. These men and their followers were known as the "Stalwarts." Opposed to them were two other factions, one supporting Mr James G. Blaine of Maine, and the other Mr John Sherman of Ohio. When the convention met and the balloting began, the contest along these factional lines started in serious earnest. For eight-and-twenty ballots no change of any consequence was noticeable. Though votes were often cast for ten names, there were but two real candidates before the convention, General Grant and Mr Blaine. That the partisans of neither would yield was certain. That the choice therefore rested with the supporters of the minor candidates was manifest, and with the cry, "Anything to beat Grant!" an effort was made to find some man on whom the opposition could unite. Such a man was Garfield. His long term of service in the House, his leadership of his party on its floor, his candidacy for the Speakership, and his recent election to the United States Senate, marked him out as the available man. Between the casting of the first and the thirty-third ballot Garfield had sometimes been given two and at others no votes. On the thirty-fourth he received seventeen, on the next fifty, and on the next almost the entire vote hitherto cast for Blaine and Sherman, and was declared nominated. In November Garfield was duly elected, and he was inaugurated 4th March 1881; but on 2nd July, while on his way to attend the commencement exercises at Williams College, the new President was shot by a crazy office-seeker named Guiteau, and, after a lingering sickness, died from the effects of his wound on 19th September 1881. (J. B. McM.)

Garhwal, (1) a district of British India, in the Kumaon division of the North-West Provinces, and (2) an adjoining native state. Both lie among the Himalayas, containing the headwaters of the Ganges. The district of Garhwal is exceedingly mountainous. At least two peaks rise above 25,000 feet. Its area is 5629 square miles. In 1881 it had a population of 345,629, and in 1891 of 407,818, giving an average density of 72 persons per square mile. In 1901 the population was 429,892, showing an increase of 5 per cent. The land revenue and rates were ₨.1,77,723, the incidence of assessment being just over 8 annas per acre; the cultivated area in 1896–97 was 262,484 acres, of which 355 were under tea; the number of police was 130; the number of vernacular schools in 1896–97 was 93, with 3937 pupils; the registered death-rate in 1897 was 23·67 per thousand. It includes Deoprayag, one of the holiest places of Hindu pilgrimage. The administrative headquarters are at Pauri, but Srinagar is the largest place; neither of these is a municipality. The STATE OF GARHWAL is also known as Tehri, after its capital. Its area is 4164 square miles. In 1891 it had a population of 241,242, being 58 persons per square mile. In 1901 the population was 267,608, showing an increase of 11 per cent. The revenue in 1897–98 amounted to ₨.3,21,287, and the expenditure to ₨.2,87,328. There is a reserve of more than ₨.8,00,000, No tribute is payable.

Garibaldi, Giuseppe (1807–1882), Italian patriot, was born at Nice on 4th July 1807. As a youth he fled from home to escape a clerical education, but afterwards joined his father in the coasting trade. After joining the *Giovine Italia* he entered the Sardinian navy, and, with a number of companions on board the frigate *Euridice*, plotted to seize the vessel and occupy the arsenal of Genoa at the moment when Mazzini's Savoy expedition should enter Piedmont. The plot being discovered, Garibaldi fled, but was condemned to death by default on 3rd June 1834. Escaping to South America in 1836, he was given letters of marque by the Republic of Rio Grande do Sul, which had revolted against Brazil. After a series of victorious engagements he was taken prisoner and subjected to severe torture, which dislocated his limbs. Regaining liberty, he renewed the war against Brazil, and took Porto Allegro. During the campaign he met his wife, Anita, who became his inseparable companion and mother of three children, Anita, Ricciotti, and Menotti. Passing into the service of Montevideo, he was sent to Corrientes with a small flotilla to support the insurrection, but was overtaken by Admiral Brown, against whose fleet he fought for three days. When his ammunition was exhausted he burned his ships and escaped. Returning to Montevideo, he formed the Italian Legion, with which he won the battles of Cerro and Sant' Antonio in the spring of 1846, and assured the freedom of Montevideo. Refusing all honours and recompense, he prepared to return to Italy upon receiving news of the incipient revolutionary movement. In October 1847 he wrote to Pius IX. offering his services to the Church, whose cause he for a moment believed to be that of national liberty.

Landing at Nice on 24th June 1848, he placed his sword at the disposal of Charles Albert, and, after various difficulties with the Piedmontese War Office, formed a volunteer army 3000 strong, but shortly after taking the field was obliged, by the defeat of Custozza, to flee to Switzerland. Proceeding thence to Rome, he was entrusted by the Roman Republic with the defence of San Pancrazio against the French, where he gained the victory of 30th April 1849, remaining all day in the saddle, although wounded in the side at the beginning of the fight. From 3rd May until 30th May he was continuously engaged against the Bourbon troops at Palestrina, Velletri, and elsewhere, dispersing an army of 20,000 men with 3000 volunteers. After the fall of Rome he started for Venice across the swamps of the Romagna, hotly pursued by the Austrians. Near Ravenna he lost his wife, Anita, who died of fever. Venice having fallen, Garibaldi went to Genoa, where he was arrested and expelled. Emigrating to New York, he, in order to earn a living, became first a chandler, and afterwards a trading skipper, returning to Italy in 1854 with a small fortune, with which he purchased the island of Caprera. On the outbreak of war in 1859 he was placed



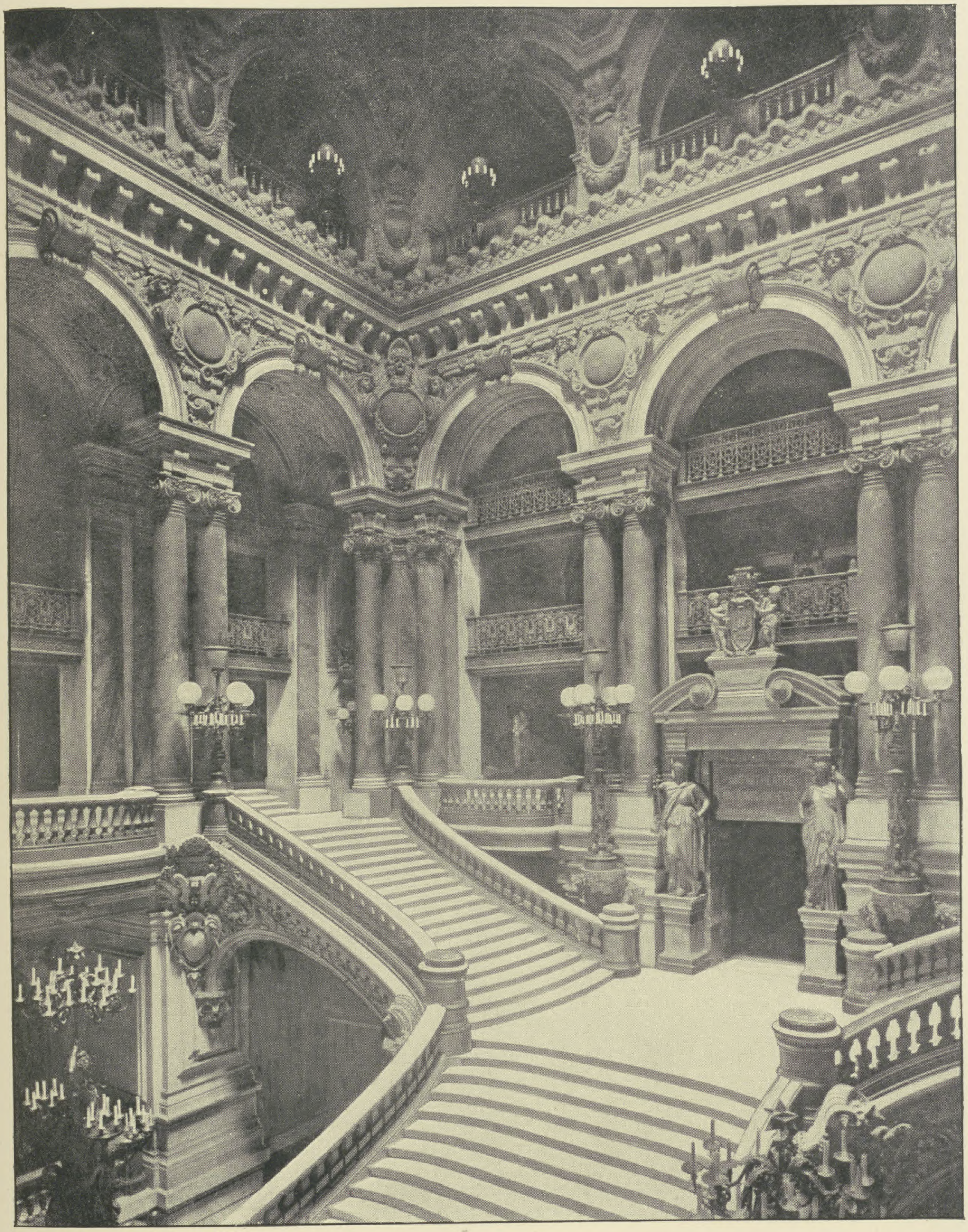
GIUSEPPE GARIBALDI.
(From a photograph by Elliott and Fry, London.)

in command of the Alpine infantry, defeating the Austrians at Casale on 8th May, crossing the Ticino on 23rd May, and, after a series of victorious fights, liberating Alpine territory up to Tirol. When about to cross the Austrian frontier he was stopped by the armistice of Villafranca. Returning then to Como to wed the Countess Raimondi, by whom he had been aided during the campaign, he was apprised, immediately after the wedding, of certain circumstances which caused him at once to abandon that lady and to start for Central Italy. Forbidden to invade the Romagna, he returned indignantly to Caprera, where with Crispi and Bertani he planned the invasion of Sicily. Assured by Sir James Hudson of the sympathy of England, he began active preparations for the expedition to Marsala. At the last moment he hesitated, but Crispi succeeded in persuading him to sail from Genoa on 5th May 1860 with two vessels carrying a volunteer corps of 1070 strong. Calling at Talamone to embark arms and money, he reached Marsala on 11th May, and landed under the protection of the British vessels *Intrepid* and *Argus*. On 12th May the dictatorship of Garibaldi was proclaimed at Salemi, on 15th May the Neapolitan troops were routed at Calatafimi, on 25th May Palermo was taken, and on the 6th of June 20,000 Neapolitan regulars, supported by nine frigates and protected by two forts, were compelled to capitulate. Once established at Palermo, Garibaldi organized an army to liberate Naples and march upon Rome, a plan opposed by the emissaries of Cavour, who desired the immediate annexation of Sicily to the Italian kingdom. Expelling Lafarina and driving out Depretis, who represented Cavour, Garibaldi routed the Neapolitans at Milazzo on 20th July. Messina fell on 20th July, but Garibaldi, instead of crossing to Calabria, secretly departed for Aranci Bay in Sardinia, where Bertani was fitting out an expedition against the Papal States. Cavour, however, obliged the expedition to sail for Palermo. Returning to Messina, Garibaldi found a letter from Victor Emmanuel II. dissuading him from invading the kingdom of Naples. Garibaldi replied asking "permission to disobey." Next day he crossed the Strait, won the battle of Reggio on 21st August, accepted the capitulation of 9000 Neapolitan troops at San Giovanni and of 11,000 more at Soveria. The march upon Naples became a triumphal progress, which the wiles of Francesco II. were powerless to arrest. On 7th September Garibaldi entered Naples, while Francesco fled to Gaeta. On 1st October he routed the remnant of the Bourbon army 40,000 strong on the Volturno. Meanwhile the Italian troops had occupied the Marches, Umbria, and the Abruzzi, a battalion of Bersaglieri reaching the Volturno in time to take part in the battle. Their presence put an end to the plan for the invasion of the Papal States, and Garibaldi unwillingly issued a decree for the *plébiscite* which was to sanction the incorporation of the Two Sicilies in the Italian realm. On 7th November Garibaldi accompanied Victor Emmanuel during his solemn entry into Naples, and on the morrow returned to Caprera, after disbanding his volunteers and recommending their enrolment in the regular army.

Indignation at the cession of Nice to France and at the neglect of his followers by the Italian Government induced him to return to political life. Elected deputy in 1861, his anger against Cavour found violent expression. Bixio attempted to reconcile them, but the publication by Cialdini of a letter against Garibaldi provoked a hostility which, but for the intervention of the king, would have led to a duel between Cialdini and Garibaldi. Returning to Caprera, Garibaldi awaited events. Cavour's successor, Ricasoli, enrolled the Garibaldians in the regular army; Rattazzi, who succeeded Ricasoli, urged Garibaldi to undertake an expedition in aid of the Hungarians, but Garibaldi, finding his followers ill-disposed towards the idea, decided to turn his arms against Rome. On 29th June 1862 he landed at Palermo and gathered an army under the banner "*Roma o morte.*" Rattazzi, frightened at the prospect of an attack upon Rome, proclaimed a state of siege in Sicily, sent the fleet to Messina, and instructed Cialdini to oppose Garibaldi. Circumventing the Italian troops, Garibaldi entered Catania, crossed to Melito with 3000 men on 25th August, but was taken prisoner and wounded by Cialdini's forces at Aspromonte on 27th August. Liberated by an amnesty, Garibaldi returned once more to Caprera amidst general sympathy.

In the spring of 1864 he went to London, where he was accorded an enthusiastic reception and given the freedom of the City. From England he returned again to Caprera. On the outbreak of war in 1866 he assumed command of a volunteer army and, after the defeat of the Italian troops at Custozza, took the offensive in order to cover Brescia. On 3rd July he defeated the Austrians at Monte Saello, on the 7th at Lodrone, on the 10th at Darso, on the 16th at Condino, on the 19th at Ampola, on the 21st at Bezzena, but, when on the point of invading Trent, he was ordered by Victor Emmanuel to retire. Replying simply, "I obey," he returned to Caprera to mature his designs against Rome, which had been evacuated by the French in pursuance of the Franco-Italian Convention of 15th September 1864. Gathering volunteers in the autumn of 1867, he prepared to enter Papal territory, but was arrested at Sinalunga by the Italian Government and conducted to Caprera. Eluding the surveillance of the Italian cruisers, he returned to Florence, and, with the complicity of the second Rattazzi cabinet, entered Roman territory at Passo Corese on 23rd October. Two days later he took Monterotondo, but on 2nd November his forces were dispersed at Mentana by French and Papal troops. Recrossing the Italian frontier, he was arrested at Figline and taken back to Caprera, where he eked out his slender resources by writing several romances. In 1870 he formed a fresh volunteer corps and went to the aid of France, defeating the German troops at Chatillon, Autun, and Dijon. Elected a member of the Versailles Assembly, he resigned his mandate in anger at French insults, and withdrew to Caprera until, in 1874, he was elected deputy for Rome. Popular enthusiasm induced the Minghetti cabinet to propose that a sum of £40,000 with an annual pension of £2000 be conferred upon him as a recompense for his services, but the proposal, though adopted by Parliament (27th May 1875), was indignantly refused by Garibaldi. Upon the advent of the Left to power, however, he accepted both gift and pension, and worked energetically upon the scheme for the Tiber embankment to prevent the flooding of Rome. At the same time he succeeded in obtaining the annulment of his marriage with the Countess Raimondi (with whom he had never lived) and contracted another marriage with the mother of his children, Clelia and Manlio. In 1880 he went to Milan for the inauguration of the Mentana monument, and in 1882 visited Naples and Palermo, but was prevented by illness from being present at the 600th anniversary of the Sicilian Vespers. A few months later, on 2nd June 1882, his death at Caprera plunged the whole of Italy into mourning. (H. W. S.)

Garnier, Jean Louis Charles (1825–1898), French architect, designer of the new Opera House in Paris, was born in that city on the 6th of November 1825. He was educated in a primary school, and it was intended that he should pursue his father's craft, that of a wheelwright. His mother, however, having heard that with a little previous study he might enter an architect's office and eventually become a *vérificateur* (measuring surveyor), and earn as much as six francs a day, and foreseeing that in consequence of his delicate health he would be unfit to work at the forge, sent him to the Petite École de Dessin, in the Rue de Médecine, the cradle of so many of the great artists of France, to learn drawing and mathematics. His progress was such as to justify his being sent first into an architect's office and then to the well-known atelier of Lebas, where he began his studies in preparation for the examination of the École des Beaux Arts, which he passed in 1842, at the age of seventeen. Shortly after his admission it became necessary that he should support himself, and accordingly he worked during the day in various architects' offices, among them in that of M. Viollet-le-Duc, and confined his studies for the École to the evening. In 1848 he carried off, at the early age of twenty-three, the Grand Prix de Rome, and, with his comrades in sculpture, engraving, and music, set off for the Villa de Medicis. His principal works were the measured drawings of the Forum of Trajan and the temple of Vesta in Rome, and the temple of Serapis at Pozzuoli. In the fifth year of his travelling studentship he went to Athens and measured the temple at Aegina, subsequently working out a complete restoration of it, with its polychromatic decoration, which was published as a monograph in 1877. The elaborate set of drawings which he was commissioned by the duc de Luynes to make of the tombs of the house of Anjou were not published, owing to the death of his patron; and since Garnier's death they have been given to the library of the École des Beaux Arts, along with other drawings he made in Italy. On his return to Paris in 1853 he was appointed surveyor to one or two Government buildings, with a very moderate salary, so that the commission given him by M. Baltard to make two water-colour drawings of the Hôtel de Ville, to be placed in the album presented to Queen Victoria in 1855, on the occasion of her visit to Paris, proved very acceptable. These two drawings are now in the library at Windsor. In 1860 came, at last,



Staircase in the Grand Opera House, Paris. Designed by J. L. C. Garnier.

Garnier's chance: a competition was announced for a design for a new Imperial Academy of Music, and out of 163 competitors Garnier was one of five selected for a second competition, in which, by unanimous vote, he carried off the first prize, and the execution of the design was placed in his hands. Begun in 1861, but delayed in its completion by the Franco-German war, it was not till 1875 that the structure was finished, at a cost of about 35,000,000 francs (£1,420,000). The history of the building is partly that of Paris, for during the war it was utilized as the municipal storehouse of provisions. The building externally is too well known to need any description; of the interior, the staircase and the magnificent hall are the finest portion, and alike in conception and realization have never been approached. Of Garnier's other works, the most remarkable are the Casino at Monte Carlo, the Bischoffsheim villa at Bordighera, the Hôtel du Cercle de la Librairie in Paris; and, among tombs, those of the musicians Bizet, Offenbach, Massé, and Duprato. In 1874 he was elected a member of the Institute of France, and after passing through the grades of chevalier, officer, and commander of the Legion of Honour, received in 1895 the rank of grand officer, a high distinction that had never before been granted to an architect. Charles Garnier's reputation was not confined to France; it was recognized by all the countries of Europe, and in England he received, in 1886, the royal gold medal of the Royal Institute of Architects, given by Queen Victoria. Besides his monograph on the temple of Aegina, he wrote several works, of which *Le Nouvel Opéra de Paris* is the most valuable. For the International Exhibition of 1889 he designed the buildings illustrating the "History of the House" in all periods, and a work on this subject was afterwards published by him in conjunction with M. Ammann. Not the least of his claims to the gratitude of his country were the services which he rendered on the various art juries appointed by the State, the Institute of France, and the École des Beaux Arts, services which in France are rendered in an honorary capacity. Garnier died on the 3rd of August 1898. (R. P. S.)

Garo Hills, The, a district of British India, in the Hills division of Assam. It takes its name from the Garos, a tribe of doubtful ethnical affinities and peculiar customs, by whom it is almost entirely inhabited. It consists of the last spurs of the Assam hills, which here run down almost to the bank of the Brahmaputra, where that river debouches upon the plain of Bengal and takes its great sweep to the south. The district was first constituted in 1866, and some trouble was experienced in enforcing authority over certain of the villages. The administrative headquarters are at Tura, of which the population in 1891 was 1045. The area of the district is 3270 square miles. In 1881 it had a population of 109,548, and in 1891 of 121,570, giving an average density of 37 persons per square mile, the highest in the hills of the province. There were 1184 Christians, of whom 21 were Europeans or Americans. In 1901 the population was 138,289, showing an increase of 14 per cent. The land revenue was Rs.63,214, the incidence of assessment being R.0–14–4 per acre; the number of police was 262; the number of boys at school in 1896–97 was 773, being 8·41 per cent. of the male population of school-going age; the number of girls at school was 178, or 1·96 per cent. The American missionaries maintain a small training school for teachers. The public buildings at Tura were entirely destroyed by the earthquake of 12th June 1897, and the roads in the district were greatly damaged by subsidence and fissures.

Garonne, a river of France, rising in the Maladetta group of the Pyrenees. The total course of the river in the valley of Aran, in Spanish territory, is about 30 miles, and the area drained 135,900 acres. It enters France at an altitude of 1800 feet, supplies motive power to several mills in the vicinity of Fos, and flows through the gorge of St Béat. The Neste, which joins it at the hill of Montrejeau, brings nearly as much water as the main stream. Between this point and Port Ste Marée the river describes a great curve of about 30 miles around the plateau of Lannemezan. At St Martory it gives off the irrigation canal of that name to water the plains of Toulouse, and at Portet, 5 miles above Toulouse, it is joined on the right bank, at an altitude of 430 feet, by the Ariège. Below Toulouse the Garonne flows through wide plains, accompanied by a lateral canal at a distance varying from half a mile to 3 miles. At Agen the lateral canal passes by a magnificent bridge aqueduct from the right to the left bank.

This canal extends from Toulouse to Castets, a length of 120 miles, or, including branches, of 132 miles. The mean depth in the level stretches is about 7 feet, and boats drawing 6 feet can navigate it except between Beaurégard and Laboulbène, where the depth is only $4\frac{3}{4}$ feet. At Toulouse, where the canal leaves the Garonne, it connects with the Canal du Midi. The Tarn and the Avance are each crossed by a bridge aqueduct, and the Bassanne by a siphon aqueduct. Below Castets a dyke, 6 miles long, protects it from river inundations. The canal was begun in 1838 and finished in 1856, at a cost of £2,500,000. It is crossed by 139 bridges. The number of boats plying on the canal in 1900 was 6184, mean tonnage 51, total tonnage 317,615, conveying chiefly agricultural produce and provisions, building materials, wood, and industrial products.

The Garonne has a breadth of 130 yards at Toulouse, 160 at Agen, 160 to about 200 to Podensac, where the river begins to widen out; and at Bordeaux, 15 miles from the head of the estuary, it is from 540 to 650 yards wide. The breadth continues to increase, and at its confluence with the Dordogne it has a width of nearly 2200 yards, interrupted, however, by the Isle of Cazeau. It is officially divided into six sections. The figures for traffic here given are those for 1900:—

1. Pont-du-Roi to Toulouse, 48 miles; mean depth, $2\frac{1}{2}$ feet; crossed by 5 bridges. Navigable only between Roquefort and Toulouse. Number of boats, 1117; total tonnage, 11,737.
2. Toulouse to mouth of Tarn, 50 miles; mean depth, $1\frac{1}{2}$ feet; crossed by 8 bridges. Number of boats, 27; total tonnage, 114.
3. Mouth of Tarn to Agen, 28 miles; mean depth, $1\frac{1}{2}$ feet; crossed by 11 bridges. Number of boats, 139; total tonnage, 12,238.
4. Agen to Castets, 66 miles; mean depth, $3\frac{1}{4}$ feet; crossed by 10 bridges. Number of boats, 2435; total tonnage, 71,367.
5. Castets to Bec d'Ambès, 48 miles; mean depth, 9·8 feet; crossed by 3 bridges. Number of boats, 30,841; total tonnage, 1,268,489.
6. Bec d'Ambès to ocean, 47 miles; mean depth, 21 feet. Number of boats, 16,159; total tonnage, 345,726. (E. J. H*.)

Garonne-Haute, a department in the south of France, watered by the Garonne, and separated from Spain by the Pyrenees.

Area, 2458 square miles. The population diminished from 481,169 in 1886 to 439,769 in 1901. Births in 1899, 7489, of which 675 were illegitimate; deaths, 10,023; marriages, 2977. There were in 1896 1122 primary schools, with 55,000 pupils, and 3 per cent. of the population was illiterate. Out of 1,423,378 acres under cultivation in 1896, 924,207 acres were plough-land and 118,614 acres vineyards. The wheat crop of 1899 yielded a value of £1,530,000; oats, £380,000; rye, £20,000; barley, £46,000; vines, £550,000; the natural pastures and grass lands, £1,032,000. The live stock in 1899 included 30,780 horses, 167,080 cattle, 234,710 sheep, and 100,260 pigs. There are marble quarries, and rock-salt was obtained in 1898 to the extent of 8000 metric tons. The industry in metals produced in 1898 only 2475 tons of iron. In 1901 Toulouse, the capital, had 147,696 inhabitants.

Garrucha, a Mediterranean seaport of Spain, in the province of Almeria. An old castle is now used as a carabineer barrack. The bay affords shelter even for large vessels, and is every year more frequented by foreign vessels, chiefly British, French, and Dutch, and by coasting vessels, many of which come in ballast and clear with valuable cargoes. In the neighbourhood the rearing of live stock is a thriving industry, and the inhabitants of rural districts around send large quantities of wheat, fruit, and vegetables to the port. In 1898 the value of the imports was £170,170; of the exports, £460,570. The imports were chiefly coal and coke from England, lead ore, bar iron, machinery, timber and deals, petroleum, rice, barley, and soap. The exports were iron ore (£95,056), silver, lead, copper mat, esparto, oranges and lemons, dried figs, marble, and lead ore. Almost all the lead and copper mat went to England, and also the esparto. In the coasting trade in 1898, 311 vessels entered and 309 cleared. In the foreign trade, 116 vessels of 125,079 tons entered, and 115 of 147,843 tons cleared. Population over 5000.

Garrús, a small province of Persia, situated between Khamseh and Azerbaïján in the north and Kurdistan and Hamadan in the south. Its population is estimated at 80,000, and its capital, Bíjár, has a population of 3000. The province is fief of the chief of the Garrús Kurds, and pays a yearly revenue of about £3000 and supplies a battalion of infantry (the 34th) to the army.

Garston, a seaport, railway station, and urban district in the Widnes division of Lancashire, England, 6 miles south of Liverpool, on the Mersey. The docks, belonging to the London and North-Western Railway Company, employ most of the working population. Population (1891), 13,444; (1901), 17,288.

GAS AND GAS LIGHTING.

THE last twenty-five years of the 19th century will always be looked back to as the most important epoch in the history of the great gas industry, this period having been marked not only by many improvements in the manufacture of illuminating gas, but by a complete revolution in the methods of enriching it and utilizing it for the production of light. In 1875 the London Argand, giving a duty of 3·2 candles illuminating power per cubic foot of ordinary 16-candle gas, was looked upon as the most perfect burner of the day, and little hope was entertained that any burner capable of universal adoption would surpass it in its power of developing light from the combustion of coal gas; but the beginning of the new century found the incandescent mantle and Bunsen burner yielding six times the light that was then produced by the consumption of an equal volume of gas. In this article the chief changes which have taken place in the manufacture of gas, its purification and enrichment, since the issue of the ninth edition of this work, will be dealt with, and then the even more important alterations in the methods used for its consumption will be fully discussed.

Gas Manufacture.

No very radical alterations have taken place in the methods employed in the destructive distillation by which the volatile constituents of the coal are driven off by heat as crude gas and tar vapour, while the residue remains behind as coke. The retorts are made of fireclay, and in all but small country works the old single-ended retort, which was about 9 feet in length, has given way to a more economical construction, known as doubles, double-ended, or through retorts, in which a retort 18 to 20 feet long is fitted with a mouthpiece and ascension pipe at each end. The number of "through" retorts in the retort bench varies from three to twelve, the common practice being to place two at the bottom, three in the middle tier, and two above, these being known as bottoms, middles, and tops. Considerable economy has been introduced in the heating of the retorts by the adoption of regenerative furnaces, the use of which on the Continent is universal, and is now fairly general in Great Britain. In this system of firing a mixture of carbon monoxide and nitrogen is produced by passing air through incandescent gas coke in a generator placed below the bench of retorts, and the heating value of the gases so produced is increased in most cases by the admixture of a small proportion of steam with the primary air supply, the steam being decomposed by contact with the red-hot coke in the generator into water gas, a mixture of carbon monoxide and hydrogen. (See Gaseous Fuel.) The gases so formed vary in proportion with the temperature of the generator and the amount of steam, but generally contain 32 to 38 per cent. of combustible gas, the remainder being the residual nitrogen of the air and carbon dioxide. These gases enter the combustion chamber around the retorts at a high temperature, and are there supplied with sufficient air to complete their combustion, this secondary air supply being heated by the hot products of combustion on their way to the exit flue. This method of firing results in a saving of about one-third the weight of coke used in the old form of furnace per ton of coal carbonized, and also enables higher temperatures to be obtained.

Retorts.

The importance of labour-saving appliances in gas works has been fully realized in recent years, and in the retort-house mechanical charging and drawing machines are now largely used, while by the use of sloping instead of horizontal retorts gravitation is employed to facilitate the same operations. In both arrangements the coal as it is taken from the stores is broken to the size of nuts in a crusher, and elevated to convenient hoppers above the benches. With the horizontal retorts a mechanical charging machine, worked by compressed air, delivers the coal into the retorts, and with the assistance of a drawing machine, using similar motive power, the work of feeding the retorts with raw material and withdrawing the residual coke is performed expeditiously, with considerable economy and less discomfort than was formerly the case. West's compressed-air drawing and charging machines are an example of this system; they are designed for working retorts in every tier, being provided with mechanism for elevating the charging and drawing frames to the various levels. For further economy retort benches of four and five tiers are sometimes constructed, and the general practice is to draw and charge all the retorts on one level at the same time, working from end to end of the retort house. In the gravitation method the retorts are inclined to the horizon at an angle to suit the slip of the class of coal used. This angle is between 28° and 34°. The coal, previously elevated to the hoppers, is dropped into feeding chambers so arranged that they can travel from end to end of the retort house and deposit the coal into the retorts. When the retort is to be charged an iron stop or barrier is placed in the lower mouthpiece and the door closed. The shoot is placed in the upper mouthpiece, and the stop or door which retains the coal in the chamber is released; the coal is then discharged into the retort, and, running down the incline, is arrested by the barrier, and banks up, forming a continuous backing to the coal following. By experience with the class of coal used, and the adjustment of the stops in the shoot, the charge can be run into the retort to form an even layer of any desired depth. For the withdrawal of the residual coke at the end of carbonization the lower mouthpiece door is opened, the barrier removed, the coke in the lower part of the retort is "tickled" or gently stirred with an iron rod to overcome a slight adhesion to the retort, and the entire mass readily discharges itself. Guides are placed in front of the retort to direct its course to coke hoppers or conveyers below, and to prevent scattering of the hot material. This system shows the greater economy in the cost of carbonizing the coal, but the large outlay and considerable wear and tear of the mechanical appliances involved have so far prevented a very general adoption of the process.

The increase in the temperature of distillation to which the coal is subjected increases considerably the volume of gas produced per ton of coal carbonized, and at the same time gives a decrease in the candle-power; but as the latter is not as great in proportion as the gain in volume, it is generally found that the candle-feet per ton of coal $\left(\frac{\text{vol. per ton} \times \text{illuminating value}}{5}\right)$ is higher than when lower temperatures were used, while the tar is also altered in character, becoming more viscid and rather less in volume as the temperature of distillation increases. In most works the yield of gas per ton of ordinary gas coal carbonized is from 10,000 to 11,000 cubic feet.

Little or no change has taken place in the treatment of the crude gas as it flows from the retort up the ascension pipe and through the dip pipe and hydraulic main to the condensers, exhauster scrubbers, and purifiers; but a clearer conception is being gained as to the actions taking place in the latter, and they are now generally so handled as to secure increased purity in the gas. In general practice slaked lime is employed for the removal of carbon dioxide and the greater quantity of sulphur compounds, while a catch-box or purifier of oxide of iron serves to remove the last traces of sulphuretted hydrogen. Not fewer than four lime purifiers are employed, and as the one which is first in the series becomes exhausted, *i.e.*, begins to show signs of allowing carbon dioxide to pass through it unabsorbed, it is filled with fresh slaked lime, and is made the last of the series, the one which was second becoming first; and this procedure goes on continuously. This operation is necessitated by the fact that carbon dioxide has the power of breaking up the sulphur compounds formed by the lime, so that until all carbon dioxide is absorbed with formation of calcium carbonate, the withdrawal of sulphuretted hydrogen cannot proceed, while since it is calcium sulphide formed by the absorption of sulphuretted hydrogen by the slaked lime that absorbs the vapour of carbon bisulphide, purification from the latter can only be accomplished after the necessary calcium sulphide has been formed. The foul gas leaving the scrubbers contains, as a general average, 30 grains of sulphuretted hydrogen, 40 grains of carbon bisulphide, and 200 grains of carbon dioxide per 100 cubic feet. On entering the first purifier, which contains calcium sulphocarbonate and other combinations of calcium and sulphur in smaller quantity, the sulphuretted hydrogen and bisulphide vapour have practically no action upon the material, but the carbon dioxide immediately attacks the calcium sulphocarbonate, forming calcium carbonate with the production of carbon bisulphide vapour, which is carried over with the gas into the second box. In the connexion between the first and second box the gas is found to contain 500 grains of sulphuretted hydrogen and 80 grains of carbon bisulphide per 100 cubic feet, but no trace of carbon dioxide. In the second box the formation of calcium sulphocarbonate takes place by the action of carbon bisulphide upon the calcium sulphide with the liberation of sulphuretted hydrogen, which is carried over to the third purifier. The gas in the connecting pipe between the second and third box will be found to contain 400 grains of sulphuretted hydrogen and 20 grains of carbon bisulphide. The contents of the third box, being mostly composed of slaked lime, by the action of sulphuretted hydrogen upon which calcium sulphide is very rapidly formed, will practically remove the remaining impurities, and the outlet gas will show 20 grains of sulphuretted hydrogen and 8 grains of carbon bisulphide per 100 cubic feet. The catch-box of oxide of iron will then remove all traces of sulphuretted hydrogen. It will be noticed that in the earlier stages the quantity of the sulphur impurities is actually increased between the purifiers; in fact, the greater amount of sulphiding procures the ready removal of the carbon bisulphide, but it is the carbon dioxide in the gas that is the disturbing element, inasmuch as it decomposes the combinations of sulphur and calcium. Consequently it is a paramount object in this system to prevent this latter impurity finding its way through the first box of the series. The finding of any traces of carbon dioxide in the gas between the first two boxes is generally the signal for a new clean purifier being put into action, and the first one shut off, emptied, and recharged with fresh lime. The impregnated material is sometimes sold for dressing certain soils. The action of oxide of iron in the catch-box depends on its power of combining with sulphuretted hydrogen to form sulphide of iron. Such is the affinity of the oxide for this impurity that it may contain 50 to 60 per cent. by weight of free sulphur after revivification, and still remain active. Upon removing the material from the vessel and exposing it to the atmosphere the oxide undergoes a revivifying process, the oxygen of the air displacing the sulphur from the sulphide as free sulphur, and converting the iron into hydrated oxide of iron. This revivification can be carried on a number of times till the material when dry contains about 50 per cent. free sulphur, and even occasionally 60 per cent. and over; it is sold to manufacturers of sulphuric acid, to be used in the sulphur kilns of their plant.

Purification.

The fact that coal gas of an illuminating power of from 14 to 16 candles can be made in ordinary circumstances at a fairly low rate, while every candle-power added to the gas increases the cost in an enormous and rapidly growing ratio, has, from the earliest days of the gas industry, caused the attention of inventors to be turned to the enrichment of coal gas. This up to 1890 had been almost universally carried out in practice by an admixture of rich cannel coal with the ordinary gas coal in the retorts, with a consequent heavy increase in the cost of the gas. But in that year cannel coal, which had been gradually growing dearer and dearer, reached a prohibitive price, with the result that other methods of enrichment were gradually adopted; and although cannel has fallen in price, it will never again be used on a large scale for the enrichment of coal gas, as not only are other methods cheaper and more convenient, but the available supplies of cannel are limited, and any large readoption of its use would soon result in increase in price. The methods which have from time to time been advocated to replace the use of cannel in the enrichment of illuminating gas may be classified as follows:—

Enrichment.

1. Enriching the gas by vapours and permanent gases obtained by decomposing the tar formed at the same time as the gas.

2. Mixing with the coal gas oil gas, obtained by decomposing crude oils by heat.

3. The carburetting of low-power gas by impregnating it with the vapours of volatile hydrocarbons.

4. Mixing with coal gas water gas which has been highly carburetted by passing it with the vapours of various hydrocarbons through superheaters in order to give permanency to the hydrocarbon gases. These methods may now be considered in detail.

1. *Enrichment by Tar.*—From the earliest days of the gas industry attempts have been made to utilize tar for the production and enrichment of gas. The patent literature of the 19th century contains many hundreds of such schemes, most of which were still-born; a few spent a short and sickly existence, but none achieved success. The reason is not difficult to understand. In order to make gas from tar two methods may be adopted—(*a*) Condensing the tar in the ordinary way, and afterwards using the whole or portions of it for cracking into a permanent gas; (*b*) cracking the tar vapours before condensation by passing the gas and vapours through superheaters. If the first method be adopted, the trouble which presents itself, and in a few hours brings the apparatus to grief, is that the tar contains 60 per cent. of pitch, which rapidly chokes and clogs up all the pipes. If an attempt be made to use a temperature at which the pitch is decomposed, it is found that a non- or very poorly luminous gas is the result, while a heavy deposit of carbon remains in the superheater or retort; and even at a high temperature easily condensable vapours escape, which afterwards create trouble in the pipes. In order to get over the difficulties arising from the choking by the pitch, attempts have been made to distil the tar at a low temperature and utilize the 40 to 50 per cent. of oil so obtained for gasifying, but here the small yield of oil and the expense of handling and distilling have prevented tar from competing with other processes of enrichment. A more economical way was to distil the tar so as to leave the pitch behind, and then, instead of condensing the vapours to oil, to pass them through a heated chamber, and thus raise their temperature above the critical point. But as soon as this was tried it was found that the lighter vapours, which distilled off first, only required a temperature to crack them which was totally inadequate to render the heavier vapours coming off later in the distillation uncondensable; while if the heat was so arranged as to crack the heavy vapours, it broke up the lighter ones into gases of very poor illuminating power. These troubles of course arise from the same cause as in the earlier experiments on carburetting gas, by passing over or through volatile naphthas—viz., that the tar, like the naphthas, is a mixture of many compounds varying in composition and properties. In order (as far as possible) to surmount this trouble, Mr George Davis proposed to distil the tar so as to remove pitch, and then to get rid of the naphthalene and anthracene, using the remainder, four-fifths of which can be gasified, for enriching the gas. He calculated that coal yields 0·7 per cent. of its weight of tar, 0·4 of which is got rid of as pitch, and the remaining 0·28 per cent. can be converted into gas, a gallon of the oil yielding 80 cubic feet of 50-candle gas. He inferred that from a ton of ordinary coal, by utilizing the tar in this way, 10,465 cubic feet of 18·4-candle gas could be obtained, instead of 10,000 of 17-candle gas.

The most apparently successful attempt to utilize certain portions of the liquid products of distillation of coal was the Dinsmore process, in which the coal gas and the vapours which, if allowed to cool, would form tar were made to pass through a heated chamber, and a certain proportion of otherwise condensable hydrocarbons were thus rendered incondensable. Even with a poor class of coal it was claimed that 9800 cubic feet of 20 to 21 candle gas could be made by this process, whereas by the ordinary process 9000 cubic feet of 15-candle gas would have been produced. This process, although strongly advocated by the gas engineer who experimented with it, could not have been commercially very successful, as nothing has been heard of it for some years. The eventual solution of the question of enrichment of gas by hydrocarbons derived from tar may be arrived at by a process which prevents the formation of part of the tar during the carbonization of the coal, but all experience points to the impossibility of again decomposing tar in such a way as to be economically successful for enrichment when once it has been formed.

2. *Enrichment by Oil Gas.*—The second method by which a coal gas of poor quality may be enriched up to any desired standard is by mixing with it "oil gas," obtained by decomposing crude oil by heat. The earliest attempts in this direction were to spray oil upon the red-hot mass in the retort during carbonization; but experience soon showed that this was not an economical method of working, and that it was far better to decompose the liquid hydrocarbon in the presence of the diluents which are to mingle with it and act as its carrier, since if this were done a higher temperature could be employed, and more of the heavier portions of the oil converted into gas, without at the same time breaking down the gaseous hydrocarbons too much. For instance, if a petroleum oil is decomposed by itself, the resulting gas would consist largely of hydrogen and methane, and the heavy hydrocarbons would probably vary from 16 to 26 per cent., a considerable quantity of carbon separating; but if it were decomposed in the presence of a stream of diluting gas, a far larger percentage of illuminants of the higher marsh gas series (ethane, &c.) would be produced, and a comparatively small quantity of hydrogen and methane. This is due to the fact that when the hydrocarbons are undiluted they can easily be broken down by heat to hydrogen and carbon; whereas when they are diluted, a far higher temperature is necessary to effect this action, and so the degradation of the hydrocarbons is stopped at an earlier stage.

In carburetting a poor coal gas with paraffin it must be borne in mind that, as the coal is undergoing distillation, in the earlier stages a rich gas is given off, but towards the end of the operation the gas is very poor in illuminants and rich in hydrogen, the methane disappearing with the other hydrocarbons, and the increase in hydrogen being very marked. Mr Lewis T. Wright employed a coal requiring six hours for its distillation, and took samples of the gas at different periods of the time. On analysis these yielded the following results :—

	Time after beginning Distillation.			
	10 Minutes.	1 Hour 30 Minutes.	3 Hours 25 Minutes.	5 Hours 35 Minutes
Sulphuretted hydrogen	1·30	1·42	0·49	0·11
Carbon dioxide .	2·21	2·09	1·49	1·50
Hydrogen . .	20·10	38·33	52·68	67·12
Carbon monoxide	6·19	5·68	6·21	6·12
Marsh gas . .	57·38	44·03	33·54	22·58
Illuminants .	10·62	5·98	3·04	1·79
Nitrogen . .	2·20	2·47	2·55	0·78

This may be regarded as a fair example of the changes which take place in the quality of the gas during the distillation of the coal. In carburetting such a gas by injecting paraffin into the retort, many of the products of the decomposition of the oil being vapours, it would be wasteful to do so for the first two hours, as a rich gas is being given off which has not the power of carrying in suspension a much larger quantity of hydrocarbons without being saturated with them. Consequently, to make it bear along with it any further quantity, in a condition not easily deposited, the paraffin would have to be broken down to a great extent, and the temperature necessary to do this would seriously affect the quality of the gas given off by the coal. When, however, the distillation had gone on for three hours the rich portions of the coal gas would all have distilled off, and the temperature of the retort would have reached its highest point; this would be the best time to feed in the oil.

Undoubtedly the best process which has been proposed for the production of oil gas to be used in the enrichment of coal gas is the "Young" or "Peebles" process, which depends on the principle of washing the oil gas retorted at a moderate temperature by means of the oil which is afterwards to undergo decomposition, whereby it is freed from all condensable vapours, and only permanent gases are allowed to escape to the purifiers. In doing this very considerable quantities of the olefines and other fixed gases are also absorbed, but no loss takes place, as these are again driven out by the heat in the subsequent retorting. Two cast-iron retorts about 10 feet in length, set so as to incline downwards to the far end, are used at Peebles's. They are fitted with the usual doors and ascension pipes, but in each door there is a small pet-cock, by opening which the colour of the gas can be seen. This should be of the palest lemon, as it is found that if any darker colour or an approach to brown is produced, decomposition of tar (besides other troubles) will begin. The oil is admitted through small cocks about 2 feet up the ascension pipe, and falls down through the ascending gas on to steel plates, which extend 3 feet into the retort, so as to prevent as far as possible the direct impact of the oil upon the bottom of the iron retort. The temperature of the retorts is from 800° to 900° C. The gas on leaving the retorts passes up the ascension pipes to the hydraulic main and through a coil of horizontal condensing pipes to the scrubber, which is of the "Young" pattern, and made in four compartments. The oil cistern is placed on top of the scrubber, and the supply pipe from it is so arranged that the oil can be made to flow into any or all of the sections. After passing through the scrubber the oil flows back along the bottom of the horizontal condensers in an opposite direction to that in which the gas is passing, and thence into the hydraulic main. From the main it passes through a seal into a small cistern containing a float connected with an indicator close to the oil feed taps in front of the working bench, so that the supply of oil can be regulated in accordance with the rate of decomposition. The oil used is what is technically known as "blue" oil, and has an average specific gravity of about ·850. Each retort will make 500 cubic feet of gas per hour, and 5½ cwt. of a very dense graphitic coke are obtained for each ton of oil decomposed. This coke collects almost entirely at the back of the retorts, and being non-adherent, is readily removed. The surface of the coke is practically horizontal, which suggests that either it has flowed to the back of the retort as pitch and has been there carbonized, or that carbon deposited in the ascension pipes and front of the retort has been washed there by the oil.

The gas obtained by the Young process, when tested by itself in the burners most suited for its combustion, gives on the photometer an illuminating value averaging from 50 to 60 candle-power, but it is claimed that the enriching power of the gas is considerably greater. The reason is, that the duty obtained from any burner is entirely dependent, firstly, on the regulation of the size of the flame, so that the gases as they burn shall get the correct proportion of oxygen within a given distance from the tip of the burner; and, secondly, upon the temperature of the flame itself. Hence every variety of gas will give different illuminating values according to the burner used, the burner adapted for a poor or medium gas being utterly unfitted for rich gas, a point which is too often overlooked in testing the illuminating power of gases as well as in their practical consumption. A 16-candle coal gas requires a very large burner to develop its maximum illuminating power as a flat flame, but as the richness of the gas in heavy hydrocarbons increases, the size of the burner has also to be rapidly decreased, in order to allow sufficient air to get to the flame; and the smaller the flame, the greater will be the cooling influence of the burner and of the nitrogen of the air upon it, with the result that a burner has to be selected for each quality of gas of such size that it will just not smoke. For instance: with an oil gas capable of emitting a light equal to 50 candles per 5 cubic feet, it would be found that the No. 2 Bray burner would give a heavy smoky flame, which will become still more smoky with increase in the size of the burner; but if a No. 0 Bray were employed, a smokeless flame would be obtained which would give an illuminating power equal to slightly under 50 candles per 5 cubic feet of gas consumed; and as the size of the burner is reduced the illuminating power recorded would also decrease, until, with a No. 000, it would only record 35 candles per 5 cubic feet, the falling off being due to the cooling of the flame. With such a gas, therefore, the No. 0 burner would give the highest results; and when experimenting with gases of over 60 candle-power it is impossible to get a burner which will develop the maximum value, as the burner has to be so small, in order to prevent smoking, that cooling destroys a large percentage of the illuminating value. Hence it is frequently found that the enrichment value of a rich oil gas is higher than would be expected from its photometric value.

The fundamental objections to oil gas for the enrichment of coal gas are, firstly, that its manufacture is a slow process, requiring as much plant and space for retorting as coal gas; and, secondly, that although on a small scale it can be made to mix perfectly with coal gas and water gas, great difficulties are found in doing this on the large scale, because in spite of the fact that, theoretically, gases of such widely different specific gravities ought to form a perfect mixture by diffusion, it is found that layering of the gases is very apt to take place in the holder, and thus there is an increased liability to wide variations in the illuminating value of the gas sent out.

3. *Enrichment by Volatile Hydrocarbons.*—The carburetting of poor coal gas by passing it over or through highly volatile hydrocarbons, such as the lighter naphthas and benzene, has always been a favourite notion, but the great trouble which in the past has presented itself in the various carburetting systems is, that all the commercial samples of naphtha are mixtures of various hydrocarbons, having each their own boiling-point; therefore, when used in any of the old forms of carburetter they gave up their more volatile constituents very freely at the beginning of the experiment, while the amount rapidly diminished as the boiling-point of the residue became higher. Hence, when 2113 cubic feet of poor coal gas were passed through a naphtha having a specific gravity of ·869 and a boiling-point of 103° C., the temperature during the experiment being 22° C. (72° F.), the first 80 cubic feet of the gas took up 23·2 grains of the naphtha, whilst the last 450

cubic feet took up only 7·3 grains. The increase of evaporation with increase of temperature presented itself as another difficulty, for, with an ordinary form of carburetter exposed to changes of the atmosphere, the enrichment of the gas, which reached 44·4 per cent. in the summer, the average temperature being 72° F. (22° C.), fell in winter to only 22 per cent., with an average temperature of 37° F. (3° C.). Much, however, depends on the form of the carburetter. In one experiment, when gas was passed through a box containing a layer of naphtha, it took up only about 3·2 grains, but when the naphtha was sucked up by cotton fibres the gas took up as much as 22 to 23 grains in the same time owing to the large surface exposed, the same naphtha being used in both cases. A most important point is that only a poor gas can be enriched in this manner, a rich gas losing some of its illuminating power. The best method of carburetting poor coal gas at the burner is that known as the albo-carbon process, in which solid naphthalene is vaporized in a chamber by means of a strip of metal kept hot by the flame, the vapour mixing with the gas passing through the chamber.

Of recent years the idea of carburetting coal gas in bulk has been revived by the construction of an ingenious apparatus, devised by Messrs Maxim and Clarke, which to a great extent overcomes the difficulties of the old forms of carburetter. This process not only does away with the trouble that the more volatile portion of the naphtha or gasoline used enriches the gas to an undue extent at the beginning of the process, but it also carburets the gas used in large works and establishments, so that each portion obtains its proper share of hydrocarbon. For small installations the apparatus consists of a circular copper retort, which is kept automatically filled to a fixed level with gasoline from a reservoir outside the building. The retort is jacketed, and steam or hot water is passed round it to volatilize the gasoline, which passes over baffle plates in the top of the retort and then through an automatic regulator into a small holder sealed with mercury. The gas to be carburetted has to pass through this holder, and as it does so the gasoline vapour is supplied to it in the following way:—The holder works on a vertical spindle which passes down the tube into the gasoline retort, and is so arranged that when no gas is passing through the opening is closed and no gasoline can enter the holder. As gas is admitted the holder rises and lifts the spindle with it, allowing the gasoline vapour to rush up through grooves cut in the bottom of it; the higher the spindle is drawn the larger the openings become, and so the supply of gasoline increases *pari passu* with the amount of gas entering the holder.

Since about 1885 the price of benzol has been rapidly falling, owing to the large quantities produced in the coke ovens, which in the old days used to be burnt to waste, but are now recovered in the processes of coking which are becoming more and more widely adopted. The quantity of benzol produced in 1901 in Germany amounted to about 5,000,000 gallons per annum, and this quantity will be increased more than fourfold as the various coke works which do not at present recover the by-products are forced by competition to erect recovery plant. The wonderful carburetting power of benzol is well known, a very large proportion of the total illuminating power of coal gas being due to the presence of a minute trace of its vapour carried in suspension; with 90 per cent. benzol at a low price it is by far the cheapest enriching material that can be obtained, and at many gas works it is used in various forms of carburetter for enriching poor coal gas up to the requisite illuminating power.

4. *Enrichment by Carburetted Water Gas.*—In the last decade of the 19th century the most successful and most generally adopted method of enrichment was by means of carburetted water gas mixed with poor coal gas. When steam acts upon carbon at a high temperature, the resulting action may be looked upon as giving a mixture of equal volumes of hydrogen and carbon monoxide, both of which are inflammable but non-luminous gases. This water gas is then carburetted, *i.e.*, rendered luminous by passing it through chambers in which oils are decomposed by heat, and the mixture of oil gas diluted with water gas is made of such richness as to give an illuminating value of 24 or 25 candles. This mixed with the poor coal gas brings up its illuminating value to the required limit. Coke or anthracite is heated to incandescence by an air blast in a generator lined with firebrick, and the heated products of combustion as they leave the generator and enter the superheaters are supplied with more air, which causes the combustion of the carbon monoxide present in the producer gas and heats up the firebrick baffles with which the superheater is filled. When the necessary temperature of the fuel and superheater has been reached, the air blasts are cut off and steam is blown through the generator, forming water gas, which meets the enriching oil at the top of the first superheater, called the carburetter, and carries the vapours with it through the main superheaters, where the fixing of the hydrocarbons takes place. The chief advantage of this apparatus is that a low temperature can be used for fixing owing to the enormous surface for superheating, and thus to a great extent the deposition of carbon is avoided. This form of apparatus has been very generally adopted in Great Britain as well as in America, and practically all carburetted water gas plants are founded upon the same set of actions. Important factors in the use of carburetted water gas for enrichment are that it can be made with enormous rapidity and with a minimum of labour; and not only is the requisite increase in illuminating power secured, but the volume of enriched gas is increased by the bulk of carburetted water gas added, which in usual English practice amounts to from 25 to 50 per cent. The public at first strongly opposed its introduction, on the grounds of the poisonous properties of the carbon monoxide, which is present in it to the extent of about 28 to 30 per cent. Still, when this comes to be diluted with 60 to 75 per cent. of ordinary coal gas, containing as a rule only 4 to 6 per cent. of carbon monoxide, the percentage of poisonous monoxide in the mixture falls to below 16 per cent., which experience has shown to be a fairly safe limit.

The price of oil suitable for carburetting has during the past few years nearly doubled, and this fact has caused the gas industry to consider other methods by which the volume of the gas obtainable from coal can be increased by admixture with "blue" or non-luminous water gas. In Germany, at several important gas-works, non-luminous water gas is passed into the foul main of the gas plant in the desired proportion, and the mixture of water gas and coal gas is then carburetted to the required extent by benzol vapour, a process which at the present price of oil and benzol is distinctly more economical than the use of carburetted water gas. Extensive experiments are also being made on the Continent and in England upon passing water gas in the desired proportion through the crown of the retort in which the distillation of the coal is proceeding so as to prevent overheating of the gas and vapours by too long contact with the crown and sides of the retorts, the water gas so used also holding in suspension some of the more volatile hydrocarbons that would otherwise condense in the tar. In 1896 Mr Carl

Dellwik introduced a modification in the process of making water gas which entirely altered the whole aspect of the industry. In all the attempts to make water gas up to that date the incandescence of the fuel had been obtained by "blowing" so deep a bed of fuel that carbon monoxide and the residual nitrogen of the air formed the chief products, this mixture being known as "producer" gas. In the Dellwik process, however, the main point is the adjustment of the air supply to the fuel in the generator in such a way that carbon dioxide is formed instead of carbon monoxide. Under these conditions the producer gas ceases to exist as a by-product, and the gases of the blow consist merely of the incombustible products of complete combustion, carbon dioxide and nitrogen, the result being that more than three times the heat is developed for the combustion of the same amount of fuel, and double the quantity of water gas can be made per pound of fuel, than was before possible. The runs or times of steaming can also be continued for longer periods. The possibility of making 70,000 cubic feet of water gas per ton of coke used in the Dellwik generator, as against 34,000 cubic feet per ton made by previous processes, reduces the price of water gas to about 3d. per 1000, so that the economic value of using it in admixture with coal gas and then enriching the mixture by any cheap carburetting process is manifest. During the past few years it has become more and more evident that the universal adoption of the incandescent mantle for lighting purposes makes the illuminating value of the gas a secondary consideration, and the whole tendency of the future will be the production of low candle-power gas at a cheap rate for fuel purposes and incandescent lighting.

Gas Lighting.

Industrial history shows the great utility of brisk competition, and in no case is this more marked than in the utilization of gas for the emission of light. From 1820, when Neilson of Glasgow first discovered the principle of the union jet burner, and gave the world an easy and at the same time fairly effective method of consuming the then newly invented illuminant, until quite recent times, coal gas had been consumed by the methods which had sufficed for illumination in the early days; and in all probability the methods of consumption would have continued to be of the same inefficient character down to the present time had it not been for the appearance of the electric light as a competitor in the latter part of the 'seventies, and the dread which suddenly arose in the minds of those interested in gas manufacture as to the effect of this brilliant rival on their commercial status. It is true that the germs of important methods of consuming gas had already been sown, but the time had not been ripe for their development, and it was only the absolute necessity of combating the inroads of electricity that caused the adoption of new and improved methods for developing the light latent in coal gas.

Regenerative burners.

In the early 'fifties Sir Edward Frankland had already pointed out that the heating of the air supply to a flame marvellously increased the light which that flame emitted. He devised a burner which consisted of an ordinary Argand, having in addition to the usual chimney a second external one which extended some distance below the first, and was closed at the bottom by a glass plate fitted air-tight to the pillar carrying the burner, so that the air needed to support the combustion of the gas had to pass down the annular space between the two chimneys, and in its passage became highly heated, partly by contact with the hot inner glass and partly by radiation. He claimed that the use of this burner gave an increase of 67 per cent. in the light over that obtained by the combustion of the same volume of gas in an ordinary Argand. In 1854 the Rev. W. R. Bowditch brought out a burner identical in nearly every respect with the above, and as this was brought prominently forward, it attracted considerable attention, with the result that the inception of the regenerative burner has been generally ascribed to Bowditch, whereas this honour was undoubtedly due to Frankland. This burner has been revived from time to time since its first invention, but has always failed, owing to the inner chimney not being able to withstand the intense heat to which it was subjected; it is of interest as being the first inception of the idea of the modern regenerative burner. In 1879 Friedrich Siemens, of Dresden, brought out his big burner, which, although one of the most effective, was also one of the most unsightly from its big overhead feed pipe. It was really first made for heating purposes, but the light it gave was so far ahead of any effect which had been obtained up to that time, that, with certain modifications, it was adopted for lighting purposes. In 1881 Mr Thwaite published in the *English Mechanic* a description of an overhead recuperative burner under the name of the Hygienic lamp; and from that time up to the present regenerative burners—good, bad, and indifferent—have increased and multiplied with great rapidity, the chief differences between them being in their names and slight details of design.

The fact that the luminosity of a coal gas flame depends upon the number of carbon particles liberated within it, and the temperature to which these carbon particles can be heated, at once points to the fact that the methods by which the light developed from a flame of coal gas can be augmented are the increase in the number of the carbon particles by increasing the material which will deposit them, and raising the temperature to which the carbon particles already present have been heated. The first process is carried out by enrichment, the second is best obtained by regeneration, the action of which is limited by the power possessed by the material of which burners are composed to withstand the superheating. Although with a perfectly-made recuperative burner it might be possible for a short time to get as high a duty as 16 candles per cubic foot from ordinary coal gas, such a burner constructed of the ordinary materials would only last a few hours, so that for practical use and a reasonable life for the burner 10 candles per cubic foot was about the highest commercial duty that could be reckoned on. This limitation naturally caused inventors to search for methods by which the emission of light could be obtained from coal gas other than by the incandescence of the carbon particles contained within the flame itself, and the fact that a coal gas flame consumed in an atmospheric burner under conditions necessary to develop from it its maximum heating power could be utilized to raise particles having a higher emissivity for light than carbon to incandescence, led to the gradual evolution of incandescent gas-lighting, which undoubtedly marks another of the most important eras in the history of gas as an illuminant.

Incandescent mantles.

Existing systems of lighting by means of incandescent mantles are the result of many years of experimental toil and disappointment, and from the day when Talbot in 1835 first noticed that blotting-paper soaked in a solution of calcium chloride and burnt in the flame of a spirit lamp leaves a white network of ashes, which heated in the feeblest flame emits a brilliant light, down to the latest developments of the Welsbach mantle, there have been many thousands of experimental failures and still-born attempts which have neither seen nor created light. That all solids can be made to emit light when heated to a certain temperature has of course always been known. The fact that at any given temperature some substances would emit more light than others gave rise to the Drummond light, in which a block of lime raised to the highest temperature possible by the intensity of the oxy-hydrogen or oxy-coal gas blast emitted a light which until the advent of the electric arc remained unrivalled. The amount of material which has in this case to be raised to incandescence rendered this very high temperature necessary, and it was gradually recognized that if instead of a block of lime a basket-work of thin filaments made of lime and magnesia could be employed better results would follow, since instead of the costly oxy-hydrogen or oxy-coal gas flame an ordinary gas and air blowpipe working at a slight pressure could be used. This was practically adopted in the Clamond mantle, which was probably the first oxide mantle which had any extended commercial existence. The same principle was utilized in the Fahnejelm comb, which was heated to incandescence by water gas. The Clamond mantle, as shown at the Crystal Palace Exhibition of 1882–83, consisted of a conical basket composed of threads of calcined magnesia. A mixture of the hydrate and acetate of magnesium, converted into a paste or cream by means of water, was moulded to the required shape, and then ignited; the heat decomposed the acetate, which in its partial fusing during decomposition formed a luting material which glued the particles of magnesium oxide produced into a solid mass, while the hydrate gave off water and became oxide. The basket was supported with its apex downwards in a little platinum wire cage, and a mixture of coal gas and air was driven into it from an inverted burner above it. Long, however, before this oxide mantle made its appearance Lewis had introduced a mantle made of fine platinum wire, which, when raised to incandescence by a blast of air and coal gas, gave for a certain period what was then considered a very high duty for gas consumed, but the rapid falling off of its power of emitting light proved a fatal obstacle to its commercial success. This deterioration was partly due to the surface of the platinum becoming corroded by the formation of traces of carbide of platinum from the action of the hydrocarbon in the flame, and partly to the deposition on its surface of traces of foreign metals due to the breaking up of the carbonoxyl compounds, of which the gas contained minute quantities. It was this latter trouble that at a more recent date militated against what at first appeared a very promising attempt to utilize thin platinum-iridium wire for the manufacture of an unbreakable incandescent mantle. The year 1886 marks the first appearance of the Welsbach system of incandescent mantles, which after many years of struggle and effort at length attained a well-earned success. Dr Auer von Welsbach, whose researches on the rare metals and their compounds had already gained him a great reputation, conceived the idea of making a mantle of refractory oxides by the methods which had been previously shadowed by Talbot and others. His process consisted in soaking an open fabric of cotton in a solution of the nitrates of the metals of which he required the oxides, drying it, and burning off the organic matter, the nitrates at the same time becoming converted into their respective oxides, which retained the shape of the original fabric. Various modifications have been introduced in the manufacture of the fabric and in the composition of the dipping material, until at the present time the incandescent mantle is far and away superior in light-emissivity to any other method for producing light from coal gas.

In the system of lighting by means of incandescent mantles the most important feature is the burner, which must give a non-luminous flame, else deposition of carbon will soon ruin the mantle as regards its light-giving powers. A non-luminous flame can be obtained either by burning a mixture of air and gas, mixed before combustion, or by burning the coal gas in so thin a sheet of flame that the air can permeate it with sufficient freedom to render it non-luminous. The former method is now employed in nearly all systems of incandescent lighting, but the latter is used in Paris in one form of the De Mare system, in which a fringe of light-giving oxides is heated by a small flat flame burner burning with a non-luminous flame. The extended use of incandescent mantles has produced many improvements in the atmospheric burners employed in connexion with them, and has led to a study of the factors necessary to obtain the best results. One of the most promising directions in which this has taken place has been the gradual realization of the fact that in order to secure the highest results the mixture of air and gas must not only be in such proportions as to ensure perfect combustion, but that the mixture itself must be so perfect that each molecule of combustible matter shall find itself side by side with the oxygen necessary for its combustion at the burner tip, as it is manifest that the intensity of the flame is greatly increased by the proper regulation of this factor. The chemical actions taking place in a Bunsen burner can be divided into two distinct parts: the first occur on the surface of the inner visible cone of the flame, where the hydrogen and hydrocarbons of the gas enter into partial combination with the oxygen of the air which has been previously mixed with the gas, forming a mixture of carbon dioxide and monoxide with some water vapour; and the second takes place in the outer flame, which is produced by the combustion of the hydrogen and carbon monoxide escaping from the inner zone, the products of the completed combustion being carbon dioxide and water vapour. The appearance of the Bunsen flame varies with the amount of air which is drawn in with the gas. Under normal conditions the zones of the flame have a violet-blue colour, and as more air is admitted the flame grows fiercer and the inner zone acquires a green tint. A still further addition of air causes the mixture to become so highly explosive that it flashes back into the tube of the burner. In the Bandsept and Kern burners the mixture of air and gas can be so regulated that not only is the green cone in the interior of the flame formed, but owing to the explosive point of the mixture being reached it is drawn down on to the surface of the gauze "atomizers" or mixers, through which it cannot pass, so that the flame consists of practically only the outer cone of the ordinary Bunsen, by which method a more even equality in temperature can be obtained than with the ordinary flame.

Atmospheric burners for mantles.

The most successful form of mantle is made by taking a cylinder of cotton net about 8 inches long, one end of which is sewn together with an asbestos thread, a loop of the same material or of thin platinum wire being fixed across the constricted portion to provide a support by which the mantle may be held by the carrying rod, which is either external to the mantle or (as is most often the case) fixed centrally in the burner head. After being sewn, the cotton net is soaked in a solution of the nitrates of the requisite metals until the microscopic fibres of the cotton are entirely filled with liquid. A longer soaking is not advantageous, as the acid nature of the liquid employed tends to weaken the fabric and render it more delicate to handle. The cotton is then wrung out to free it from the excess of liquid attached to the exterior of the threads, and is stretched over a conical mould and dried. It is

Mantle manufacture.

then ready for "burning off," a process in which the organic matter is removed and the nitrates are converted into oxides. The flame of an atmospheric burner is first applied to the constricted portion at the top of the mantle, whereupon the cotton gradually burns downwards, the shape of the mantle to a great extent depending on the regularity with which the combustion takes place. A certain amount of carbon is left behind after the flame has died out, and this is burnt off by the judicious application of a flame from an atmospheric blast burner to the interior. The action which takes place during the burning off is as follows:—The cellulose tubes of the fibre are filled with the crystallized nitrates of the metals used, and as the cellulose burns the nitrates decompose, giving up oxygen and forming fusible nitrites, which in their semi-liquid condition are rendered coherent by the rapid shrinkage which takes place. As the action continues the nitrites become oxides, losing their fusibility, so that by the time the organic matter has disappeared a coherent thread of oxide is left in place of the nitrate-laden thread of cotton. The great drawback in the early days of incandescent lighting was that the mantles had to be sent out unburnt and the consumer had to burn them off when required, as no process was known by which the burnt mantle could be rendered sufficiently strong to bear carriage. As the success of the mantle depends upon its fitting the flame, and as the burning off requires considerable skill, this was a great difficulty. Moreover, the acid nature of the nitrates present in the fibres rapidly rotted them, unless they had been subjected to the action of ammonia gas, which neutralized any excess of acid; but it was found that treatment with ammonia rendered the mantles after burning off even more fragile than before, as the fusible nitrates were converted into hydrates, which could not be pressed together into a coherent mass during the burning off. It was discovered, however, that the burnt-off mantle could be temporarily strengthened by being dipped in collodion, a solution of soluble gun-cotton in ether and alcohol together with a little castor oil or similar material to prevent excessive shrinkage during drying: when the mantle was removed from the solution a thin film of solid collodion was left on it, and this burned away on the application of a light when required, no bad after-effects being left.

The oxides first used in England for Welsbach mantles consisted of mixtures of zirconia, lanthania, and yttria, or zirconia and lanthania, but these gave a very fragile mantle, and only yielded 4 to 7 candles per cubic foot of gas consumed. In 1886 the second Welsbach patent was taken out, which covered the use of thoria, either alone or mixed with zirconia, magnesia, yttria, erbia, neodidymia, lanthania, alumina, &c. The idea which was held at that time was that a pure thoria mantle had a very high power of light emission, but in point of fact really pure thoria emits practically no light at all, although later experience showed that it possessed important properties for mantle-making, its refractory nature giving the mantle a stability unattainable by any other known body. The thoria mantles made under this patent gave a duty of 6 candles per cubic foot of gas consumed, but when made with pure thoria they give a duty of less than 1 candle per cubic foot of gas, and the other mixtures specified in the patent give results which hardly come within the range of practical utility. About 1891, mantles on the Continent began to show a marked improvement, and in 1891–92 it was reported that Welsbach had produced new mantles yielding as much as 16 and 17 candles per cubic foot of gas consumed, and the same improvement was manifested in the English mantles. The cause was shown in the following year, 1893, in a patent taken out by Mr Moeller, in which protection was sought for a combination of thoria with very small traces—not exceeding 1 or 2 per cent.—of the oxides of certain other rare metals, such as uranium, cerium, terbium, neodidymium, samarium, prazeodymium, yttrium, and lanthanum. The present mantles nearly all consist of 99 per cent. thoria with 1 per cent. cerium, this latter oxide having qualities far in advance of any of the others mentioned.

It will be seen from the above description that the mantles of to-day are the outcome of three stages—(1) The method of making the mantle, and the use of the oxides of the rare earths; (2) using thoria instead of zirconia as the basis of the mantle; and (3) the effect of traces of other oxides on the light-emissivity of the thoria. In the days prior to Welsbach's discovery the rare earths had been studied by but few, although several famous chemists, foremost among them Bunsen, had devoted special attention to them, and no method was known by which they could be obtained in a state of absolute purity. The price of the raw materials being excessive, their purification was not pushed to the extreme limits, and consequently the candle-power of the earlier mantles was more often influenced by the impurities present in the materials used than by the actual composition of the mantle. Many experiments have been made in order to determine the effect of the percentage of ceria when added to thoria on the light-emissivity of the mantle, and the results obtained show that, starting with a pure thoria mantle giving practically no light, the candle-power rapidly increases as traces of ceria are added to it, until the maximum is reached, when increase in the amount of ceria decreases the light emitted, the colour of the light also acquiring a yellowish tint, which gradually deepens to a reddish character with excess of ceria. These results show such a narrow limit for the production of the highest light-emissivity, that a very careful proportioning of the liquid for soaking the mantle is necessary. The effect of varying proportions of ceria upon the life of the mantle shows that with a Welsbach mantle made in the ordinary manner by soaking the fabric in the nitrates solution, the higher the initial illuminating value the greater is the falling off in light over a given space of time. It is generally found that the light from a Welsbach mantle increases for a certain period and then steadily falls, the initial increase being probably due to the mantle shaping itself to the flame, while the subsequent diminution in power is chiefly due to dust particles containing silica, which are drawn in over the surface of the mantle by the chimney draught and, fusing on the outside of the fine filaments, form silicates which have a much lower power of light-emissivity than the original oxides.

Effect of Ceria.

Many theories have been advanced to explain the marvellous power possessed by the minute trace of ceria in exciting the light-giving power of the mantle. The explanation put forward by Dr Drossbach, that the ceria has some occult power of converting the heat rays into light, is now regarded as untenable. Drs Killing and Moschelles are of opinion that the ceria (CeO_2), at a high temperature under the influence of the hydrogen and carbon monoxide, becomes reduced to cerous oxide (Ce_2O_3) with liberation of oxygen, which, combining on the surface of the ceria with the combustible gases of the flame, induces a far higher temperature in the ceria than exists in the thoria, the cerous oxide then undergoing oxidation to the higher compound by the action of the excess of air present. This theory, however, would imply that the more ceria were present the greater would be the light-emitting power of the mantle; but this is not so, as any increase over 1 per cent. tends to reduce the light-giving power. In the explanation of Dr Bunte, which is the one most generally accepted, the action is ascribed to a catalysis of the same nature as causes a piece of platinum foil after cleaning to become red-hot when a mixture of coal gas and air is allowed to impinge upon it, the action being due to the power which the platinum possesses of condensing within its pores both coal gas and air, and rendering them so chemically active that they unite upon the surface of the metal and emit sufficient heat to raise it to a bright red. Dr Bunte found that at 1200° F. (649° C.) a mixture of hydrogen and oxygen, in the proportion of two to one, when passed through a heated porcelain tube, combined to form water, and that the presence of thoria in the tube had no influence upon the temperature at which the combination took place. When he passed the same mixture through a tube containing ceria, the action commenced at 600° F. (315·5° C.), and his inference was that this catalytic action, by localizing a high temperature in the small particles of ceria spread over the surface of the inert thoria, is the cause of the high light-emissivity. Proof of Drossbach's theory ought easily to have been obtained by observing the way in which the rare oxides and mixtures behave when out of contact with air, but Dr Bunte found on experiment that there was very little difference in the noticeable light radiation from bodies of such widely different light-emissivity as carbon, magnesia, thoria, or the mixtures used in the Welsbach mantle. In order to prove this fact he used a thick-walled tube of retort carbon, the thickness of the walls of the centre portion of which for a length of 4 inches was reduced to 0·059 inch. When a strong current of electricity was passed through the thin-walled portion it was raised to a white heat, about 3630° F. (1999° C.), the tube being protected from burning away at this point by a coating of magnesia covered by an outer wrapper of asbestos paper. In the interior of the tube small square prisms of magnesia were placed, coated with the substance under examination, and each prism compared side by side in the hottest portion of the tube, a small sight-hole being left at the end of the carbon tube for observation purposes. By using double prisms, one coated with the substance to be tested and the other with a standard material of known composition, it was found that there was practically no difference in the various materials. This was also confirmed by some experiments made by Mr Campbell Swinton, in which various mantle materials were enclosed in a vacuum tube and submitted to cathode rays: he found that although the mixture of 99 per cent. thoria and 1 per cent. cerium in a vacuum heated up to incandescence more rapidly than pure thoria alone and cooled down afterwards more rapidly, its incandescence was only very slightly greater than that of the thoria alone. Many other facts can be adduced to support the theory that the light is due to the particles of ceria being heated to a higher temperature than that of the flame. The luminosity of an ordinary flame has been shown to be due to the splitting up of the molecule of acetylene with the liberation of endothermic heat, by which the carbon particles are heated to a temperature far above that which exists in the flame. So in the same way the heat of the flame which heats the whole mantle *plus* the locally intensified points of excessively high temperature, due to the catalytic action of the ceria upon the oxygen, carbon monoxide, and hydrogen, probably accounts for the intense light-emissivity of the mantle. Additional confirmation of the fact is gained from the circumstance that similar results, though not so marked, are obtained by the use of other materials known to have catalytic powers. The quantity of ceria may seem so small that it does not appear possible for it to play any important part in the light-giving power of the mantle. Dr Bunte, however, points out that in an ordinary gas flame the luminosity is due to liberated carbon particles heated to an intense degree; the carbon is chiefly obtained from the decomposition of unsaturated hydrocarbons, which only form about 5 per cent. of the volume of the gas. Supposing all the carbon of the unsaturated hydrocarbons to be liberated, it may be calculated that about 54 milligrams of carbon are separated from a litre of coal gas, or 23·6 grains from 1 cubic foot. Thus 4 per cent. of ethylene and 1 per cent. of benzene give per litre of gas 60 cc. of carbon vapour from the benzene and 40 cc. from the ethylene, in all 100 cc., equal to about 54 milligrams of carbon. The volume of the luminous portion of a flame consuming 5·297 cubic feet per hour, with an illuminating power of 17·5 candles, is about 2 cc. at 32° F. (0° C.). It therefore contains $2 \times 54 \div 1000$ mg. or 0·1 mg. (0·0015 grain) of incandescent carbon, and this small quantity is sufficient to yield a light of 17·5 candles. In a Welsbach mantle the amount of ceria is about 4 mg., 0·06 grain, or forty times the quantity of incandescent carbon in an ordinary flame, and this will explain why the Welsbach mantle gives a light of 80 candles when the Argand burner affords only 16 candles.

Improvements in mantles.

Of late years improved methods have arisen in the manufacture of some mantles, the principle of the Clamond mantle being revived. As already mentioned, these Clamond baskets were made by weaving together threads made from a paste of magnesia and magnesium acetate, which after baking could be rendered incandescent by means of an ordinary burner. On 4th November 1890 an improvement on this method was patented by Lungren. It was found that in the weaving the threads at the points of intersection did not weld properly, as the first threads laid on the mould dried before the cross threads were put on, so that on pressing them together the dry threads cut through the softer ones and did not unite with them, with the result that it was difficult to get a coherent mantle. Lungren, however, mixed the earths into a paste with a combustible elastic material, formed the thread, and then wove the mantle from it, the binding material being afterwards burnt out. Suitable materials are said to be glue mixed with glycerine, indiarubber dissolved in naphtha, &c. At the present time collodion is being largely used as a vehicle for holding the incandescent oxides. Among numerous other applications it has been employed for the manufacture of artificial silk, and large factories have been erected in Europe for this purpose. The usual method is to convert wood pulp into collodion by nitration. This collodion is then dissolved in as little alcohol and ether as possible, and the solution is squeezed under great pressure through capillary glass tubes, the bore of which is less than one-hundredth of a millimetre. The filament dries a few inches from the orifice of the tube, and ten or twelve of them are twisted together and wound on to a bobbin. The twisted thread is then denitrated by dipping the skeins into a solution of ammonium sulphide, by which they are converted into ordinary cellulose and lose their excessive inflammability. After washing and drying the skeins are ready for weaving into fabric. This artificial silk was utilized by De Mare in 1894 for making mantles by adding to the collodion the necessary salts, and in the next year Knofler and then Plaissetty patented the manufacture of mantles by a similar process to De Mare's, the difference between them being that Knofler used ammonium sulphide for denitrating purposes, while Plaissetty employed calcium sulphide, the objection to which is the trace of lime left in the material. Another process is the Lehner, in which the high pressures employed for the formation of the filament in the early processes are done away with, the solution used being of a more liquid character and the thread hardened by passing through certain organic solutions. This form of silk has been found well adapted for the manufacture of mantles, and the finished mantles are far superior to the older makes.

Mantles made in the above way are evidently developments of the Clamond class, as the filaments are made by squeezing the material through small holes to form rods or threads, leaving a thread of even density when the collodion is burnt off. In the Auer mantle, however, the filaments on burning off each leave a minute rod of oxides having a dense central portion surrounded by a more or less spongy coating, formed by the salts on the exterior of the filament, which are kept in a porous condition by the escape through them of the gases given off during the burning of the organic matter. In the Welsbach mantle this filamentary matter is twisted in the thread into what, after burning off, becomes practically a fluted column of oxides, but in the Clamond mantle each separate filament stands out by itself, so that the complete thread is really a bundle of filaments, the number of which varies according to the make of the mantle. The Lehner mantle, for instance, contains more filaments than the Knofler or Plaissetty. This difference in structure between the two classes has a very important effect on the life and strength of the mantle. The decrease in light due to the formation of silicates from dust on the surface of the mantle is considerably less in the case of the Clamond type than with the ordinary Welsbach mantle; the Welsbach mantle after 500 to 600 hours' burning becomes but a mere shadow of its former self, and yields only about a third of the original light, whereas mantles such as the Knofler and Lehner keep up their light-emitting power to a much greater extent, more especially in the case of the latter.

In Germany nearly 90 per cent. of the gas lighting is done by the aid of the incandescent mantle, but in England it has only reached to about 30 per cent. of the whole. It is, however, rapidly spreading, and, with improvements in the strength and lasting power of the mantle, and a cheapening in price, must soon pass into general use. Moreover, in spite of the cost of breakages and renewals, the fact that the use of the mantle increases sevenfold the light obtainable from a cubic foot of gas, as compared with what was possible with the flat flame or Argand, renders gas lighting the cheapest method of obtaining artificial light. (V. B. L.)

Gas Engines. See ENGINES.

Gaseous Fuel.—Natural gas (see *Ency. Brit.*, 9th ed. vol. ix. p. 809, and vol. xxiii. p. 813) has become of practical importance only in some states of the United States, especially in Pennsylvania, where it still plays a very great part for both household and industrial purposes, hundreds of gas wells having been bored and long pipe lines having been constructed. The gas, which contains from 68 to 94 per cent. of methane, with a little hydrogen, ethylene, &c., is evidently an accumulation of many ages, and is gradually approaching exhaustion, the maximum yield having been reached in 1890. The gas used in 1899 was valued at $11\frac{1}{2}$ million dollars.

Of much more importance, and that in a constantly increasing proportion, is artificial gas of all kinds. It is necessary to distinguish between the gaseous fuel obtained as a by-product of certain technical operations and that prepared on purpose. In the former case the combustible gases have been and are still frequently wasted, but their utilization is becoming more and more extended. This is true especially of the gases from blast-furnaces and from coke-ovens. Of the gaseous fuel prepared on purpose there are two different classes. The first comprises combustible gases generated by the destructive distillation of coal, lignite, bituminous schist, cheap oils, and substances of analogous character. By far the most important case of this kind is the manufacture of coal gas, which is primarily made for the purpose of illumination, but which serves also as a fuel for domestic use, for laboratories, and to some extent even for industrial purposes. In all cases belonging to this class only a comparatively small proportion of the heat-value of the coal is obtained in the shape of gaseous fuel, by far the greater portion remaining behind in the shape of coke. Where the latter is the principal object of the operation, as in the manufacture of coke for metallurgical purposes, the gases necessarily evolved are still wasted in the great majority of cases, although their fuel value is almost equal to that of ordinary illuminating gas.

An entirely different class of gaseous fuels comprises those produced by the incomplete combustion of the total carbon contained in the raw material, where the result is a mixture of gases which, being capable of combining with more oxygen, can be burnt and employed for heating purposes. Apart from some descriptions of waste gases belonging to this class (of which the most notable are those from blast-furnaces), we must distinguish two ways of producing such gaseous fuels entirely different in principle, though sometimes combined in one operation. The incomplete combustion of carbon may be brought about by means of atmospheric oxygen, by means of water, or by a simultaneous combination of these two actions. In the first case the chemical reaction is

$$C + O = CO \quad . \quad . \quad . \quad (a);$$

the nitrogen accompanying the oxygen in the atmospheric air necessarily remains mixed with carbon monoxide, and the resulting gases, which always contain some carbon dioxide, some products of the destructive distillation of the coal, &c., are known as *producer gas* or *Siemens gas*. In the second case the chemical reaction is mainly

$$C + H_2O = CO + H_2 \quad . \quad . \quad (b);$$

that is to say, the carbon is converted into monoxide and the hydrogen is set free. As both of these substances can combine with oxygen, and as there is no atmospheric nitrogen to deal with, the resulting gas (*water gas*) is, apart from a few impurities, entirely combustible. Another kind of water gas is formed by the reaction

$$C + 2H_2O = CO_2 + 2H_2 \quad . \quad . \quad (c),$$

but this reaction, which converts all the carbon into the incombustible form of CO_2, is considered as an unwelcome, although never entirely avoidable, concomitant of (*b*).

The reaction by which water gas is produced being endothermic (as we shall see), this gas cannot be obtained except by introducing the balance of energy in another manner. This might be done by heating the apparatus from without, but as this method would be uneconomical, the process is carried out by alternating the endothermic production of water gas with the exothermic combustion of carbon by atmospheric air. Pure water gas is not, therefore, made by a continuous process, but alternates with the production of other gases, combustible or not. But instead of constantly interrupting the process in this way, a continuous operation may be secured by simultaneously carrying on both the reactions (*a*) and (*b*) in such proportions that the heat generated by (*a*) at least equals the heat absorbed by (*b*). For this purpose the apparatus is fed at the same time with atmospheric air and with a certain quantity of steam, preferably in a superheated state. Gaseous mixtures of this kind have been made, more or less intentionally, for a long time past. One of the best known of them, intended less for the purpose of serving as ordinary fuel than for that of driving machinery, is the Dowson gas.

An advantage common to all kinds of gaseous fuel, which indeed forms the principal reason why it is intentionally produced from solid fuel, in spite of inevitable losses in the course of the operation, is the following. The combustion of solid fuel (coal, &c.) cannot be carried on with the theoretically necessary quantity of atmospheric air, but requires a considerable excess of the latter, at least 50 per cent., sometimes 100 per cent. and more. This is best seen from the analyses of smoke gases. If all the oxygen of the air were converted into CO_2 and H_2O, the amount of CO_2 in the smoke gases should be in the case of pure carbon nearly 21 volumes per cent., as carbon dioxide occupies the same volume as oxygen; while ordinary coal, where the hydrogen takes up a certain quantity of oxygen as well, should show about 18·5 per cent. CO_2. But the best smoke gases of steam boilers show only 12 or 13 per cent., much more frequently only 10 per cent. CO_2, and gases from reverberatory furnaces often show less than 5 per cent. This means that the volume of the smoke gases escaping into the air is from $1\frac{1}{2}$ to 2 times (in the case of high-temperature operations often 4 times) greater than the theoretical minimum; and as these gases always carry off a considerable quantity of heat, the loss of heat is all the greater the less complete is the utilization of the oxygen and the higher the temperature of the operation. This explains why, in the case of the best-constructed steam-boiler fires provided with heat economizers, where the smoke gases are deprived of most of their heat, the proportion of the heat value of the fuel actually utilized may rise to 70 or even 75 per cent., while in some metallurgical operations, in glass-making and similar cases, it may be below 5 per cent.

One way of overcoming this difficulty to a certain extent is to reduce the solid fuel to a very fine powder, which can be intimately mixed with the air so that the consumption of the latter is only very slightly in excess of the theoretical quantity; but this process, which has been only recently introduced on a somewhat extended scale, involves much additional expense and trouble, and cannot as yet be considered a real success. Generally, too, it is far less easily applied than gaseous fuel. The latter can be readily and intimately mixed with the exact quantity of air that is required and distributed in any suitable way, and much of the waste heat can be utilized for a preliminary heating of the air and the gas to be burned by means of "recuperators."

We shall now describe the principal classes of gaseous fuel.

A. *Ordinary Coal Gas.*—Although this gas is primarily manufactured for illuminating purposes, it is now extensively used for cooking, frequently also for heating domestic rooms, baths, &c., and to some extent also for industrial operations on a small scale, where cleanliness and exact regulation of the work are of particular importance. In chemical laboratories it is preferred to every other kind of fuel wherever it is available. The manufacture of coal gas having been described elsewhere in this work (see GAS AND GAS-LIGHTING), we need here only point out that it is obtained by heating bituminous coal in fireclay retorts and purifying the products of this destructive distillation by cooling, washing, and other operations. The residual gas, the ordinary composition of which is given in the table below, amounts to about 10,000 cubic feet for a ton of coal, and represents about 21 per cent. of its original heating value, 56·5 per cent. being left in the coke, 5·5 per cent. in the tar, and 17 per cent. being lost. As we must deduct from the coke that quantity which is required for the heating of the retorts, and which, even when employing good gas producers, amounts to 12 per cent. of the weight of the coal, or 10 per cent. of its heat value, the total loss of heat rises to 27 per cent. Taking, further, into account the cost of labour, the wear and tear, and the capital interest on the plant, coal gas must always be an expensive fuel in comparison with coal itself, and cannot be thought of as a general substitute for the latter. But in many cases the greater expense of the coal gas is more than compensated by its easy distribution, the facility and cleanliness of its application, the general freedom from the mechanical loss, unavoidable in the case of coal fires, the prevention of black smoke, and so forth. The following table shows the average composition of coal gas by volume and weight, together with the heat developed by its single constituents, the latter being expressed in kilogram calories per cubic metre (0·252 kilogram calories = 1 British heat unit; 1 cubic metre = 35·3 cubic feet; therefore 0·1123 calories per cubic metre = 1 British heat unit per cubic foot).

Constituents.	Volume per cent.	Weight per cent.	Heat-value per Cubic Metre Calories.	Heat-value per Quantity contained in 1 Cub. Met.	Heat-value per cent. of Total.
Hydrogen, H_2	47	7·4	2,582	1213	22·8
Methane, CH_4	34	42·8	8,524	2898	54·5
Carbon monoxide, CO	9	19·9	3,043	273	5·1
Benzene vapour, C_6H_6	1·2	7·4	33,815	405	7·7
Ethylene, C_2H_4	3·8	8·4	13,960	530	9·9
Carbon dioxide, CO_2	2·5	8·6			
Nitrogen, N_2	2·5	5·5			
Total	100·0	100·0	...	5319	100·0

One cubic metre of such gas weighs 568 grams. "*Rich gas*," viz., such made by the destructive distillation of certain bituminous schists, of oil, &c., contains much more of the heavy hydrocarbons, and its heat-value is therefore much higher than the above. The carburetted water gas, very generally made in America, and sometimes employed in England for mixing with coal gas, is of varying composition; its heat-value is generally rather less than that of coal gas (see below).

B. *Coke-oven Gas.*—In the United Kingdom the great bulk of metallurgical coke is still made by the old "beehive" ovens, in which all the volatile products of the destructive distillation of coal are completely wasted. Only about 5 per cent. of British coke is made in ovens fitted with apparatus for the recovery of the by-products; in Germany these are employed for nearly half of the coke made, and they are also coming into extensive use in America. The gas drawn away from these ovens, and remaining after the condensation of the tar and ammonia, is everywhere applied to the heating of the coke-ovens themselves, thus effecting a considerable increase in the yield of coke. But in all the better systems there is a considerable surplus of gas applicable to extraneous purposes. Its composition resembles that of ordinary coal gas, but as it contains less heavy hydrocarbons (especially when intentionally deprived of its benzene vapour), its heat-value is much less. Still, being a waste product and costing practically nothing, it is worthy of much more attention than it has hitherto received, especially in Great Britain.

C. *Producer Gas, Siemens Gas* (see *Ency. Brit.*, 9th ed., xxii. 182).—As we have seen above, this gas is made by the incomplete combustion of fuel. The materials generally employed for its production are anthracite, coke, or other fuels which are not liable to cake during the operation, and thus stop the draught or otherwise disturb the proccss, but by special measures also bituminous coal, lignite, peat, and other fuel may be utilized for gas producers. The fuel is arranged in a deep layer, generally from four feet up to ten feet, and the air is introduced from below, either by natural draught or by means of a blast, and either by a grate or only by a slit in the wall of the "gas producer." Even if the primary action taking place at the entrance of the air consisted in the complete combustion of the carbon to dioxide, CO_2, the latter, in rising through the high column of incandescent fuel, must be reduced to monoxide: $CO_2 + C = 2CO$. But as the temperature in the producer rises pretty high, and as in ordinary circumstances the action of oxygen on carbon above 1000° C. consists almost entirely in the direct formation of CO, we may regard this compound as primarily formed. It is true that ordinary producer gas always contains more or less CO_2, but this is evidently formed higher up by air entering through leakages in the apparatus. If we ignore the hydrogen contained in the fuel, the theoretical composition of producer gas would be 33·3 per cent. CO and 66·7 per cent. N, both by volume and weight. Its weight per cubic metre is 1·251 grams, and its heat-value 1013 calories per cubic metre, or less than one-fifth of the heat-value of coal gas. Practically, however, producer gas contains a small percentage of gases, increasing its heat-value, like hydrogen, methane, &c., but on the other hand it is never free from carbon dioxide to the extent of from 2 to 8 per cent. Its heat-value may therefore range between 800 and 1100 calories per cubic metre. Even when taking as the basis of our calculation a theoretical gas of 33·3 per cent. CO, we find that there is a great loss of heat-value in the manufacture of this gas. Thermo-chemistry teaches us that the reaction $C + O$ develops 29·5 per cent. of the heat produced by the complete oxidation of C to CO_2, thus leaving only 70·5 per cent. for the stage $CO + O = CO_2$. If, therefore, the gas given off in the producer is allowed to cool down to ordinary temperature, nearly 30 per cent. of the heat-value of the coal is lost by radiation. If, however, the gas producer is built in close proximity to the place where the combustion takes place, so that the gas does not lose very much of its heat, the loss is correspondingly less. Even then there is no reason why this mode of burning the fuel, *i.e.*, first with "primary air" in the producer ($C + O = CO$), then with "secondary air" in the furnace ($CO + O = CO_2$), should be preferred to the direct complete burning of the fuel on a grate, unless the above-mentioned advantage is secured, viz., reduction of the smoke gases to a minimum by confining the supply of air as nearly as possible to that required for the formation of CO_2, which is only possible by producing an intimate mixture of the producer gas with the secondary air. The advantage in question is not very great where the heat of the smoke gases can be very fully utilized, *e.g.*, in well-constructed steam boilers, salt-pans, and the like, and as a matter of fact gas producers have not found much use in such cases. But a very great advantage is attained in high-temperature operations, where the smoke gases escape very hot, and where it is on that account all-important to confine their quantity to a minimum.

It is precisely in these cases that another requirement frequently comes in, viz., the production at a given point of a higher temperature than is easily attained by ordinary fires. Gas-firing lends itself very well to this end, as it is easily combined with a preliminary heating up of the air, and even of the gas itself, by means of "recuperators." The original and best-known form of these, due to Siemens Brothers, consists of two brick chambers filled with loosely-stacked fire-bricks in such manner that any gases passed through the chambers must seek their way through the interstices left between the bricks, by which means a thorough interchange of temperature takes place. The smoke gases, instead of escaping directly into the atmosphere, are made to pass through one of these chambers, giving up part of their heat to the brickwork. After a certain time the draught is changed by means of valves, the smoke gases are passed through another chamber, and the cold air intended to feed the combustion is made to pass through the first chamber, where it takes up heat from the white-hot bricks, and is thus heated up to a bright red heat until the chamber is cooled down too far, when the draughts are again reversed. Sometimes the producer gas itself is heated up in this manner (especially when it has been cooled down by travelling a long distance); in that case four recuperator chambers must be provided instead of two. Another class of recuperators is not founded on the alternating system, but acts continuously; the smoke gases travel always in the same direction in flues contiguous to other flues or pipes in which the air flows in the opposite direction, an interchange of heat taking place through the walls of the flues or pipes. Here the surface of contact must be made very large if a good effect is to be produced. In both cases not merely is a saving effected of all the calories which are abstracted by the cold air from the recuperator, but as less fuel has to be burned to get a given effect, the quantity of smoke gas is reduced and thus a second advantage is secured.

Gas-firing in the manner just described can be brought about by very simple means, viz., by lowering the fire-grate of an ordinary fire-place to at least 4 ft. below the fire-bridge, and by introducing the air partly below the grate and partly behind the fire-place, at or near the point where the greatest heat is required. Usually, however, more elaborate apparatus is employed. Very many "gas producers" or "generators" have been constructed, commencing with Faber du Faur in Wasseralfingen (Würtemberg) in 1836, and Bischof of Mägdesprung in the Harz in 1839. But the greatest impetus to this mode of firing was given by Siemens Brothers, commencing in 1856, not only by the construction of their gas producers and heat recuperators, but also by the publicity they gave to the advantages of the system. They were followed by many other inventors, and gas-firing has now become universal in some of the most important industries, and nearly so in others. The present extension of steel-making and other branches of metallurgy is intimately connected with this system, as is the modern method of glass-making, of heating coal gas retorts, and so forth.

The composition of producer gas differs considerably, principally according to the material from which it is made. Analyses of ordinary producer gas (not such as falls under the heading of "semi-water gas," comp. sub F.) by volume show 22 to 33 per cent. CO, 1 to 7 per cent. CO_2, 0·5 to 2 per cent. H_2, 0·5 to 3 per cent. hydrocarbons, and 64 to 68 per cent. N_2.

D. *Blast-Furnace Gases.*—The gases issuing from the mouths of blast-furnaces in composition closely resemble those which are generated in gas producers, but they contain less CO and more CO_2. They represent an enormous aggregate heat-value, for it may be taken that the volume of gas given off per ton of iron made is about 4500 cubic metres (158,000 cubic ft.), and that each cubic metre is capable of yielding from 800 to 1000 calories. Although some of this heat has been utilized for a long time past (first by Faber du Faur in 1837), and since 1865 or 1870 all blast-furnaces have been provided with gas-collecting apparatus, the gas is mostly only applied to the heating of the blast, to the roasting of ore, and to the raising of steam for the blowing-engine, &c., a large proportion still being allowed to go to waste. Quite recently attempts have been made to utilize this gas in gas engines for the direct production of motive power, which, after providing for all the wants of the blast-furnace itself, is stated to leave an excess of 10 h.p. per ton of pig-iron made in twenty-four hours.

E. *Water Gas.*—The reaction of steam on highly heated carbonaceous matter was first observed by Fontana in 1780. This was four years before Cavendish isolated hydrogen from water, and thirteen years before Murdoch made illuminating gas by the distillation of coal, so that it was no wonder that Fontana's laboratory work was soon forgotten. Nor had the use of carburetted water gas, as introduced by Donovan in 1830 for illuminating purposes, more than a very short life. More important is the fact that during nine years the illumination of the town of Narbonne was carried on by incandescent platinum wire, heated by water gas, where also internally heated generators were for the first time regularly employed. The Narbonne process was abandoned in 1865, and for some time no real progress was made in this field in Europe. In America, however, Lowe, Strong, Tessié du Motay, and others, took up the matter, the first permanent success being obtained in 1873 by the introduction of Lowe's system at Phœnixville. In the United States the abundance of anthracite, as well as of petroleum naphtha, adapted for carburetting the gas, secures a great commercial advantage to this kind of illuminant over coal gas, so that now three-fourths of all American gas-works employ carburetted water gas. In Europe the progress of this industry was naturally much less rapid, but here also since 1882, when the apparatus of Lowe and Dwight was introduced in the town of Essen, great improvements have been worked out, principally by E. Blass, and by these improvements water gas obtained a firm footing also for certain heating purposes. The American process for making carburetted water gas, as an auxiliary to ordinary coal gas, was first introduced by the London Gas-Light and Coke Company on a large scale in 1890.

Water gas in its original state is called "blue gas," because it burns with a blue, non-luminous flame, which produces a very high temperature. According to the equation $C + H_2O = CO + H_2$, this gas consists theoretically of equal volumes of carbon monoxide and hydrogen. We shall presently see why it is impossible to avoid the presence of a little carbon dioxide and other gases, but we shall for the moment treat of water gas as if it were composed according to the above equation. The reaction $C + H_2O = CO + H_2$ is endothermic, that is, its thermal value is negative. One gram-molecule of carbon produces 97 great calories (1 great calorie or kilogram-calorie = 1000 gram-calories) when burning to CO_2, and this is of course the maximum effect obtainable from this source. If the same gram-molecule of carbon is used for making water gas, that is, $CO + H_2$, the heat produced by the combustion of the product is $68{\cdot}4 + 57{\cdot}6 = 126$ great calories, an apparent surplus of 29 calories, which cannot be got out of nothing. This is made evident by another consideration. In the above reaction C is not burned to CO_2, but to CO, a reaction which produces 28·6 calories per gram-molecule. But as the oxygen is furnished from water, which must first be decomposed by the expenditure of energy, we must introduce this amount = 68·5 calories in the case of liquid water, or 57·6 calories in the case of steam, as a negative quantity, and the difference, viz. $+28{\cdot}6 - 57{\cdot}6 = 29$ great calories, represents the amount of heat to be expended from another source in order to bring about the reaction of one gram-molecule of carbon on one gram-molecule of H_2O in the shape of steam. This explains why steam directed upon incandescent coal will produce water gas only for a very short time: even a large mass of coal will quickly be cooled down so much that at first a gas of different composition is formed and soon the process will cease altogether. We can avoid this by carrying it on in a retort heated from without by an ordinary coal fire, and all the early water gas apparatus were constructed in this way; but such a method is very uneconomical, and was long ago replaced by a process first patented by J. and T. N. Kirkham in 1854, and very much improved by successive inventors. This process consists in conducting the operation in an upright brick shaft, charged with anthracite, coke, or other suitable fuel. This shaft resembles an ordinary gas producer, but it differs in being worked, not in a continuous manner, which, as shown above, would be impossible, but by alternately blowing air and steam through the coal for periods of a few minutes each. During the first phase, when carbon is burned by atmospheric oxygen, and thereby heat is produced, this heat, or rather that part of it which is not carried away by radiation and by the products of combustion on leaving the apparatus, is employed in raising the temperature of the remaining mass of fuel, and is thus available for the second phase, in which the reaction (*b*) $C + H_2O = CO + H_2$ goes on with the abstraction of a corresponding amount of heat from the incandescent fuel, so that the latter rapidly cools down, and the process must be reversed by blowing in air, and so forth. The formation of exactly equal volumes of carbon monoxide and hydrogen goes on only at temperatures over 1200° C., that is, for a very few minutes. Even at 1100° C. a little CO_2 can be proved to exist in the gas, and at 900° its proportion becomes too high to allow the process to go on. About 650° C. the CO has fallen to a minimum, and the reaction is now essentially (*c*) $C + 2H_2O = CO_2 + 2H_2$; soon after the temperature of the mass will have fallen to such a low point that the steam passes through it without any perceptible action. The gas produced by reaction (*c*) contains only two-thirds of combustible matter, and is on that account less valuable than proper water gas formed by reaction (*b*); moreover, it requires the generation of twice the amount of steam, and its presence is all the less desirable since it must soon lead to a total cessation of the process. In ordinary circumstances it is evident that the more steam is blown in during a unit of time, the sooner reaction (*c*) will set in; on the other hand, the more heat has been accumulated in the producer the longer can the blowing-in of steam be continued.

The process of making water gas consequently comprises two alternating operations, viz., first, "blowing-up" by means of a current of air, by which the heat of the mass of fuel is raised to about 1200° C.; and, secondly, "steaming," by injecting a current of (preferably superheated) steam until the temperature of the fuel had fallen to about 900° C., and too much carbon dioxide appears in the product. During the steaming the gas is carried off by a special conduit into a scrubber, where the dust mechanically carried away in the current is washed out, and the gas is at the same time cooled down nearly to the ordinary temperature. It is generally stored in a gas-holder, from which it is conducted away as required. It is never quite free from nitrogen, as the producer at the beginning of steaming contains much of this gas, together with CO or CO_2. The proportion of hydrogen may exceed 50 per cent., in consequence of reaction (*c*) setting in at the close of the steaming. Ordinary "blue" water gas, if, as usual, made from coke or anthracite, contains 48–52 per cent. H_2, 40–41 per cent. CO, 1–5 per cent. CO_2, 4–5 per cent. N_2, and traces of hydrocarbons, especially methane. If made from bituminous coal it contains more of the latter. If "carburetted" (a process which increases its volume 50 per cent. and more) by the vapours from superheated petroleum naphtha, the proportion of CO ranges about 25 per cent., with about as much methane, and from 10 to 15 per cent. of "illuminants" (heavy hydrocarbons). The latter, of course, greatly enhance the fuel-value of the gas. Pure water gas would possess the following fuel-value per cubic metre:—

$$\begin{array}{ll} 0{\cdot}5 \text{ cub. met. } H_2 = 1291 & \text{calories} \\ 0{\cdot}5 \quad ,, \quad ,, \quad CO = 1522 & ,, \\ \hline \qquad\qquad\quad 2813 & ,, \end{array}$$

Ordinary "blue" water gas has a fuel-value of at least 2500 calories. Carburetted water gas, which varies very much in its percentage of hydrocarbons, sometimes reaches nearly the heat-value of coal gas, but such gas is only in exceptional cases used for heating purposes.

We must now turn to the "blowing-up" stage of the process. Until recently it was assumed that during this stage the combustion of carbon cannot be carried on beyond the formation of carbon monoxide, for as the gas producer must necessarily contain a deep layer of fuel (generally about 6 to 10 feet), any CO_2 formed at first would be reduced to CO; and it was further assumed that hardly any CO_2 would be formed from the outset, as the temperature of the apparatus is too high for this reaction to take place. But as the combustion of C to CO produces only 29·5 per cent. of the heat produced when C is burned into CO, the quantity of fuel consumed for "blowing-up" is very large, and in fact considerably exceeds that consumed in "steaming." There is, of course, a further loss by radiation and minor sources, and the result is that 1 kilogram of carbon yields only about 1·2 cub. met. of water gas. Each period of blowing-up generally occupies from 8 to 12 minutes, that of steaming only 4 or 5 minutes. This low yield of water gas until quite recently appeared to be unavoidable, and the only question seemed to be whether and to what extent the gas formed during blowing-up, which is in fact identical with ordinary producer gas (Siemens gas), could be utilized. In America, where the water gas is mostly employed for illuminating purposes, at least part of the blowing-up gas is utilized for heating the apparatus in which the naphtha is volatilized and the vapours are "fixed" by superheating. This process, however, never utilizes anything like the whole of the blowing-up gas, nor can this be effected by raising and superheating the steam necessary for the second operation; indeed, the employment of this gas for raising steam is not very easy, owing to the irregularities of and constant interruptions in the supply. In some systems the gas made during the blowing-up stage is passed through chambers, loosely filled with bricks, like Siemens recuperators, where it is burned by "secondary" air: the heat thus imparted to the brickwork is utilized by passing through the recuperator, and thus superheating the steam required for the next steaming operation. In many cases, principally where no carburetting is practised, the blowing-up gas is simply burned at the mouth of the producer, and is thus altogether lost; and in no case can it be utilized without great waste. This state of matters was entirely changed by the invention of Dellwik, improved by Fleischer, who found that the view that it is unavoidable to burn the carbon to monoxide during the blowing-up holds good only for the pressure of blast formerly applied. This did not much exceed that which is required for overcoming the frictional resistance within the producer. If, however, the pressure is considerably increased, and the height of the column of fuel reduced, both of these conditions being strictly regulated in accordance with the result desired, it is easy to attain a combustion of the carbon to dioxide, with only traces of monoxide, in spite of the high temperature. Evidently the excess of oxygen coming into contact with each particle of carbon in a given unit of time produces other conditions of chemical equilibrium than those existing at lower pressures. At any rate, experience has shown that by this process, in which the full heat-value of carbon is utilized during the blowing-up stage, the time of heating-up can be reduced from 10 to 1½ or 2 minutes, and the steaming can be prolonged from 4 or 5 to 8 or 10 minutes, with the result that twice the quantity of water gas formerly obtained, viz. 2·5 cub. met., is made from 1 kilogram of carbon.

The application of water gas as a fuel mainly depends upon the high temperatures which it is possible to attain by its aid, and these are principally due to the circumstance that it forms a much smaller flame than coal gas, not to speak of Siemens gas, which contains at most 33 per cent. of combustible matter against 90 per cent. or more in water gas. The latter circumstance also allows the gas to be conducted and distributed in pipes of moderate dimensions. Its application, apart from its use as an illuminant (with which we are not concerned here), was formerly retarded by its high cost in comparison with Siemens gas and other sources of heat, but as this state of affairs has been changed by the invention of the Dellwik-Fleischer process, its use is rapidly extending, especially for metallurgical purposes.

F. *Mixed Gas* (*Semi-Water Gas*).—This class is sometimes called Dowson gas, irrespective of its method of production, although it was made and extensively used a long time before Mr Dowson constructed his apparatus for generating such a gas principally for driving gas engines. By a combination of the processes for generating Siemens gas and water gas, it is produced by injecting into a gas producer at the same time a certain quantity of air and a corresponding quantity of steam, the latter never exceeding the amount which can be decomposed by the heat-absorbing reaction, $C + H_2O = CO + H_2$, at the expense of the heat generated by the action of the air in the reaction $C + O = CO$. Such gas used to be frequently obtained in an accidental way by introducing liquid water or steam into an ordinary gas producer for the purpose of facilitating its working by avoiding an excessive temperature, such as might cause the rapid destruction of the brickwork and the fusion of the ashes of the fuel into troublesome cakes. It was soon found that by proceeding in this way a certain advantage could be gained in regard to the consumption of fuel, as the heat abstracted by the steam from the brickwork and the fuel itself was usefully employed for decomposing water, its energy thus reappearing in the shape of a combustible gas. It is hardly necessary to mention explicitly that the total heat obtained by any such process from a given quantity of carbon (or hydrogen) can in no case exceed that which is generated by direct combustion; some inventors, however, whether inadvertently or intentionally, have actually represented this to be possible, in manifest violation of the law of the conservation of energy.

Some of the best-known apparatus belonging to this class are the Munich or Schilling-Bunte generator, the Wilson producer, and the Loomis producer. The Dowson producer has been already mentioned. The gas they yield differs very much in composition, but is always much richer in hydrogen (of which it contains sometimes as much as 20 per cent.) and poorer in carbon monoxide (sometimes down to 20 per cent.) than Siemens gas; generally it contains more of CO_2 than the latter. The proportion of nitrogen is always less, about 50 per cent. It is therefore a more concentrated fuel than Siemens gas, and better adapted to the driving of gas engines. It costs hardly more to make than ordinary Siemens gas, except where the steam is generated and superheated in special apparatus, as is done in the Dowson producer, which, on the other hand, yields a correspondingly better gas. As is natural, its properties are some way between those of Siemens gas and of water gas; but they approach more nearly the former, both as to cost and as to fuel-value, and also as to the temperatures reached in combustion. This is easily understood if we consider that gas of just the same description can be obtained by mixing one volume of real water gas with the four volumes of Siemens gas made during the blowing-up stage—an operation which is certainly too expensive for practical use.

A modification of this gas is the *Mond gas*, which is made, according to Mond's patent, by means of such an excess of steam that most of the nitrogen of the coke is converted into ammonia (Grouven's reaction). Of course much of this steam passes on undecomposed, and the quantity of the gas is greatly increased by the reaction $C + 2H_2O = CO_2 + 2H_2$; hence the fuel-value of this gas is less than that of gas made in other ways. Against this loss must be set the gain of ammonia which is recovered by means of an arrangement of coolers and scrubbers, and, except at very low prices of ammonia, the profit thus made is probably more than sufficient to cover the extra cost. But as the process requires very large and expensive plant, and its profits would vanish in the case of the value of ammonia becoming much lower (a result which would very probably follow if it were somewhat generally introduced), it is no matter of surprise that it has hitherto found only a very limited application.

G. *Air Gas.*—By forcing air over or through volatile inflammable liquids a gaseous mixture can be obtained which burns with a bright flame and which can be used for illumination. Its employment for heating purposes is quite exceptional, *e.g.*, in chemical laboratories, and we abstain, therefore, from describing any of the numerous appliances, some of them bearing very fanciful names, which have been devised for its manufacture. (G. L.)

Gas Plants for Power Purposes.—The term *Producer Gas*, *Generator Gas*, or *Poor Gas* (*gaz pauvre*), as the French prefer to call it, is applied to non-luminous heating gas made by passing air, or air and steam together, through incandescent carbonaceous fuel. As is well known, the ordinary town gas used for lighting purposes (see p. 590 *ante*, and 9th edition, vol. x. p. 87) is produced by the destructive distillation of bituminous coal in retorts highly heated by external fires. The apparatus in which producer gas is made has no external fire, and the small amount of distillation which occurs is of secondary importance. The producer usually consists of a vertical cylindrical or rectangular iron casing, lined with fire-bricks; on the top there is a feeding hopper and valve, and near the bottom is a grate or hearth on which a fire is built up. In some producers air is drawn into the producer by suction, in some it is forced in by a blower, and in others a jet of steam is used to inject the air. In the latter case the air is mixed with steam when it enters the fire. (See GASEOUS FUEL.)

When air alone is used, the oxygen combines with the carbon of the fuel, and either or both of the following reactions occur, according to the temperature and other conditions in the producer. At first carbon dioxide (CO_2) may be formed, and in that case the greater part of this is afterwards reduced to the monoxide (CO), as it ascends the column of heated fuel. The well-known reactions which occur are thus expressed: $C + O_2 = CO_2$, and $CO_2 + C = 2CO$. If the temperature developed is about 1000° C. or higher, carbon monoxide is probably formed without the intermediate formation of carbon dioxide, but in practice there is always more or less of the dioxide mixed with the monoxide. When bituminous coal is used in the producer some of the hydrocarbons are oxidized, others are decomposed and converted into olefiant gas (C_2H_4) and marsh gas (CH_4), while others leave the producer in the form of condensable vapours which mix with the currents of hot gas. When steam is mixed with the air it is decomposed on coming in contact with the heated fuel, and the resultant gases are hydrogen, carbon monoxide, and carbon dioxide. The reactions are $H_2O + C = H_2 + CO$ and $2H_2O + C = 2H_2 + CO_2$.

The earlier examples of gas-producers were used for furnace work; and, owing to Sir William Siemens's skilful application of producer gas to the regenerative furnaces which he devised (see GASEOUS FUEL and *Ency. Brit.*, 9th ed., vol. xxii. p. 37), his system and various modifications of it are much used in all manufacturing countries for metallurgical and other work. Fig. 1 represents an

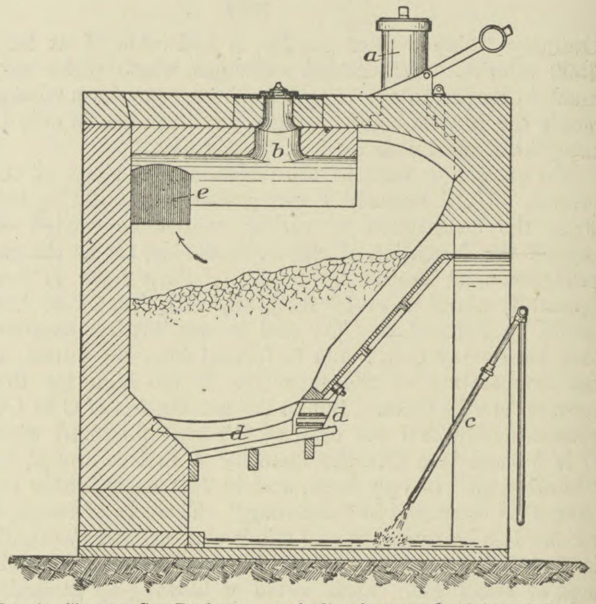


FIG. 1.—Siemens Gas Producer. *a*, feeding hopper; *b*, stoking holes; *c*, water supply (in some producers steam is introduced instead of water); *d*, *d*, horizontal and inclined fire-bars; *e*, gas outlet.

ordinary type of Siemens producer. In producers used for furnace work the hot crude gas is taken directly from the producer to the furnace, and the gas is usually made with bituminous or semi-bituminous coal; the tarry vapours distilled off in the producer mix with the gas and enrich it, and all are burnt in the furnace.

The chemical composition of ordinary producer gas, as used in furnaces, depends somewhat on the nature of the coal used, but it usually contains about 24 to 27 per cent. of carbon monoxide, and only 5 to 10 per cent. of hydrogen. It is not suitable for driving gas engines, as it is too weak and does not ignite promptly enough in the cylinder. For engine work the gas should contain not less than 15 per cent. of hydrogen, and its calorific power should not be less than 1200 calories per cubic metre, or 140 British thermal units per cubic foot, at 0° C. and 760 mm.; moreover, it must not carry tar or other impurities, and it must be cool and fairly constant in quality and pressure. It was therefore necessary not only to improve the quality of the gas, but to devise complete apparatus for cooling and cleaning it, and for fulfilling the other conditions required. The first to do this was J. E. Dowson. The Dowson plant was tried for the first time with a small Otto engine in 1879 by Messrs Crossley of Manchester, and in 1881 the same engine and gas plant were tested by Mr D. K. Clark, on behalf of the committee of the Smoke Abatement Exhibition, South Kensington, who awarded the inventor a special prize given by Sir William Siemens. As a measure of what this has led to, it may be mentioned that up to the end of 1899 gas engines developing an aggregate of about 60,000 h.p. were working with gas made in the Dowson plant. From time to time various other gas plants for engine work have been introduced, and broadly they may be divided into three types, as follows:—

A. Producer with jet of superheated steam forcing in air, *e.g.*, the *Dowson* plant.

B. Producer without steam-jet, and with blower to force in air, *e.g.*, the *Lencauchez* and the *Mond* plants.

C. Producer without steam-jet and without blower, the air being drawn into the producer by a suction-pump attached to the gas engine, *e.g.*, the *Bénier* plant.

The first type, A, is represented in Fig. 2.

The boiler is provided with superheating tubes, and a jet of dry steam is used for the double purpose of supplying the steam to be decomposed, and of carrying an induced current of air into the gas generator to maintain combustion of the fuel and develop the high temperature required for the necessary chemical reactions to take place. In practice about 90 per cent. of the steam produced in the boiler is decomposed in the gas generator, the remainder being lost; and it may here be noted that the percentage of hydrogen in the gas is not an exact measure of the quantity of steam decomposed, as some of the hydrogen is derived from the coal in the generator. In practical work, when anthracite is used in the generator, about ⅘ lb of steam is decomposed for each pound of anthracite consumed, and this can be done without having more than about 5 per cent. of carbon dioxide in the resultant gas. The following table gives the results of tests made by different authorities with the Dowson gas plant, when working with anthracite in the generator:—

Table showing Results of Tests with Dowson Gas Plant.

No. of Trial.	Date of Trial.	Locality.	B.H.P. of Plant.	Volume of Gas produced, at 0° C. and 760 mm. per kilo. of Anthracite consumed in Generator + Coke consumed in Boiler.	Volumetric Composition of Gas per cent. Hydrogen.	Marsh Gas, CH_4.	Olefiant Gas. C_2H_4.	Carbon Monoxide.	Carbon Dioxide.	Oxygen.	Nitrogen, &c.	Heat-value of Fuel consumed.	Heat-value of Gas, produced at 0° C. and 760 mm.	Heat-efficiency of Plant per cent.	Heat-value of One Cubic Metre of Gas produced, at 0° C. and 760 mm.	Authority.
				Cubic Metres.								Calories.	Calories.		Calories.	
1	Jan. 1883	Battersea . .	8	5·00	18·73	·31	·31	25·07	6·57	·03	48·98	9350	7100	75·9	1420	Prof. W. Foster, F.C.S., London.
2	Nov. 1885	Rouen, France .	8	..	..	..	..	..	..	..	..	..	..	..	1350*	Prof. A. Witz, Lille University.
3	July 1889	Schwabing, Germany	60	5·02	17·00	2·00	..	23·00	6·00	..	52·00	8790	7130	81·1	1420	Mr F. Uppenborn, Munich.
4	Jan. 1890	Canale, Italy . .	40	4·74	16·67	..	..	27·50	8·40	·90	46·73	8740	6450	73·8	1360	Dr C. Monaco, Turin.
5	April 1890	London . . .	10	..	24·00	..	..	22·50	7·50	..	46·00	..	..	..	1430	Dr Langer, London.
6	Sept. 1890	Rouen, France .	100	..	..	..	..	..	..	..	..	..	..	..	1487*	Prof. A. Witz, Lille University.
7	June 1894	Sabadell, Spain .	120	5·34	16·50	1·00	..	25·40	4·80	1·20	51·10	9160	7390	80·7	1384	,, ,, ,,
8	Feb. 1897	Basingstoke . .	40	5·04	19·80	1·30	..	23·80	6·30	..	48·80	9500	7370	77·6	1463	Mr G. C. Jones, F.C.S., London.
9	April 1898	Millwall . . .	250	5·07	15·30	1·40	..	27·60	3·90	..	51·80	9120	7350	80·6	1451	,, ,, ,,
10	April 1898	Openshaw . .	300	4·88	17·50	2·10	..	26·50	4·40	..	49·50	9200	7570	82·3	1552	,, ,, ,,
				Average	18·18	..	..	25·17	5·98	..	49·36	9123	7194	78·9	1432	

* By calorimetric bombs.

From this summary it will be seen that the average calorific power of the gas tested is 1432 calories per cubic metre, or 161 B.T.U. per cubic foot, at 0° C. and 760 mm.; while the average heat-efficiency of the plant is 78·9 per cent., one plant giving as much as 81·1 and another 82·3 per cent. If an efficiency of 80 per cent. is assumed, the loss of heat may be accounted for approximately as follows:—

Loss in steam boiler	7 per cent.
Steam not decomposed in generator .	1 ,, ,,
Unburnt anthracite lost in ashes . .	2 ,, ,,
Sensible heat of gas lost in cooling and scrubbing and in radiation from the generator	10 ,, ,,
	20 per cent.

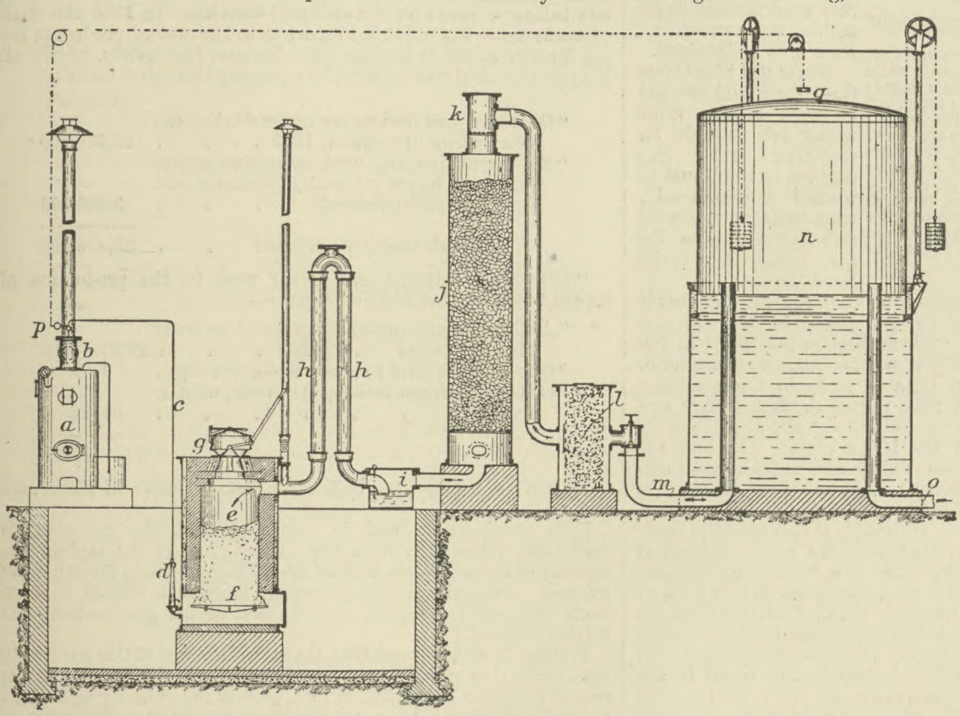


FIG. 2.—Dowson Gas Plant. *a*, boiler; *b*, steam superheater; *c*, steam pipe; *d*, air injector; *e*, gas generator; *f*, fire-bars; *g*, feeding hopper; *h*, *h*, cooling pipes; *i*, hydraulic box with water seal; *j*, coke scrubber; *k*, washer; *l*, sawdust scrubber; *m*, inlet of gasholder; *n*, gasholder; *o*, outlet of gasholder; *p*, valve with weighted lever to regulate admission of steam to gas generator; *q*, weight to actuate lever *p* by rise or fall of gasholder.

In the Lencauchez plant, which is an example of the second type, B, there is no boiler, the gas being made by forcing air from a blower into the gas generator, and there saturating it with moisture before it enters the fire. When good gas has been made and the engine is running, the blower is driven by the engine, but when the latter is not working it is driven by hand power. Some of these plants are working in France, and though a few have been tested for the fuel consumption per h.p., none appear to have been tested thoroughly as to their heat-efficiency, &c. Professor Witz of Lille refers to this plant in his *Moteurs à Gaz*, but seems doubtful about the heat value of the gas. Dr Ludwig Mond's plant (see also GASEOUS FUEL) was devised primarily for the recovery of ammonium sulphate, and the gas produced was of secondary importance. At first all the gas was used for heating furnaces, but afterwards trials with a gas engine showed that it was suitable for such work, and several engines are now working with it at the chemical works of Messrs Brunner, Mond, and Company. To be profitable, a recovery plant of this kind must be worked on a large scale, night and day; in the existing plant each producer makes gas enough for about 2000 h.p. an hour, and the bulk of the gas is still used for furnace work. The plant is worked with bituminous coal, the tar being removed by an elaborate system of washing and scrubbing. The calorific power of the gas, calculated from its published analysis, is 1385 calories per cubic metre, or 155·6 B.T.U. per cubic foot, at 0° C. and 760 mm. The percentage of hydrogen (24·8) is high, but against this the carbon monoxide is only 13·2, while the carbon dioxide is as high as 12·9. It has been proposed to work a plant of this type without the recovery of ammonium sulphate, and if this were done the working would be nearly on the same lines as those of the Lencauchez plant.

In the third type of plant, C, *e.g.*, Bénier's (Fig. 3), there is no steam boiler or air-blower, the air being drawn into the producer by a suction-pump attached to the engine. The quantity of air drawn in varies with the load on the engine; and, as it is governed by the engine itself, the storage of gas in a holder is dispensed with altogether. The whole plant consists merely of a producer, a washer, and a scrubber. Water is vaporized in the fire-grate, which is of special construction, and the water vapour mixes with the air before the latter enters the fuel column. The idea is ingenious, but the results obtained have not been encouraging. Professor Witz of Lille tested it carefully with an engine of about 15 b.h.p. The first trial was with English anthracite of good quality, and the calorific power of the gas was only 1149 calories per cubic metre, or 129 B.T.U. per cubic foot, at 0° C. and 760 mm. The engine developed 27·6 i.h.p., but only 14·59 b.h.p.; while the consumption of anthracite was 714 grams, or 1·57 ℔ per b.h.p. per hour. A second trial was made with ordinary gas coke in the generator, and the calorific power of the gas was then as low as 1035 calories per cubic metre, or 116 B.T.U. per cubic foot, at 0° C. and 760 mm. The engine developed 14·7 b.h.p., and the consumption of coke was 752 grams, or 1·66 ℔ per b.h.p. per hour. These results were with a full load on the engine, and it is probable that the gas would have been still weaker if the load had been much reduced, as the temperature of the fuel most favourable for making the gas would not have been maintained.

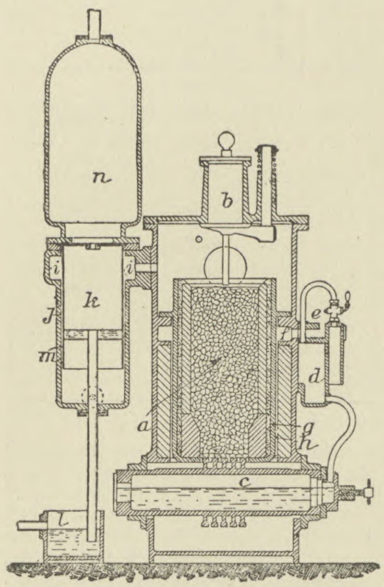


FIG. 3.—Bénier Gas Plant. *a*, gas generator; *b*, feeding hopper; *c*, revolving grate with water inside; *d*, chamber to receive steam from *c*; *e*, air inlet; *f*, mixing chamber for steam and air at atmospheric pressure; *g*, inner casing of generator; *h*, annular space for steam and air to pass from *f* to bottom of fire, the steam and air being heated on the way; *i*, *i*, annular space for hot gas from generator; *j*, cylinder with water inside; *k*, inner tube, of which lower end is dipped in water, with overflow leading to tank *l*; *m*, annular space for gas to pass from *i* to interior of *k*; *n*, chamber for gas.

Water gas plants (see GASEOUS FUEL) are not included among those which are suitable for working with gas engines, as they must be worked intermittently, with frequent reversals, and the quality of the gas necessarily varies considerably.

Fuel.

Owing to the difficulty of removing tar from generator gas made with bituminous coal, most of the gas plants in use with gas engines are worked with anthracite (*Ency. Brit.*, 9th ed., ii. 106). Formerly it was necessary to use nuts or cobbles, but with a suitable grate in the generator the size known as peas (which have passed through $\frac{3}{4}$ inch and over $\frac{3}{8}$ or $\frac{3}{16}$ inch openings in the screens at the pit) is extensively employed, being cheaper than the larger sizes. The best anthracite is found in the Swansea Valley and neighbouring districts; and, owing to the development of the gas-power industry, a new trade has sprung up for suitable anthracite, and a considerable quantity is exported. Some anthracite is also found in Scotland, but, with the exception of that from the neighbourhood of Coltness, it is not good; even the latter is a little more troublesome to work with than the Welsh for gas engines, as it is more or less mixed with bituminous compounds. On the Continent anthracite is found in Belgium, at Kohlscheid near Aachen (Aix-la-Chapelle) in Germany, and in Russia and Spain; a *charbon maigre* (lean coal) which is anthracitic, but of inferior quality, is also found in the department of the Nord and elsewhere in France. There are immense beds of excellent anthracite in Pennsylvania; there is some in Japan, and it is reported that there are large fields of it undeveloped in China. Ordinary gas coke can also be used for generator gas instead of anthracite, provided it is of good quality, clean, and in small pieces; and there are some installations of gas power (*e.g.*, at the Elswick Works of Messrs Armstrong, Whitworth, and Company) where no other fuel has been adopted, and where the results have been satisfactory. Coke that yields an excessive amount of clinker, as well as much tar and sulphur, should be avoided. With bituminous coal the difficulties are increased when the plant is worked on a comparatively small scale, *e.g.*, 200 b.h.p.; but promising trials with bituminous coal have recently been made in a modified plant of the type A, and it is expected that plants of moderate size will soon be working with tar-yielding coal. Dr Mond's large plant is the only one which is worked regularly with bituminous coal and yields a gas suitable for gas engines.

Reference to the table will show that in type A the production of gas at 0° C. and 760 mm. is about 5 cubic metres per kilogram, or 80 cubic feet per ℔, of anthracite consumed in the gas generator. When this gas is used for driving an engine the total fuel consumption (including anthracite in the generator and coal or coke in the little boiler which supplies it with steam) is about 1 ℔ (454 grams) per b.h.p. per hour. The consumption of water varies with the size and type of plant used. For type A it is as under, and in order that a comparison may be made with the water required for a steam boiler of the same h.p., the figures for the latter are added on the basis of 20 ℔ of water per b.h.p.

	Pounds of Water per Hour.	
	Gas Plant.	Steam Boiler.
100 brake h.p. . .	300	2000
200 ,, ,, . .	400	4000
300 ,, ,, . .	500	6000

With ordinary care the cost of repairs is moderate. For type A the following averages (based on several years' experience) may be taken as approximately correct, exclusive of painting:—

For 100 brake h.p.	plant	about	£4	per	annum.
,, 200	,,	,,	,,	6	,,	,,
,, 300	,,	,,	,,	8	,,	,,
,, 400	,,	,,	,,	12	,,	,,
,, 500	,,	,,	,,	14	,,	,,

Cost of gas.

The cost of the gas depends somewhat on the price of fuel and wages, and on the scale of production. In a plant of moderate size of type A working with anthracite peas costing 16s. per ton, the gas usually costs from 2d. to 3d. per 1000 cubic feet filled into the gasholder, including fuel, wages, and repairs. Gas of this kind made with anthracite nuts has been used regularly for several years at the Gloucester County Asylum for driving engines, as well as for all the cooking and baking of bread for the staff and inmates. In 1895 the clerk of works made the following report as to the cost of producing the gas for a year, and it is given here because, fortunately, nearly all the gas produced was measured by passing through a meter:—

	Cubic feet.
"Quantity produced as per meter during the year ending 31st March 1895 . . .	22,211,700
"Estimated quantity used by engine pumping three hours a day at 3000 cubic feet per hour (not registered) . . .	3,285,000
"Total quantity produced . .	25,496,700

"Details of material and labour used in the production of 25,496,700 cubic feet of Dowson gas:—

	£	s.	d.
"Anthracite coal [nuts], 124 tons 19 cwts. at 21s. 2d. per ton	£132	4	10
"One year's repairs to plant at 6d. per day .	9	2	6
"Gasman's wages, making gas only, at 21s. a week	54	12	0
	£195	19	4

"Thus costing $1\frac{7}{8}$d. per 1000 cubic feet, exclusive of slack used for steam boiler."

[The small boiler used in connexion with the gas plant is fired with ashes, &c., from the various fires in the asylum; no account of these is kept, as they are treated as waste for any other purpose. Recently the gas generators have been altered so as to work with anthracite peas, and the cost of the gas has been still further reduced.]

It must be remembered that the calorific power of this gas is only one-fourth that of ordinary town gas; the cost of the generator gas should therefore be multiplied by 4, so that the quantity equivalent to 1000 cubic feet of town gas usually costs from 8 to 12 pence.

The loss of fuel in a gas generator when standing with a fire in it is much smaller than in a steam boiler of the same h.p. A series of tests extending over several days, made at Messrs Crossley's works with a 250-h.p. generator, showed an average loss of only $5\frac{1}{2}$ pounds per standing hour. In smaller plants it is even less.

Heat-efficiency.

The heat-efficiency of the gas plant is a measure of the heat lost in the transformation of the solid fuel into gas suitable for working an engine. To determine this efficiency, account should be taken of all the fuel consumed in connexion with the apparatus used for making the gas, and a balance-sheet should be prepared showing what percentage of the heat energy contained in all the fuel consumed is available in the gas finally passed into the holder. This basis of comparison should be adopted for all types of gas plants, since no other can be correct. If the steam decomposed in the gas generator is produced in an independent boiler, as in type A, the fuel consumption in the latter should be included; or if air is forced into the generator by engine power, as in type B, the expenditure of heat-energy which this involves should be included. The heat-value of the fuel, as well as that of the gas, should be determined, also the volume of gas produced per unit of fuel consumed. For practical purposes it is more simple to determine the heat-value of the gas by a calorimeter (Dowson's or Junker's), or by a calorimetric bomb (Mahler's), than by analysing the gas.

The calorific powers given in Table A and elsewhere are based on the following heat values:—

Hydrogen . . .	3,070	calories per cubic metre.
Marsh gas, CH_4 . .	9,550	,, ,,
Olefiant gas, C_2H_4 .	14,970	,, ,,
Carbon monoxide, CO .	3,070	,, ,,

The calorific power of the fuel, where it was not tested by calorimeter, has been calculated from the formula

$$80{\cdot}8\ C + 345\left(H - \frac{O}{8}\right) + 25\ S,$$

where C, H, O, and S represent the percentages of carbon, hydrogen, oxygen, and sulphur in the fuel. One cubic metre of CO, CO_2, or CH_4 contains 537·6 grams of carbon, and one cubic metre of C_2H_4 contains 1075·2 grams of carbon. All the calculations as to calorific power are also based on the standard temperature and pressure of 0° C and 760 mm., and all the steam derived from the combustion of the fuel or gas is treated as condensed. Some experimenters do not treat the steam as though it were condensed, and deduct its latent heat from the heat-value of the gas. It should, however, be remembered that in considering the production of gas in a gas plant, and in stating a balance-sheet of the heat units, we should on the one side give all those in the solid fuel consumed, and on the other side the total heat units the gas derived from it is capable of yielding when burnt to the best advantage. When the hydrogen in the gas is burnt steam is produced, and the latent heat of this steam is available for heating purposes; the latent heat of the steam should therefore be included in the heat units derivable from combustion of the gas. It happens that in the gas engine of to-day the exhaust products leave at a high temperature, so that the steam formed on combustion of the hydrogen in the cylinder is not condensed; if there were complete expansion the steam would be condensed. The present loss of the latent heat of the steam is due entirely to the engine, and should not be debited to the process of making the gas.

Theoretically, one volume of generator gas requires little more than one volume of air for its combustion, whereas ordinary town gas requires from 5 to 6 volumes of air to one of gas. For this reason it is possible to get into an engine cylinder of given capacity four times more of generator gas than town gas, with the proportion of air required. In practice the same cylinders are used for both kinds of gas; but the maximum h.p. obtainable with generator gas is usually from 10 to 12 per cent. less than with town gas. In engines of the Otto type a space is provided in the cylinder in which the charge of gas and air is compressed, and as this remains full of spent products of combustion after the exhaust is closed, it follows that these products mix with and dilute the next ingoing charge of gas. This is disadvantageous for generator gas, as it is already weakened by the presence of about 50 per cent. of nitrogen and carbon dioxide; and in the early engines, where a compression of only 35 lb per square inch was in vogue, it was difficult to ensure prompt and regular ignition of the charge. When the slide-valve was superseded, it became possible to raise the compression before ignition without trouble from excessive friction, and this is now usual. Fig. 4 represents an indicator diagram taken on a Crossley engine working with Dowson gas, and in this

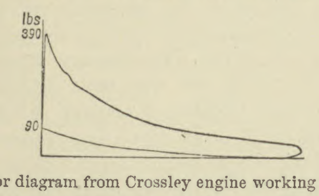


FIG. 4.—Indicator diagram from Crossley engine working with Dowson gas.

Pressures { Compression before ignition 90 lb per sq. inch.
Maximum after explosion . 390 ,, ,,
Mean ,, ,, . 94·6 ,, ,, }

the compression is 90 lb, while the mean pressure is as high as 94·6 lb per square inch. When running at 170 revolutions per minute the engine developed a maximum of 44·1 i.h.p. and 38·6 b.h.p.; at a speed of 220 revolutions per minute it gave a maximum of 57·3 i.h.p. and 48·8 b.h.p. With the earlier low compression the molecules of oxygen, surrounded more or less by inert gas, were too far apart from those of the hydrogen and carbon monoxide, and the high compression now used has remedied this defect to a great extent. A still further improvement is the removal or *scavenging* of all products of combustion from the compression space in the cylinder. Apart from ensuring a more prompt and more regular ignition of the charge, scavenging reduces the risk of the explosive mixture being fired prematurely. With non-scavenging engines of large size there is often a good deal of trouble owing to the liability of the new charge to be fired by some of the hot residual products in the cylinder. By scavenging, these hot products are displaced by air, which also helps to cool the cylinder and piston. Another consideration is that if, from any cause, the explosive charge in a non-scavenging engine is not fired, there is a much stronger charge to fire after the next intake of gas, because some of the products of combustion from the last charge fired are displaced by new gas and air. After a misfire in a non-scavenging engine of large size the explosive force is excessive, and has to be provided for by specially strengthening the engine. With a scavenging engine this trouble is avoided.

A steam engine is associated with a boiler, which should be able at all times to yield the maximum quantity of steam required; and in the same way the gas plant should be able to supply the maximum quantity of gas required by the engine or engines associated with it. If the gas generator or generators have ample producing power, there is no need to store much gas in a holder; the gas should be made as quickly as it can be consumed, just as a steam boiler makes steam as quickly as it is wanted. A gas plant need not occupy more ground space than is required for a horizontal boiler of about the same horse-power, and no chimney-stalk is needed. To avoid an over-production of gas when the load on the engine falls off, the rate at which the gas is made should be governed automatically to suit a varying rate of consumption. In the Dowson plant this is done by using the rise and fall of the gasholder to regulate the quantity of steam and air sent into the generator (Fig. 2); the maximum production of the latter can be reduced easily by 30 or 40 per cent., and in some sizes by 50 per cent., without appreciably affecting the quality of the gas. Two or more gas generators can work together as easily as a bench of retorts in a lighting gas plant. Generator gas does not condense or deteriorate by cooling or storage, or by travelling through long pipes; on the contrary, for the good working of an engine it is desirable that the charge of gas admitted to the cylinder should be cool, so that a given volume may yield as much energy as possible. Generator gas is made rapidly, and in a plant of moderate size it usually leaves the generator at a temperature of about 900° F. (500° C.). Special attention should therefore be given to the cooling of the gas, so that when it leaves the gasholder its temperature should not be higher than that of the surrounding air; it should also be well washed and scrubbed. The gas plant, as a whole, should be compact and easy to work, and its first cost should not be excessive. As a final note, it is interesting to observe that a modern Dowson gas plant is now working regularly at the historical works of Boulton and Watt, at Soho, Birmingham, and that the holder used for this gas is one which was erected there by William Murdoch, the pioneer of gas lighting (see *Ency. Brit.*, 9th ed., vol. x. p. 88).

AUTHORITIES.—AYRTON. "De l'emploi des moteurs à gaz pour la production de l'electricité," *Revue industrielle*, 5th October 1881; *Electrician*, 10th December 1881.—AYRTON and PERRY. "The Gas Engine Indicator Diagram," *Proc. Physical Soc.* and *Phil. Mag.*, July 1884.—BRAMWELL. Presidential Address, *Proc. Inst. C. E.*, 1885.—CLERK. "Recent Development in Gas Engines," *Proc. Inst. C. E.*, 1896; *The Gas and Oil Engine*, London, 1897.—DONKIN. *Gas, Oil, and Air Engines*, London, 1896.—DOWSON. "On the Economical Effect of using Cheap Gas for Gas Motors, with a Description of Apparatus for producing such Gas," *Brit. Assoc.*, 1881; "The Production and Use of Gas for Heating and Motive Power," *Jour. Soc. Arts*, 1882; "Cheap Gas for Motive Power," *Proc. Inst. C. E.*, 1883; "Gas Power compared with Steam Power," *Proc. Inst. C. E.*, 1887; "Gaseous Fuel," *Brit. Assoc.*, 1888; "Gas Power for Electric Lighting," *Proc. Inst. C. E.*, 1893; "Gas Power," *Trans. Gas Inst.*, 1893; "Gas Power," *Trans. Inst. Min. Eng.*, 1898; "Gas Power," *Proc. Cleveland Inst. Eng.*, 1899.—ELLIOTT. *Gas and Petroleum Engines*, London, 1898.—*Engineer*, "Dowson's Gas as a Motive Power," 2nd November 1883.—*Engineering*, "Gas Engine," 26th March 1886.—HUMPHREY. "The Mond Gas-Producer Plant and its Application," *Proc. Inst. C. E.*, 1897.—JENKIN. "On Gas and Caloric Engines," Forrest Lecture, Inst. C. E., 1884.—KENNEDY. "Possible and Impossible Economies in the Utilisation of Energy," *Proc. Roy. Inst.*, 1893.—MEYER. "Versuche an der 160 pferdigen Kraftgasanlage mit koksgeneratoren des Gas und Wasserwerkes zu Basel," *Zeitschrift des Vereines Deutscher Ingenieure*, Berlin, 1896.—NORRIS. *The Otto Cycle Gas Engine*, London, 1896.—PERRY. *The Steam Engine and Gas and Oil Engines*, London, 1899. — ROBINSON. *Gas and Petroleum Engines*, London, 1890.—SCHÖTTLER. *Die Gasmaschine*, Brunswick, 1899.—SMOKE ABATEMENT COMMITTEE. *Report*, London, 1883.—WITZ. *Moteurs à gaz*, vols. i. ii. iii., Paris, 1892–95–99.

(J. E. DO.)

Gases, Condensation of. See Condensation of Gases.

Gases, Diffusion of. See Diffusion of Gases.

Gastein, a valley in the Austrian duchy of Salzburg, celebrated for its mineral springs. The visitors number about 8000 annually, of whom three-fourths stay at Wildbad (population, 558). There is now a Protestant church belonging to the German Emperor. The mountain torrent, the Ache, supplies motive-power for the electric lighting of the district, which has made considerable progress in the matter of accommodation for its increasing stream of visitors, including a sheltered glass gallery, or kurhaus, for rainy weather. It was at Gastein (August–September 1879) that Prince Bismarck negotiated the Austro-German Treaty with Count Julius Andrassy. In 1890 the population of the entire valley was 4372, and in 1900, 4436.

Gateshead, a municipal, parliamentary, and county borough of Durham, England. It has greatly extended, but although one of the largest towns in the county, neither its streets nor its public buildings, except perhaps its ecclesiastical buildings, make any claim to architectural beauty. The area of the borough is 3300 acres; population (1881), 65,845; (1891), 85,692; (1901), 109,887. Between 1881 and 1899 the rateable value increased from £220,000 to £359,562. The birth and death rates, 36·2 and 20·4 per 1000 respectively, show no great change over a series of years. The number of voters for the borough member of Parliament is (1900) 17,065. For municipal purposes the town is divided into ten wards, each of which returns three members to the Town Council. The town possesses a children's hospital, a very efficient school of art, and public library, and a workhouse, built at a cost of £40,000, providing accommodation for 1000 inmates. The School Board has seventeen schools under its control. Technical education is provided in the Higher Grade School (1891). A large day school for girls has also been established. Steam trams run through the main streets, and the Corporation have built suitable swimming-baths and wash-houses. More than two thousand hands are employed in the North-Eastern locomotive depôt. Large gas works of the Newcastle and Gateshead Gas Company are also situated in the borough.

Gauhati, a town of British India, in the Kamrup district of Assam, on the left bank of the Brahmaputra, with a population in 1881 of 11,695, and in 1891 of 8283. The municipal income in 1897–98 was Rs.46,800. It is still the headquarters of the district, though no longer a military cantonment, and is the river terminus of a section of the Assam–Bengal railway. There are a government high school, with 195 pupils in 1896–97, a law class, a training school for masters, and four printing-presses. Gauhati suffered very severely from the earthquake of 12th June 1897.

Gaya, a city and district of British India, in the Patna division of Bengal. The city is situated 85 miles south of Patna by rail. Population (1881), 76,415; (1891), 80,383; (1901), 71,186. During the Mutiny the large store of treasure here was conveyed safely to Calcutta by Mr Money. The city contains a government high school, with 351 pupils in 1896–97, a hospital, with a Lady Elgin branch for women, and five printing-presses. The district of Gaya comprises an area of 4712 square miles. It had a population in 1881 of 2,124,682, and in 1891 of 2,138,331, giving an average density of 454 persons per square mile. Classified according to religion, Hindus numbered 1,911,254; Mahommedans, 226,705; Christians, 174, of whom 74 were Europeans; "others," 198. In 1901 the population was 2,064,077, showing a decrease of 3 per cent. The land revenue and rates were Rs.17,73,901; the number of police was 767; the number of boys at school in 1896–97 was 29,015, being 18·5 per cent. of the male population of school-going age; the registered death-rate in 1897 was 37·07 per thousand. Opium is largely cultivated, indigo hardly at all. There are forty-one lac factories, employing 1200 persons, with an annual out-turn valued at Rs.31,45,000. The district is traversed in the south by the Grand Trunk Road, and three branches of the East Indian Railway now run to Gaya city. In 1901 it suffered severely from the plague.

Gayangos y Arce, Pascual de (1809–1897), Spanish scholar and Orientalist, was born at Seville, 21st June 1809. At the age of thirteen he was sent for education to France, where he passed several years, and studied Arabic under Silvestre de Sacy. After a visit to England, where he married, he obtained a post in the Spanish Treasury, and was afterwards translator to the Foreign Office. In 1836 he returned to England, became well known in English society, wrote extensively in English periodicals, and translated Almakkari's *History of the Mahommedan Dynasties in Spain* for the Royal Asiatic Society. In England he also made the acquaintance of the American historian of Spanish literature, Ticknor, to whom he was very serviceable. In 1843 he returned to Spain as professor of Arabic at the university of Madrid, which post he held until 1881, when he was made director of public instruction. This office he resigned upon being elected senator for the district of Huelva. His latter years were almost equally divided between Spain and England, where he made a catalogue of the Spanish manuscripts in the British Museum: he had previously continued the work commenced by Mr Bergenroth in cataloguing the manuscripts relating to England in the archives of Simancas. His best known original work is his dissertation on Spanish romances of chivalry in Aribau's *Biblioteca de Autores Españoles*. He died in London on 4th October 1897.

Gaza, now Ghuzzeh, the most southerly of the five allied Philistine cities, situated, near the sea, at the point where the old trade routes from Egypt and Petra to Syria met. It was always a strong border fortress and a place of commercial importance. The earliest notice of it is in the Tell el-Amarna tablets, in a letter from the local governor, who then held it for Egypt. The history of Gaza is that of its many sieges from the time of Alexander to that of Richard Cœur de Lion. Under the Romans it prospered, but under the Moslems it gradually declined, and before the 14th century it had lost all its importance. Christianity made way slowly, and paganism was dominant until 400, when the temples and statues of Dagon (Marnas) were destroyed by imperial edict. The prosperity of Ghuzzeh has partially revived through the growing trade in barley, of which the average annual export to Great Britain for 1897–99 was over 30,000 tons. The population numbers 25,000, including 1000 Christians. The dress of the people is Egyptian rather than Syrian. The Church Missionary Society maintains a mission, with schools for both sexes, and a hospital.

Geelong, a seaport town, in the county of Grant, Victoria, Australia, on the western arm (Corio Bay) of Port Phillip Bay, 45 miles south-west of Melbourne, with which it is connected by rail. Corio Bay is entered by two channels across the bar, one of which—the New Channel—has a depth of 23½ feet. The harbour has four jetties, affording extensive quayage, and vessels drawing 17 to 19 feet can lie alongside at low water. The first woollen mill in the state was established here, and the cloths, tweeds, and woollen fabries of the town are noted throughout Australia. Extensive vineyards were destroyed under the Phylloxera Aet, but replanting has commenced throughout the district. There are three parks and a botanie garden. There are extensive tanneries and rope works, and at Fyansford, 3 miles distant, is a large paper mill. Five reservoirs for water supply have a capacity of over 500 million gallons. Population of the town of Geelong (1881), 9721; (1901), 12,399; of the borough of Geelong West (1881), 4845; (1901), 5860.

Geestemünde, a seaport town of Prussia, province of Hanover, on the right bank of the Weser, immediately south of Bremerhaven. It is a centre of the German North Sea fishing and the seat of a superior school of navigation. Since 1888 upwards of £800,000 has been spent upon harbour works and improvements. In 1899 the port was entered by 2416 vessels of 347,469 tons. Population (1885), 14,200; (1900), 20,113.

Gefle, a seaport town of Sweden, on a bay of the east coast, 112 miles by rail north-north-west from Stockholm. It is the ehief port of the productive eounty of Dalecarlia (Kopparberg), with its iron and copper mines and big forests, and the third eommereial port of the kingdom. The exports, which totalled £804,000 in 1885 and £1,705,400 in 1900, consist almost entirely of timber (£508,700 in 1887; £1,048,300 in 1900), iron and steel (£222,600 in 1888; £381,850 in 1900), and wood-pulp (£50,000 in 1892; £268,450 in 1900). The imports increased from £366,600 in 1885 to £678,400 in 1900. In 1900 the port was eleared by 918 vessels of 505,000 tons, of which 83 of 77,605 tons were British. The harbour, which has two entrances of about 20 feet depth, is usually elosed for four or five months in the winter. In 1897 the town authorities voted £60,000 for deepening and improving it. Large vessels usually load in the roads at Gråberg, 6 miles distant. In 1898 Gefle possessed a mercantile fleet of 40 to 50 vessels of some 22,000 tons. It is also a place of some industrial activity. At Skutskär (population 2000 in 1897), a new place at the mouth of the river, are a wood-pulp mill and one of the largest sawmills in Sweden. Population (1880), 18,758; (1890), 23,484; (1900), 29,522.

Gegenbaur, Carl (1826- ——), German anatomist, was born on the 21st August 1826 at Würzburg, at the university of which he was student (1845) and afterwards *docent*. In 1852–53 he studied the marine fauna on the Sieilian eoast. In 1855 he was appointed to a medical chair at Jena, where after 1865 his fellow-worker, Ernst Haeckel, was professor of zoology; and in 1858 Gegenbaur became ordinary professor of anatomy. In 1873 he was appointed to Heidelberg, where he became professor of anatomy and director of the Anatomical Institute. In 1875 he became editor of the *Morphologisches Jahrbuch*, but the work by which perhaps he is best known is his *Grundriss der vergleichenden Anatomie* (1874, 2nd edition 1878). This was translated into English by W. F. Jeffery Bell (*Elements of Comparative Anatomy*, 1878), with additions by Professor E. Ray Lankester. While reeognizing the importance of eomparative embryology in the study of descent, Gegenbaur lays stress on the higher value of comparative anatomy as the basis of the study of homologies, *i.e.*, of the relations between corresponding parts in different animals, as, for example, the arm of man, the foreleg of the horse, and the wing of a fowl. A distinetive piece of work was effected by him in 1871 in supplementing the evidenee adduced by Huxley in refutation of the theory of the origin of the skull from expanded vertebræ, whieh, formulated independently by Goethe and Oken, had been championed by Owen. Huxley demonstrated that the skull is built up of eartilaginous pieees; Gegenbaur showed that "in the lowest (gristly) fishes, where hints of the original vertebræ might be most expected, the skull is an unsegmented gristly brain-box, and that in higher forms the vertebral nature of the skull cannot be maintained, since many of the bones, notably those along the top of the skull, arise in the skin." Other publieations by Gegenbaur include a *Text-Book of Human Anatomy* (1883), the *Epiglottis* (1892), and *Comparative Anatomy of the Vertebrates in Relation to the Invertebrates* (vol. i., 1898).

Geibel, Emanuel (1815–1884), German poet, was born at Lübeck, 17th Oetober 1815, and was the son of a pastor in the eity. He was originally intended for his father's profession, but, determining to devote himself to philology and literature, accepted in 1838 a tutorship at Athens, where he remained until 1840. In the same year he brought out, in conjunction with his friend Ernst Curtius, a volume of translations from the Greek. His first poems, the *Zeitstimmen*, appeared in 1841; a tragedy, *King Roderick*, followed in 1849. In the same year he received a pension from the King of Prussia, which he retained until his invitation to Munich by the King of Bavaria in 1851 as honorary professor at the university. In the interim he had produced *König Sigurds Brautfahrt*, an epic, and *Juniuslieder*, lyrics in a more spirited and manlier style than his early poems. A volume published at Munich in 1857, and principally consisting of poems on elassical subjects, denoted a further considerable advance in objectivity, and the series was worthily elosed by the *Herbstlieder*, published in 1877. He had quitted Munich in 1869 and returned to Lübeck, where he died on the 6th of April 1884. His works further include two tragedies, *Brunhild*, 1858, and *Sophonisbe*, 1869, and translations of French and Italian popular poetry. Beginning with writing, as hostile eritics affirmed, "for boarding-school misses," Geibel gradually acquired vigour of thought and style, and, after Rückert and Platen, is perhaps the best representative of the modern German school of the poetry of literary culture. (R. G.)

Geikie, Sir Archibald (1835- ——), Scottish geologist, was born at Edinburgh on 28th December 1835. He was educated at the High School and University of Edinburgh, and in 1855 was appointed an assistant on the Geological Survey. Wielding the pen with no less facility than the hammer, he inaugurated his long list of works with *The Story of a Boulder; or, Gleanings from the Note-Book of a Geologist* (1858). His ability at once attracted the notice of his chief, Sir Roderick Murchison, with whom he formed a lifelong friendship, and whose biographer he subsequently became. The geological map of Scotland published in 1862 was their joint work. In 1865 appeared Geikie's *Scenery of Scotland* (3rd edition 1901), which was, he claimed, "the first attempt to elueidate in some detail the history of the topography of a country." At this time the Edinburgh school of geologists—prominent among them Sir Andrew Ramsay, with his *Physical Geology and Geography of Great Britain*—were maintaining the supreme importance of denudation in the eonfiguration of land-surfaces, and particularly the erosion of valleys by the action of running water. This view, now universally accepted, met with opposition from the old-fashioned school, who held that the main features of the earth's surface were determined by eataclysms of Nature. Geikie's book was an able contribution, based on extensive personal knowledge of the districts described, to the doctrines of the Edinburgh school, of which he himself soon began to rank as one of the leaders. Two years later, when a separate branch of the Geological Survey was established for Scotland, he was appointed director. On the foundation of the Murchison Professorship of Geology and Mineralogy at the University of Edinburgh in 1871, he became the first occupant of the chair. These two appointments he continued to hold till 1881, when he succeeded Sir Andrew Ramsay in the joint offices of Director-General of the Geological Survey of the United Kingdom and Director of the Museum of Practical Geology, London, from which he retired in February 1901. A feature of his tenure of the latter post was the impetus given to microscopic petrography, a branch of geology to which he had devoted special study, by a splendid collection of sections of British rocks. His official work on the Geological Survey culminated in his admirable *Geological Map of England and Wales, with descriptive notes* (1897). His intimate acquaintance with the geology of Scotland brought him face to face with, and helped him to solve, some of the most difficult problems of stratigraphy. Here he was greatly aided by his extensive travels, not only throughout Europe, but in Western America. In that world, new from the standpoint of geology no less than of civilization, the forces of Nature have acted both on a greater scale and with less complication. While the cañons of Colorado confirmed his long-standing views on erosion, the eruptive region of Oregon supplied him with valuable data for that study of volcanic phenomena which has been the chief work of his later years. His researches, first given to the world in his presidential addresses to the Geological Society in 1891 and 1892, were embodied in his great work on *The Ancient Volcanoes of Great Britain* (1897), which sums up the present state of our knowledge on the whole question of volcanic disturbances. He lays down the two important generalizations, that in the same area the sequence of volcanic matter erupted is constant, and that the composition and structure of lavas of all ages remain the same. Other results of his travels are collected in his *Geological Sketches at Home and Abroad* (1882). His experience as a field geologist resulted in an admirable text-book, *Outlines of Field Geology* (5th edition 1900). After editing and practically re-writing Jukes's *Student's Manual of Geology* in 1872, he published a *Text-Book* and a *Class-Book* of geology, which have taken rank as standard works of their kind. His writings are marked in a high degree by charm of style and power of vivid description. His literary ability has given him peculiar qualifications as a writer of scientific biography, and his *Memoir* of his old chief Sir Andrew Crombie Ramsay (1895) is a model of what such a work should be. His *Founders of Geology* consists of the inaugural course of Williams Lectures at the Johns Hopkins University, Baltimore, delivered in 1897. In 1898 he delivered the Romanes Lectures, and his address was published under the title of *Types of Scenery and their Influence on Literature*. The study of geography owes its improved position in Great Britain largely to his efforts. Among his works on this subject is *The Teaching of Geography* (1887). He was foreign secretary of the Royal Society from 1890 to 1894, president of the Geological Society in 1891 and 1892, and president of the British Association 1892. He received the honour of knighthood in 1891.

Geikie, James (1839– ——), younger brother of Sir Archibald, and like him a distinguished geologist, was born at Edinburgh on 23rd August 1839. He entered the Geological Survey in 1861, and in 1882 succeeded his brother as Murchison Professor of Geology and Mineralogy at the University of Edinburgh. He has taken as his special subject of investigation the origin of surface-features, and in particular the part played in their formation by glacial action. His views are embodied in his chief work, *The Great Ice Age and its Relation to the Antiquity of Man* (1874; 3rd edition 1894). He is the leader of the school that upholds the all-important action of land-ice, as against those geologists who assign chief importance to the work of pack-ice and icebergs. Continuing this line of investigation in his *Prehistoric Europe* (1881), he maintained the hypothesis of five inter-Glacial periods in Great Britain, and argued that the Palæolithic deposits of the Pleistocene period were not post- but inter- or pre-Glacial. His *Fragments of Earth Lore: Sketches and Addresses, Geological and Geographical* (1893), and *Earth Sculpture* (1898) are mainly concerned with the same subject. Like Forbes, Ramsay, and Tyndall, he has familiarized himself with the Alps, the classic ground for the investigation of the action of land-ice. His *Outlines of Geology* (1886), a standard text-book of its subject, reached its third edition in 1896. In 1887 he broke fresh ground with a volume of *Songs and Lyrics by H. Heine and other German poets, done into English verse.* His interest in geography is shown in the fact that since 1888 he has been editor of the *Scottish Geographical Magazine.*

Geislingen, a town of Würtemberg, Germany, 38 miles by rail east-south-east of Stuttgart. It has shops for the carving and turning of bone, ivory, wood, and horn, besides iron-works, machinery factories, glass-works, brewing, bleaching, &c. The Church of St Mary's contains wood-carving by Jörg Syrlin the Younger (1512). Here are ruins of the castle of Helfenstein (1552), a monument of the Emperor William I., and a drawing and modelling school. Population (1900), 7050.

Gellivare, or GELLIVARA, a mining town of Sweden, county Finmarken, 127 miles by rail north by west from Luleå, at the head of the Gulf of Bothnia. It owes its importance to the iron mines in the mountain 4½ miles to the north, situated in 67° 11′ N. lat. and rising to 2024 feet above sea-level (830 feet above Gellivare town). During the dark winter months work proceeds by the aid of the electric light. Some 3000 to 4000 men are employed at the mines. The output has increased at an enormously rapid rate—namely, from 85 tons in 1885 to 178,000 tons in 1892 and to over 1,000,000 tons in 1900. In 1864 the mines were acquired by an English company, but abandoned in 1867. In 1884 another English company took them up and completed a provisional railway from Luleå to Gellivare, besides executing a considerable portion of the preliminary works for the continuation of the line on the Norwegian side from Ofoten Fjord upwards. But this company, after extracting some 150,000 tons of ore in 1888–89, became bankrupt in the latter year. Two years later the mines passed into the hands of a Swedish company, and the railway was acquired by the Swedish Government (see LULEÅ). Population of parish (1900), 11,745.

Gelnhausen, a town of the province of Hesse-Nassau, Prussia, 27 miles by rail east-north-east of Frankfort-on-Main, on the Kinzig. On an island in the river are the ivy-covered ruins of the imperial palace which Frederick (Barbarossa) I. built before 1170, and which was destroyed by the Swedes during the Thirty Years' War. It has an interesting parish church, with three towers, built in the 13th century, and restored in 1876–79; also several other ancient buildings, such as the town-hall, the Princes' Court (now administrative offices), the Witches' Tower, &c. Indiarubber and cigars are manufactured, and wine is made. Gelnhausen became an imperial town in 1169, and in 1186 was the scene of a great Diet of the empire. In 1634 and 1635 it suffered severely from the Swedes. In 1803 the town became the property of Hesse-Cassel, and in 1866 was assigned to Prussia. Population (1900), 4591.

Gelsenkirchen, a town of Prussia, province of Westphalia, 19 miles by rail west of Dortmund. It has coal mines, iron furnaces, steel and boiler works, and soap factories. Population (1885), 20,289; (1900), 36,937.

Gems, Artificial.—The term "Artificial Gems" does not mean *imitations* of real gems, but the actual formation by artificial means of the real precious stone, so that the product is identical, chemically, physically, and optically, with the one found in nature. For instance, in chemical composition the lustrous diamond is nothing but crystallized carbon. Could we take black amorphous carbon in the form of charcoal or lamp-black and dissolve it in a liquid, and by the slow evaporation of that liquid allow the dissolved carbon to separate out, it would probably crystallize in the transparent form of diamond. This would be a true synthesis of diamond, and the product would be just as much entitled to the name as the choicest products of Kimberley or Golconda. But this is a very different thing from the imitation diamond so common in shop windows. Here the chemist has only succeeded in making a paste or glass having limpidity and a somewhat high refractivity, but wanting the hardness and "fire" of the real stone.

The Diamond.—Within the last few years chemists have actually succeeded in making the real diamond by artificial means, and although the largest yet made is not more than one-fiftieth of an inch across, the process itself and the train of reasoning leading up to such an achievement are sufficiently interesting to warrant a somewhat full description. Attempts to make diamonds artificially have been numerous, but, with the sole exception of those of Moissan, all have resulted in failure. The nearest approach to success was attained by Hannay in 1880 and Marsden in 1881; but their results have not been verified by others who have tried to repeat them, and the probability is that what was then thought to be diamond was in reality carborundum or carbide of silicon.

Attempts have been made by two methods to make carbon crystallize in the transparent form. One is to crystallize it slowly from a solution in which it has been dissolved. The difficulty is to find a solvent. Many organic and some inorganic bodies hold carbon so loosely combined that it can be separated out under the influence of chemical action, heat, or electricity, but invariably the carbon assumes the black amorphous form. The other method is to try to fuse the carbon by fierce heat, when from analogy it is argued that on cooling it will solidify to a clear limpid crystal. The progress of science in other directions has now made it pretty certain that the true mode of making diamond artificially is by a combination of these two methods. Until recently it was assumed that carbon was non-volatile at any attainable temperature, but it is now known that at a temperature of about 3600° C. it does volatilize, passing without liquefying directly from the solid to the gaseous state. Very few bodies act in this manner, the great majority when heated at atmospheric pressure to a sufficient temperature passing through the intermediate condition of liquidity. Some few, however, which when heated at atmospheric pressure do not liquefy, when heated at higher pressures in closed vessels obey the common rule, and first become liquid and then volatilize. Professor Dewar found the critical pressure of carbon to be about fifteen tons on the square inch; that is to say, if heated to its critical temperature (3600° C.), and at the same time subjected to a pressure of 15 tons to the square inch, it will assume the liquid form. Enormous as such pressures and temperatures may appear to be, they have been exceeded in some of Sir Andrew Noble's and Sir F. Abel's researches; in their investigations on the gases from gunpowder and cordite fired in closed steel chambers, these chemists obtained pressures as great as ninety-five tons to the square inch, and temperatures as high as 4000° C. Here then, if the observations are correct, we have sufficient temperature and enough pressure to liquefy carbon; and, were there only sufficient time for these to act on the carbon, there is little doubt that the artificial formation of diamonds would soon pass from the microscopic stage to a scale more likely to satisfy the requirements of science, if not those of personal adornment.

It has long been known that the metal iron in a molten state dissolves carbon and deposits it on cooling as black opaque graphite. Moissan has carried out a laborious and systematic series of experiments on the solubility of carbon in iron and other metals, and has come to the conclusion that whereas at ordinary pressures the carbon separates from the solidifying iron in the form of graphite, if the pressure be greatly increased the carbon on separation will form liquid drops, which on solidifying will assume the crystalline shape and become true diamond. Many other metals dissolve carbon, but molten iron has been found to be the best solvent. The quantity entering into solution increases with the temperature of the metal. But temperature alone is not enough; pressure must be superadded. Here Moissan ingeniously makes use of a property which molten iron possesses in common with some few other liquids — water, for instance — of increasing in volume in the act of passing from the liquid to the solid state. Pure iron is mixed with carbon obtained from the calcination of sugar, and the whole is rapidly heated in a carbon crucible in an electric furnace, using a current of 700 amperes and 40 volts. The iron melts like wax and saturates itself with carbon. After a few minutes' heating to a temperature above 4000° C.—a temperature at which the lime furnace begins to melt and the iron volatilizes in clouds — the dazzling, fiery crucible is lifted out and plunged beneath the surface of cold water, where it is held till it sinks below a red heat. The sudden cooling solidifies the outer skin of molten metal and holds the inner liquid mass in an iron grip. The expansion of the inner liquid on solidifying produces enormous pressure, and under this stress the dissolved carbon separates out in a hard, transparent, dense form—in fact, as diamond. The succeeding operations are long and tedious. The metallic ingot is attacked with hot aqua regia till no iron is left undissolved. The bulky residue consists chiefly of graphite, together with translucent flakes of chestnut-coloured carbon, hard black opaque carbon of a density of from 3·0 to 3·5, black diamonds—carbonado, in fact—and a small quantity of transparent colourless diamonds showing crystalline structure. Besides these there may be corundum and carbide of silicon, arising from impurities in the materials employed. Heating with strong sulphuric acid, with hydrofluoric acid, with nitric acid and potassium chlorate, and fusing with potassium fluoride—operations repeated over and over again—at last eliminate the graphite and impurities and leave the true diamond untouched. The precious residue on microscopic examination shows many pieces of black diamond, and other colourless transparent pieces, some amorphous, others crystalline. Although many fragments of crystals are seen, the writer has scarcely ever met with a complete crystal. All appear broken up, as if, on being liberated from the intense pressure under which they were formed, they burst asunder. Direct evidence of this phenomenon has been seen. A very fine piece of diamond, prepared in the way just described and carefully mounted on a microscopic slide, exploded during the night and covered the slide with fragments. This bursting paroxysm is not unknown at the Kimberley mines.

The artificial diamonds, so far, have not been larger than microscopic specimens, and none has measured more than about half a millimetre across. That, however, is quite enough to show the correctness of the train of reasoning leading up to the achievement, and there is no reason to doubt that, working on a larger scale, larger diamonds will result. Diamonds so made burn in the air when heated to a high temperature, with formation of carbonic acid; and in lustre, crystalline form, optical properties, density and hardness, they are identical with the natural stone.

It having been shown that diamond is formed by the separation of carbon from molten iron under pressure, it became of interest to see if in some large metallurgical operations similar conditions might not prevail. A special form of steel is made at some large establishments by cooling the molten metal under intense hydraulic pressure. In some samples of the steel so made Professor Rosel, of the university of Bern, has found microscopic diamonds. The higher the temperature at which the steel has been melted the more diamonds it contains, and it has even been suggested that the hardness of steel in some measure may be due to the carbon distributed throughout its mass being in this adamantine form. The largest artificial diamond yet formed was found in a block of steel and slag from a furnace in Luxembourg; it is clear and crystalline, and measures about one-fiftieth of an inch across.

A striking confirmation of the theory that natural diamonds have been produced from their solution in masses of molten iron, the metal from which has gradually oxidized and been washed away under cycles of atmospheric influences, is afforded by the occurrence of diamonds in a meteorite. On a broad open plain in Arizona, over an area of about 5 miles in diameter, lie scattered thousands of masses of metallic iron, the fragments varying in weight from half a ton to a fraction of an ounce. There is little doubt that these fragments formed part of a meteoric shower, although no record exists as to when the fall took place. Near the centre, where most of the fragments have been found, is a crater with raised edges, three-quarters of a mile in diameter and 600 feet deep, bearing just the appearance which would be produced had a mighty mass of iron—a falling star—struck the ground, scattered it in all directions, and buried itself deeply under the surface, fragments eroded from the surface forming the pieces now met with. Altogether ten tons of this iron have been collected, and specimens of the Cañon Diablo meteorite are in most collectors' cabinets. Dr Foote, a mineralogist, when cutting a section of this meteorite, found the tools injured by something vastly harder than metallic iron, and an emery wheel used for grinding it was ruined. He attacked the specimen chemically, and soon afterwards announced to the scientific world that the Cañon Diablo meteorite contained diamonds, both black and transparent. This startling discovery was subsequently verified by Professors Friedel and Moissan, and also by the writer.

The Ruby.—It is evident that of the other precious stones only the most prized are worth producing artificially. Apart from their inferior hardness and colour, the demand for what are known as "semi-precious stones" would not pay for the necessarily great expenses of the factory. Moreover, were it to be known that they were being produced artificially, the demand—never very great—would almost cease. The only other gems, therefore, which need be mentioned in connexion with their artificial formation are those of the corundum or sapphire class, which include all the most highly prized gems, rivalling, and sometimes exceeding, the diamond in value. Here a remarkable and little-known fact deserves notice. Excepting the diamond and sapphire, each of the precious stones—the emerald, the topaz, and amethyst—possesses a more noble, a harder, and more highly-prized counterpart of itself, alike in colour, but superior in brilliancy and hardness; still more strange, the precious stone to which its special name is usually attached is the variety the least prized. The ruby itself might almost be included in the same category. The true ruby consists of the earth alumina, in a clear, crystalline form, having a minute quantity of the element chromium as the colouring matter. It is often called the "Oriental Ruby," or red sapphire, and when of a paler colour, the "Pink Sapphire." But the ruby as met with in jewellers' shops of inferior standing is usually no true ruby, but a "spinel ruby" or "balas ruby," sometimes very beautiful in colour, but softer than the Oriental ruby, and different in chemical composition, consisting essentially of alumina and magnesia and a little silica, with the colouring matter chromium. The colourless basis of the true Oriental precious stones being taken as crystallized alumina or white sapphire, when the colouring matter is red the stone is called ruby, when blue sapphire, when green Oriental emerald, when orange-yellow Oriental topaz, and when violet Oriental amethyst. Clear, colourless crystals are known as white sapphire, and are very valuable. It is evident, therefore, that whosoever succeeds in making artificially clear crystals of white sapphire has the power, by introducing appropriate colouring matter, to make the Oriental ruby, sapphire, emerald, topaz, and amethyst. All of these stones, even when of small size, are costly and readily saleable, while when they are of fine quality and large size they are highly prized, a ruby of fine colour, and free from flaws, a few carats in weight, being of more value than a diamond of the same weight.

This being the case, it is not surprising that repeated attempts have been made to effect the crystallization of alumina. This is not a matter of difficulty, but unfortunately the crystals generally form thin plates, of good colour, but too thin to be useful as gems. In 1837 Gaudin made true rubies, of microscopic size, by fusing alum in a carbon crucible at a very high temperature, and adding a little chromium as colouring matter. In 1847 Ebelmen produced the white sapphire and rose-coloured spinel by fusing the constituents at a high temperature in boracic acid. Shortly afterwards he produced the ruby by employing borax as the solvent. The boracic acid was found to be too volatile to allow the alumina to crystallize, but the use of borax made the necessary difference. But it was not till about the year 1877 that MM. Frémy and Feil first published a method whereby it was possible to produce a crystallized alumina from which small stones could be cut. They first formed lead aluminate by the fusion together of lead oxide and alumina. This was kept in a state of fusion in a fireclay crucible (in the composition of which silica enters largely). Under the influence of the high temperature the silica of the crucible gradually decomposes the lead aluminate, forming lead silicate, which remains in the liquid state, and alumina, which crystallizes as white sapphire. By the admixture of 2 or 3 per cent. of a chromium compound with the original materials the resulting white sapphire became ruby. More recently MM. Frémy and Verneuil obtained artificial rubies by reacting at a red heat with barium fluoride on amorphous alumina containing a small quantity of chromium. The rubies obtained in this manner are thus described by MM. Frémy and Verneuil: "Their crystalline form is regular; their lustre is adamantine; they present the beautiful colour of the ruby; they are perfectly transparent, have the hardness of the ruby, and easily scratch topaz. They resemble the natural ruby in becoming dark when heated, resuming their rose-colour on cooling." Des Cloizeau says of them that "under the microscope some of the crystals show bubbles. In converging polarized light the coloured rings and the negative black cross are of a remarkable regularity."

Other experimentalists have attacked the problem in other directions. Besides those already mentioned, Elsner, De Senarmont, Deville, and Caron and Debray have succeeded with more or less success in producing rubies. The general plan adopted has been to form a mixture of salts fusible at a red heat, forming a liquid in which alumina will dissolve. Alumina is now added till the fused mass will take up no more, and the crucible is left in the furnace for a long time, sometimes extending over weeks. The solvent slowly volatilizes, and the alumina is deposited in crystals, coloured by whatever colouring oxide has been added.

Mention has been made above of a stone frequently substituted for the true ruby, called the "spinel" or "balas" ruby. The spinel and ruby occur together in nature, stones from Burma being as often spinel as true Oriental ruby. In the artificial production of the ruby it sometimes happens that spinel crystallizes out when true Oriental ruby is expected. The fusion bath is so arranged that only red-coloured alumina shall crystallize out, but it is difficult to have all the materials of such purity as to ensure the complete absence of silica and magnesia. In this case, when these impurities have accumulated to a certain point they unite with the alumina, and spinel then separates, as it crystallizes more easily than ruby. When all the magnesia and silica have been eliminated in this way the bath resumes its deposition of crystalline ruby. A few years ago rubies of fine colour and of considerable size were shown in London, made on the Continent by a secret process. The writer has seen several cut stones so made weighing over a carat each, the uncut crystals measuring half an inch along a crystal edge, and weighing over 70 grains, and a clear plate of ruby cut from a single crystal weighing over ten grains. Ruby has lately been made by Sir W. Roberts-Austen as a by-product in the production of metallic chromium. Oxide of chromium and aluminium powder are intimately mixed together in a refractory crucible, and the mixture is ignited at the upper part. The aluminium and chromium oxide react with evolution of so much heat that the reduced chromium is melted. Such is the intensity of the reaction that the resulting alumina is also completely fused, floating as a liquid on the molten chromium. Sometimes the alumina takes up the right amount of chromium to enable it to assume the ruby colour. On cooling the melted alumina crystallizes in large flakes, which on examination by transmitted light are seen to be true ruby. The development of the red colour is said by Greville-Williams only to take place at a white heat. It is not due to the presence of chromic acid, but to a reaction between alumina and chromic oxide, which requires an elevated temperature.

The Sapphire.—Daubrée has shown that when a full quantity of chromium is added to the bath from which white sapphire crystallizes the colour is that of ruby, but when much less chromium is added the colour is blue, forming the true Oriental sapphire. The real colouring matter of the Oriental sapphire is not definitely known, some chemists considering it to be chromium, and others cobalt. Artificial sapphires have been made of a fair size and perfectly transparent by the addition of cobalt to the igneous bath of alumina, but the writer does not consider them equal in colour to true Oriental sapphire.

The Oriental Emerald.—The stone known as emerald consists chemically of silica, alumina, and glucina. Like the ruby, it owes its colour to chromium, but in a different state of oxidation. As already mentioned, there is another stone which consists of crystallized alumina coloured with chromium, but holding the chromium in a different state of oxidation. This is called the Oriental emerald, and, owing to its beauty of colour, its hardness, and rarity, it is more highly prized than the emerald itself, and commands higher prices. The Oriental emerald has been produced artificially in the same way as the ruby, by adding a larger amount of chromium to the alumina bath and regulating the temperature.

The Oriental Amethyst.—The amethyst is rock crystal (quartz) of a bluish-violet colour. It is one of the least valuable of the precious stones. The sapphire, however, is found occasionally of a beautiful violet colour; it is then called the Oriental amethyst, and, on account of its beauty and rarity, is of great value. It is evident that if to the igneous bath of alumina some colouring matter, such as manganese, is added capable of communicating a violet colour to the crystals of alumina, the Oriental amethyst will be the result. Oriental amethyst has been so formed artificially, but the stone being known only as a curiosity to mineralogists and experts in precious stones, and the public not being able to discriminate between the violet sapphire and amethystine quartz, there is no demand for the artificial stone.

The Oriental Topaz.—The topaz is what is called a semi-precious stone. It occurs of many colours, from clear white to pink, orange, yellow, and pale green. The usual colour is from straw-yellow to sherry colour. The exact composition of the colouring matter is not known; it is not entirely of mineral origin, as it changes colour and sometimes fades altogether on exposure to light. Chemically the topaz consists of alumina, silica, and fluorine. It is not so hard as the sapphire. There is also a yellow variety of quartz, which is sometimes called "false topaz." The Oriental topaz, on the other hand, is a precious stone of great value. It consists of clear crystalline sapphire coloured with a small quantity of ferric oxide. It has been produced artificially by adding iron instead of chromium to the matrix from which the white sapphire crystallizes.

The Zircon.—The zircon, jargoon, or hyacinth is a very beautiful stone, varying in colour, like the topaz, from red and yellow to green and blue. It is sometimes met with colourless, and such are its refractive powers and brilliancy that it has been mistaken for diamond. It is a compound of silica and zirconia. H. Sainte-Claire Deville formed the zircon artificially by passing silicium fluoride at a red heat over the earth zirconia in a porcelain tube. Octahedral crystals of zircon are then produced, which have the same crystalline form, appearance, and optical qualities as the natural zircon. (W. C.)

General Average. See AVERAGE, GENERAL.

Geneva, a canton and city of Switzerland. It was the last to be admitted into the Confederation (in 1815), and so ranks last. In point of population the city now ranks as the third in Switzerland, being surpassed by both Zürich and Basel. The canton has an area of 107 square miles (88·8 square miles being "productive," 11·1 square miles of this being covered by forests and 7·4 square miles by vineyards). The population of the canton in 1900 was 131,714, divided linguistically thus: French-speaking, 110,058; German-speaking, 13,766; Italian-speaking, 7300. The population of the city was in 1888 stated at 71,807, and in 1900 it was (with Carouge and other suburbs) 104,044. The canton is divided into three administrative districts, one taking in the town itself, and the two others the regions on the left and right banks of the Rhone respectively. The cantonal constitution of 1847 is still in force, but has been modified in various particulars. Both the legislature (in the proportion of one member per 1000 inhabitants, or a fraction over 500) and the executive (of seven members) are elected by a direct popular vote, while in each case since 1892 the principles of proportional representation have the force of law. Three thousand five hundred citizens have the right of requiring a "facultative referendum" as to any legislative projects, while 2500 citizens have the "right of initiative" as to the revision of the cantonal constitution, or as to any legislative projects. At the end of 1897 the Genevese people refused to adopt the principle of the separation of Church and State, but in some cases the alienated country churches have been restored to the Romanists, the Old Catholics being there in such small numbers that they could not themselves use these edifices. In the town the monument of the duke of Brunswick now forms a conspicuous feature, while the restored 15th-century "chapel of the Maccabees," attached to the cathedral, is very interesting to antiquaries. In 1890 the "Musée Ariana," a magnificent collection of art treasures, was bequeathed to the town by its owner, M. Revilliod, and is now open to the public. The restoration of the cathedral has also proceeded apace. The university of Geneva (founded as an "académie" by Calvin, and raised in 1873 to the rank of a university) was attended in the winter of 1898–99 by 250 matriculated students, and in that of 1899–1900 by 773 (besides 280 hearers). In 1900 the State revenue of the canton was 9,100,432 francs, and the State expenditure 8,764,802 francs, but the budget for 1901 reckons a deficit of 463,000 francs. In 1897 the public debt of the canton was 30,945,400 francs.

Borgeaud. *Histoire de l'Université de Genève, 1559–1798.* Geneva, 1900.—Dunant. *Les Relations Politiques de Genève avec Berne et les Suisses, 1536–1564.* Geneva, 1894.—Fatio and Boissonnas. *Genève à travers des siècles.* Geneva, 1900.—Roget. *Hist. du peuple de Genève jusqu'à l'Escalade*, 5 vols. Geneva, 1870–1879.—Vaucher. *Luttes de Genève contre la Savoie, 1517–1530.* Geneva, 1889.—Rilliet. *Le Rétablissement du Catholicisme à Genève il y a deux siècles.* Geneva, 1880. (W. A. B. C.)

Geneva, Lake of, the largest lake of which any portion belongs to Switzerland. According to Professor Forel, its area is 582·36 square kilometres, or 225 square miles, but the Swiss Government estimate of 1898 makes it slightly less, 577·84 square kilometres, or 223 square miles. The latest estimate allots 123½ square miles of the lake to Vaud, 11½ square miles to Geneva, 4¾ square miles to the Valais, and 83¼ square miles to France. The Petit Lac occupies 30½ square miles of M. Forel's area. The length of the entire lake, from Geneva to Chillon, is 39½ miles, but along its axis 45 miles. The maximum depth is 309·7 metres, or 1015½ feet, but the mean depth is only 152·7 metres, or 500 feet. Its greatest width (between Morges and Amphion) is 8½ miles (13·8 kilometres), but the normal width is 5 miles, or 8·1 kilometres. Its height above the sea-level is estimated at 371·9 metres (1200 feet) by Forel, and at 375 metres (1230¼ feet) by the Swiss Government officials in 1898. Professor F. A. Forel (of Morges) has made a most complete and detailed study of the lake from every point of view. The results of his prolonged investigations were given to the world in his monumental work, entitled *Le Léman.* Professor Forel mentions (vol. i. pp. 17 *et seqq.*) a curious fact which deserves to be noticed here. Near the Jardin Anglais in Geneva, on the left bank of the Rhone, there are several erratic blocks in the lake, of which one is called the Pierre du Niton (from a popular tradition that it was once an altar of Neptune). Now this rock was taken many years ago as the base of the Government survey, known later as the Dufour Map. Its height was then determined at 376·64 metres (1236 feet), or later at 376·84 metres. But Professor Forel found that its true height above the sea was only 373·5 metres (1225¼ feet), so that all the heights on the two great Swiss maps are thus nearly 3 metres (nearly 10 feet) too large. (W. A. B. C.)

Geneva, a village of Ontario county, New York, U.S.A., in 42° 52′ N. and 76° 59′ W., at the foot of Seneca Lake, on the Lehigh Valley and the New York Central and Hudson River railways, at an altitude of 453 feet. The manufactures consist mainly of iron and steel goods. The village is widely known for the nurseries in the surrounding country, the products of which are distributed to all parts of the United States. Hobart College, situated here, is a Protestant Episcopal institution, founded in 1822. In 1899 it had 15 instructors and was attended by 92 students. Population (1880), 5878; (1890), 7557; (1900), 10,433, of whom 1916 were foreign-born and 193 negroes.

Genoa, chief port and commercial city of Italy, seat of a university and of an archbishopric, near the middle of the Gulf of Genoa, 119 miles north-west of Leghorn by rail, in 44° 24′ 16″ N. lat., 8° 54′ 15″ E. long. After the inclusion of Sampierdarena and the suburban communes in the city (1872–73) the population numbered 160,000, and was at later periods (1881), 179,515; (1890), 206,033; (1901), 234,809, including 11,469 floating population. The duke of Galliera's gift of £800,000 to the city in 1875 permitted the enlargement of the harbour, which was begun in 1877 by a Venetian company. The works included the Molo Lucedio, which more than doubled the length of the mole that starts from the lighthouse; the Nuove Calate, and the quays of Paleocazia, Sapri, Caracciolo, Biagio Assereto, Cristoforo Colombo, Andrea Doria, Federico Guglielmo (for passenger steamers), Adolfo Parodi, Morosini, and Guglielmo Embriaco. All these quays were equipped with the most modern sheds and appliances. Towards the west, outside the harbour, near the Calata delle Grazie, was built the Molo Giano, to which docking basins and repairing yards were afterwards added. Simultaneously Via Carlo Alberto, skirting the harbour, was enlarged; the porticos with the marble terrace, near Piazza Caricamento, were demolished; and under the terrace in Via Milano (formerly Via alla Lanterna) were placed the Magazzini Generali. The opening of the Gothard tunnel (1882), which extended the commercial range of the port through Switzerland to Mannheim, necessitated yet further enlargement of the harbour. In 1897 a convention to this end was agreed to between the municipality and the Italian Government. These new works included the enlargement of the existing railway station at Piazza Principe, and the creation of another; the cutting of railway tunnels and the widening of the wharf at the Federico Guglielmo bridge. Meanwhile an English company—the Customs and Bonded Warehouses Company—has constructed two huge groups of parallel buildings, several storeys high, on the Molo Vecchio, as a warehouse and bonded stores. The neighbouring Mandraccio, formerly a stagnant pool, has been filled up so as to gain further warehouse room. The total traffic of the port in 1899 was 3,966,493 tons, of which 215,814 tons were exported; 370,697 were goods in transit; duty was paid on 3,006,092 tons, while 373,890 tons were placed in bond. The port was visited by 12,970 vessels, representing an aggregate tonnage of 9,049,877 tons. The commerce is constantly increasing, and has now attained a greater volume than that of any Mediterranean port except Marseilles.

The only new line of local railway is that known as the Succursale dei Giovi, built to relieve the pressure of traffic which the opening of the Gothard tunnel placed upon the old Giovi line. The new line from Genoa to Ronco Scrivia is 23 miles long. It contains a tunnel quite as difficult as that of the Giovi at Busalla, and cost more than £3,000,000. At present surveys are being made for a new line to Piacenza. The first horse tramway was opened in 1878 by a French company, between the Piazza Annunziata and Sampierdarena. A tunnel was bored through the San Benigno Hill for the passage of the line. Subsequently the horse tramway system was extended to Pontedecimo and along the shore to Pegli and Voltri. The same company has also installed an omnibus service within the city. In 1893 the first electric tramway was opened between Piazza Corvetto and Piazza Manin. A German company has since extended the electric tramway service from the central Piazzi dei Ferrari to Staglieno and Nervi. Other lines run from Piazza Raibetta along Via San Lorenzo, Via Carignano, Via Circonvallazione a Mare and a Monte to the Righi, which is reached by an electric funicular railway. Towards the west, lines run from Piazza Caricamento to Pontedecimo and Pegli. A non-electric funicular railway belonging to a Genoese company has been built between the central Piazza Portello and the elevated Corso Magenta. A cog-wheel funicular runs from the hill of San Rocco to the summit of Granarolo, whence a magnificent view is to be obtained. An important electric line was in 1901 in course of construction to Laguardia, a famous sanctuary upon a high hill to the west of the city.

Much has been done by the municipality to improve the streets. In Via Roma, which, with the Galleria Mazzini, was planned in 1871 and completed in 1876, a part of the Palazzo Spinola, which formerly obstructed traffic, has been cut away. Piazza Corvetto has been laid out between the two sides of the Acquasola Promenade. Via Circonvallazione a Monte has been completed and extended. In 1890 Corso Firenze was begun, and a carriage road built to the Height of Oregona. Behind Via Milano, Via Venezia has been laid out and is now being connected with the magnificent Circonvallazione a Monte. In 1891 Via a Mare, which ran from Piazza Caricamento to the Molo Giano, was extended and enlarged as far as the Bisagno Esplanade, and named Corso Aurelio Saffi. In the Carignano district the grandiose Galliera Hospital has been built, and Via Corsica laid out as far as the Rotonda, the favourite rendezvous of the Genoese. Corso Mentana, Corso Alessandro Volta, and Corso Silvio Pellico were added. Between the monumental bridge, which connects the two divisions of Via Venti Settembre and Via Corsica, a wide thoroughfare named Corso Andrea Podestà has been laid out.

The organization of the Italo-American Exhibition in 1892 (fourth centenary of the discovery of America by Columbus) necessitated several important works, namely, the opening of a new thoroughfare between Porta d'Arco and Porta Pila, the demolition of the Fronti Bassi, separating the city from the Bisagno quarter, the embankment of the river Bisagno, the reconstruction of the Pila Bridge, and the lowering of Via Minerva, the name of which was changed to Corso Buenos Ayres. New streets have been constructed in the same quarter, namely, Corso Galliera, Via Torino, Via della Libertà, Via Casa Regis, Via Barabino, Via Volturno, and Via Ferruccio. New streets have also been laid out in the San Fruttuoso and Cavaletto quarters. The road from Piazza Manin to Staglieno has been completed, the colonnades in Via Carlo Alberto and Piazza Caricamento have been restored, Piazza Principe has been reorganized, and the cemetery of Staglieno embellished with a semicircular colonnade. A large new prison has been built by the Government, and a new public market erected in Via Venti Settembre. Several public monuments have been restored, namely, Porta Soprana, Palazzo San Giorgio, the cathedral of San Lorenzo (of which the three naves have been restored in Gothic style), the ancient church of San Donato, and the temple of the Immacolata. A munificent bequest of the duchess of Galliera provided means for the reorganization of the museum in Palazzo Bianco (in Via Garibaldi), which, with the Palazzo Rosso, containing the celebrated picture gallery, has become municipal property. New monuments have been erected to Mazzini, Garibaldi, Nino Bixio, Victor Emmanuel II., Raffaele Rubatino (founder of the Navigazione Generale), the duke of Galliera (by Monteverde), and to the duchess of Galliera (also by Monteverde). Many new school buildings have been erected since 1875, and those previously existing much enlarged. There are twenty-five boys' schools, with a total of 9120 scholars and 287 teachers; twenty-four girls' schools, with 8042 scholars and 241 teachers. In addition there are three technical evening and Sunday schools, with 750 pupils, who are instructed in Italian literature, French, English, algebra, geometry, chemistry, and physics; a boys' school of arts and crafts, founded in 1892; and two superior female schools, one named after Queen Margherita and the other after the duchess of Galliera, with more than 400 pupils. The sums voted by the municipality for education have increased from £33,000 in 1877 to £76,000 in 1899. Further sums are provided by the provincial council. One of the most important educational institutes is the superior school of practical commerce, founded by private initiative. It has 100 students, who take a three years' course. A new lyceum has been founded by the municipality. The previously existing nautical school is in a flourishing condition. Since 1880 the university has been promoted from secondary to primary status, and now includes the faculties of jurisprudence, medicine, mathematical and natural sciences, and philosophy and letters. The students in 1900 numbered 1400.

The development of industry has kept pace with that of the harbour. The Ansaldo shipbuilding yards now construct armoured cruisers both for the Italian navy and for foreign governments. The Odero yards, for the construction of merchant and passenger steamers, have been similarly extended. The two docking basins near the Calata delle Grazie are respectively 540 feet and 670 feet long. A number of foundries and metallurgical works supply material for repairs and shipbuilding. The sugar-refining industry has been introduced by two important companies, and most of the capital employed in sugar-refining in other parts of Italy has been subscribed at Genoa, where the administrative offices of the principal companies and individual refiners are situated. The old industries of maccaroni and cognate products maintain their superiority. Tanneries and cotton spinning and weaving mills have considerably extended throughout the province. Cement works have acquired an extension previously unknown, more than thirty firms being now engaged in that branch of industry.

New charitable institutions have arisen. In 1876 the Galliera Asylum for the poor was founded with a capital of nearly £80,000. In 1877 the duchess of Galliera gave £400,000 for the creation of three hospitals, one known as Sant' Andrea Apostolo (300 beds), in Carignano, for invalids born in Liguria; a second, for invalid children, at San Bartolomeo degli Armeni; and a third, for convalescent patients, at Cornigliano. These three hospitals now possess an endowment of more than £1,000,000. In 1881 the Tollot Infant Asylum was founded with a legacy of £60,000 bequeathed by Giuseppina Tollot. It has accommodation for 300 children. Other infant asylums provide for an aggregate of nearly 1000 children. The Pammatone Hospital, founded in 1429 by Bartolomeo Bosco, now contains 857 beds. It possesses an endowment of £530,000. The municipality pays it an annual subsidy of £7500 as contribution to the expense of nursing indigent patients. The Hospital for Incurables has 650 beds, and receives from the Pammatone Hospital children whose cases are not chronic. The Lunatic Asylum in Via Brera, with a capacity for 600 inmates, has now a capital of £210,000. A branch asylum has been built near the sea at the expense of the provincial authorities. The Pauper Asylum and Workhouse, situated above Murassi, deals with the fluctuating mendicant population. It receives an annual subsidy of £320 from the municipality. The Foundling Hospital, dating from the 15th century, has been detached from the Pammatone. It costs £8000 a year, of which the provincial authorities provide £7000. A Sailors' Orphan Asylum, a Public Dormitory, a Hospital for Cripples, a Patronato Scholastico, for supplying indigent children with food, have also been founded. A munificent priest, Francesco Montebruno, has established an Artigianelli Institute with a capital of £40,000, for training foundling children in arts and crafts. Its inmates at present number 150 boys and 80 girls. Altogether, Genoa has 180 bequests and legacies for charitable purposes.

The municipal budget for 1900 showed a revenue of £708,760 and an expenditure of £746,760. Taxes and *octroi* yield about £500,000 a year. The chief item of expenditure is represented by interest on the municipal debt (£124,600). The present indebtedness is £2,280,000, more than £800,000 of new debt having been incurred since 1890. (H. W. S.)

GEOGRAPHY.

GEOGRAPHY may be defined as the exact and organized knowledge of the distribution of phenomena on the surface of the Earth. The fundamental basis of geography is the vertical relief of the Earth's crust, which controls all mobile distributions. The grander features of the relief of the lithosphere or stony crust of the Earth control the distribution of the hydrosphere or collected waters which gather into the hollows, filling them up to a height corresponding to the volume, and thus producing the important practical division of the surface into land and water. The distribution of the mass of the atmosphere over the surface of the Earth is also controlled by the relief of the crust, its greater or lesser density at the surface corresponding to the lesser or greater elevation of the surface. The distribution of solar energy is entirely altered from the mathematical simplicity of the zones, which would characterize a uniform globe, by the dissimilar action of land and water with regard to radiant heat, and the influence of crust-forms on the direction of the resulting circulation. The influence of physical environment becomes clearer and stronger when the distribution of plant and animal life is considered, and if it is less distinct in the case of man, the reason is found in the modifications of environment consciously produced by human effort. Geography is a synthetic science, dependent for the data with which it deals on the results of specialized sciences such as astronomy, geology, oceanography, meteorology, biology, and anthropology, as well as topographical description (which has too long been supposed to be the whole of geography). The physical and natural sciences are concerned in geography only so far as they deal with the forms of the Earth's surface, or as regards the distribution of phenomena. The distinctive task of geography as a science is to investigate the control exercised by the crust-forms directly and indirectly upon the various mobile distributions. This gives to it unity and definiteness, and renders superfluous the attempts that have been made from time to time to define the limits which divide geography from geology on the one hand and from history on the other. It is essential to classify the subject-matter of geography in such a manner as to give prominence not only to facts, but to their mutual relations and their natural and inevitable order.

Definition and scope.

The fundamental conception of geography is form, including the figure of the Earth and the varieties of crustal relief. Hence mathematical geography, including cartography as a practical application, comes first. It merges into physical geography, which takes account of the forms of the lithosphere (geomorphology), and also of the distribution of the hydrosphere and the rearrangements resulting from the workings of solar energy throughout the hydrosphere and atmosphere (oceanography and climatology). Next follows the distribution of plants and animals (biogeography), and finally the distribution of mankind and the various artificial boundaries and redistributions (anthropogeography). The applications of anthropogeography to human uses give rise to political and commercial geography, in the elucidation of which all the earlier departments or stages have to be considered, together with historical and other purely human conditions. The evolutionary idea has revolutionized and unified geography as it did biology, breaking down the old hard-and-fast partitions between the various departments, and displacing the discovery and exploration of new lands as the central motive by the study of the nature and influence of actual terrestrial environments.

History of Geographical Theory.

The earliest conceptions of the Earth, like those held by the primitive peoples of the present day, are difficult to discover and almost impossible fully to grasp. Generalizations, as far as they were made from known facts, were usually expressed in symbolic language, and for our present purpose it is not profitable to speculate on the underlying truths which may sometimes be suspected in the old mythological cosmogonies.

The first definite geographical theories to affect the Western world were those evolved, or at least first expressed, by the Greeks.[1] The earliest theoretical problem of geography was the form of the Earth. The natural supposition that the Earth is a flat disc, circular or elliptical in outline, had in the time of Homer acquired a special definiteness by the introduction of the idea of the ocean river bounding the whole, an application of imperfectly understood observations. Thales of Miletus is claimed as the first exponent of the idea of a spherical Earth; but although this does not appear to be warranted, his disciple Anaximander (*c.* 580 B.C.) put forward the theory that the Earth had the figure of a solid body hanging freely in the centre of the hollow sphere of the starry heavens. The Pythagorean school of philosophers adopted the theory of a spherical Earth, but from metaphysical rather than scientific reasons; their convincing argument was that a sphere being the most perfect solid figure, was the only one worthy to circumscribe the dwelling-place of man. The division of the sphere into parallel zones and some of the consequences of this generalization seem to have presented themselves to Parmenides (*c.* 450 B.C.); but these ideas did not influence the Ionian school of philosophers, who in their treatment of geography preferred to deal with facts demonstrable by travel rather than with speculations. Thus Hecatæus, claimed by Tozer[2] as the father of geography on account of his *Periodos*, or general treatise on the Earth, did not advance beyond the primitive conception of a circular disc. He systematized the form of the land within the ring of ocean —the *oekumene*, or habitable world—by recognizing two continents: Europe to the north, and Asia to the south of the midland sea. Herodotus, equally oblivious of the sphere, criticized and ridiculed the circular outline of the *oekumene*, which he knew to be longer from east to west than it was broad from north to south. He also pointed out reasons for accepting a division of the land into three continents — Europe, Asia, and Africa. Beyond the limits of his personal travels Herodotus applied the characteristically Greek theory of symmetry to complete, in the unknown, outlines of lands and rivers analogous to those which had been explored. Symmetry was in fact the first geographical theory, and the effect of Herodotus's hypothesis that the Nile must flow from west to east before turning north in order to balance the Danube running from west

Early Greek ideas.

Flat Earth of Homer.

Hecatæus.

Herodotus.

The idea of symmetry.

[1] A concise sketch of the whole history of geographical method or theory as distinguished from the history of geographical discovery is only to be found in the introduction to H. Wagner's *Lehrbuch der Geographie* (vol. i., Leipzig, 1900), which is in every way the most complete treatise on the principles of geography.

[2] *History of Ancient Geography*, Cambridge, 1897, p. 70.

to east before turning south lingered in the maps of Africa down to the time of Mungo Park.[1]

To Aristotle (384–322 B.C.) must be given the distinction of founding scientific geography. He demonstrated the sphericity of the Earth by three arguments, two of which could be tested by observation. These were—(1) that the Earth must be spherical, because of the tendency of matter to fall together towards a common centre; (2) that only a sphere could always throw a circular shadow on the moon during an eclipse; and (3) that the shifting of the horizon and the appearance of new constellations, or the disappearance of familiar stars, as one travelled from north to south, could only be explained on the hypothesis that the Earth was a sphere. Aristotle, too, gave greater definiteness to the idea of zones conceived by Parmenides, who had pictured a torrid zone uninhabited by reason of heat, two frigid zones uninhabited by reason of cold, and two intermediate temperate zones fit for human occupation. Aristotle defined the temperate zone as extending from the tropic to the arctic circle, but there is some uncertainty as to the precise meaning he gave to the term "arctic circle." Soon after his time, however, this conception was clearly established, and with so large a generalization the mental horizon was widened to conceive of a geography which was a science. Aristotle had himself shown that in the southern temperate zone winds similar to those of the northern temperate zone should blow, but from the opposite direction.

Aristotle and the sphere.

While the theory of the sphere was being elaborated the efforts of practical geographers were steadily directed towards ascertaining the outline and configuration of the *oekumene*, or habitable earth, the only portion of the terrestrial surface known to the ancients and to the mediæval peoples, and still retaining a shadow of its old monopoly of geographical attention in its modern name of the "Old World." The fitting of the *oekumene* to the sphere was the second theoretical problem. The circular outline had given way in geographical opinion to the elliptical with the long axis lying east and west, and Aristotle was inclined to view it as a very long and relatively narrow band almost encircling the globe in the temperate zone. His argument as to the narrowness of the sea between west Africa and east Asia, from the occurrence of elephants at both extremities, is difficult to understand, although it shows that he looked on the distribution of animals as a problem of geography.

Fitting the oekumene to the sphere.

Pythagoras had speculated as to the existence of antipodes, but it was not until the first approximately accurate measurements of the globe and estimates of the length and breadth of the *oekumene* were made by Eratosthenes (*c.* 250 B.C.) that the fact that, as then known, it occupied less than a quarter of the surface of the sphere was clearly recognized. It was natural, if not very logical, that the ocean river should be extended from a narrow stream to a world-embracing sea, and here again Greek theory, or rather fancy, gave its modern name to the greatest feature of the globe. The old instinctive idea of symmetry must often have suggested other *oekumene* balancing the known world in the other quarters of the globe. The Stoic philosophers, especially Crates of Mallos, arguing from the love of nature for life, placed an *oekumene* in each quarter of the sphere, the three unknown world-islands being those of the Antöken, Periöken, and Antipodes. This was a theory not only attractive to the philosophical mind, but eminently adapted to promote exploration. It had its opponents, however, for Herodotus showed that sea-basins existed cut off from the ocean, and it is still a matter of controversy how far the pre-Ptolemaic geographers believed in a water-connexion between the Atlantic and Indian oceans. It is quite clear that Pomponius Mela (*c.* A.D. 40), following Strabo, held that the southern temperate zone contained a habitable land, which he designated by the name *Antichthones.*

Problem of antipodes.

Aristotle left no work on geography, so that it is impossible to know what facts he would associate with the science of the Earth's surface. The word geography did not appear before Aristotle, the first use of it being in the *Peri Kosmon*, which is one of the writings doubtfully ascribed to him, and Berger considers that the expression was introduced by Eratosthenes.[2] Aristotle was certainly conversant with many facts, such as the formation of deltas, coast-erosion, and to a certain extent the dependence of plants and animals on their physical surroundings. He formed a comprehensive theory of the variations of climate with latitude and season, and was convinced of the necessity of a circulation of water between the sea and rivers, though, like Plato, he held that this took place by water rising from the sea through crevices in the rocks, losing its dissolved salts in the process. He speculated on the differences in the character of races of mankind living in different climates, and correlated the political forms of communities with their situation on a seashore, or in the neighbourhood of natural strongholds.

Aristotle's geographical views.

Claudius Ptolemæus (*c.* A.D. 150) concentrated in his writings the final outcome of all Greek geographical learning, and passed it across the gulf of the Middle Ages by the hands of the Arabs, to form the starting-point of the science in modern times. His geography was based more immediately on the work of his predecessor, Marinus of Tyre, and on that of Hipparchus, the follower and critic of Eratosthenes. It was the ambition of Ptolemy to describe and represent accurately the surface of the *oekumene*, for which purpose he took immense trouble to collect all existing determinations of the latitude of places, all estimates of longitude, and to make every possible rectification in the estimates of distances by land or sea. His work was mainly cartographical in its aim, and theory was as far as possible excluded. The symmetrically placed hypothetical islands in the great continuous ocean disappeared, and the *oekumene* acquired a new form by the representation of the Indian Ocean as a larger Mediterranean completely cut off by land from the Atlantic. The *terra incognita* uniting Africa and farther Asia was an unfortunate hypothesis which helped to retard exploration. Ptolemy used the word *geography* to signify the description of the whole *oekumene* on mathematical principles, while *chorography* signified the fuller description of a particular region, and *topography* the very detailed description of a smaller locality. He introduced the simile that geography represented an artist's sketch of a whole portrait, while chorography corresponded to the careful and detailed drawing of an eye or an ear.[3]

Ptolemy.

The Middle Ages saw geographical knowledge die out in Christendom, although it retained, through Arabic translations of Ptolemy, a certain vitality in Islam. The verbal interpretation of Scripture led Lactantius (*c.* A.D. 320) and other ecclesiastics to denounce the spherical theory of the Earth as heretical. The wretched subterfuge of Cosmas (*c.* A.D. 550) to explain the phenomena of the apparent

Geography in the Middle Ages.

[1] See Myres, "An Attempt to reconstruct the Maps used by Herodotus," *Geographical Journal*, viii. (1896), p. 605.

[2] *Geschichte der wissenschaftlichen Erdkunde der Griechen*, Leipzig, 1891, Abt. 3, p. 60.

[3] Bunbury's *History of Ancient Geography*, 2 vols., London, 1879; Müller's *Geographi Græci Minores*, 2 vols., Paris, 1855, 1861; and Berger's *Geschichte der wissenschaftlichen Erdkunde der Griechen*, 4 vols., Leipzig, 1887–93, are standard authorities on the Greek geographers.

movements of the sun by means of an earth modelled on the plan of the Jewish Tabernacle, gave place ultimately to the wheel-maps—the T in an O—which reverted to the primitive ignorance of the times of Homer and Hecatæus.[1]

The journey of Marco Polo, the increasing trade to the East, and the voyages of the Arabs in the Indian Ocean prepared the way for the re-acceptance of Ptolemy's ideas when his works became known through the Moors in Spain, and when the sealed books of the Greek original were translated into Latin by Angelus in 1410.

Revival of geography.

The old arguments of Aristotle and the old measurements of Ptolemy were used by Toscanelli and Columbus in urging a westward voyage to India; and mainly on this account did the crossing of the Atlantic rank higher in the history of scientific geography than the laborious feeling out of the coast-line of Africa. But not until the voyage of Magellan shook the scales from the eyes of Europe did modern geography begin to advance. Discovery had outrun theory; the rush of new facts made Ptolemy practically obsolete in a generation, after having been the fount and origin of all geography for a millennium.

Apianus.

The earliest evidence of the reincarnation of theoretical geography is to be found in the text-books by Peter Apian and Sebastian Munster. Apian in his *Cosmographicus Liber*, published in 1524, and subsequently edited and added to by Gemma Frisius under the title of *Cosmographia*, based the whole science on mathematics and measurement. He followed Ptolemy closely, enlarging on his distinction between geography and chorography, and expressing the artistic analogy in a rough diagram. This slender distinction was made much of by most subsequent writers until Nathanael Carpenter in 1625 pointed out that the difference between geography and chorography was simply one of degree, not of kind.

Munster.

Sebastian Munster, on the other hand, in his *Cosmographia Universalis* of 1544, paid no regard to the mathematical basis of geography, but, following the model of Strabo, described the world according to its different political divisions, and entered with great zest into the question of the productions of countries and into the manners and costumes of the various peoples. Thus early commenced the separation between what were long called mathematical and political geography, the one subject appealing mainly to mathematicians, the other to historians.

Throughout the 16th and 17th centuries the rapidly accumulating store of facts as to the extent, outline, and mountain and river systems of the lands of the Earth were put in order by the generation of cartographers of which Mercator was the chief; but the writings of Apian and Munster held the field for a hundred years without a serious rival, unless the many annotated editions of Ptolemy might be so considered. Meanwhile the new facts were the subject of original study by philosophers and by practical men without reference to classical traditions. Bacon argued keenly on geographical matters and was a lover of maps, in which he observed and reasoned upon such resemblances as that between the outlines of South America and Africa.

Cluverius.

Philip Cluver's *Introductio in Geographiam universam tam veteram quam novam* was published in 1624. Geography he defined as "the description of the whole Earth, so far as it is known to us." It is distinguished from cosmography by dealing with the Earth alone, not with the universe, and from chorography and topography by dealing with the whole Earth, not with a country or a place. The first book, of fourteen short chapters, is concerned with the general properties of the globe; the remaining six books treat in considerable detail of the countries of Europe and of the other continents. Each country is described with particular regard to its people as well as to its surface, and the prominence given to the human element is of special interest.

Carpenter.

A little-known book which appears to have escaped the attention of most writers on the history of modern geography was published at Oxford in 1625 by Nathanael Carpenter, fellow of Exeter College, with the title *Geographie delineated forth in Two Bookes, containing the Sphericall and Topicall parts thereof.* It is discursive in its style and verbose; but, considering the period at which it appeared, it is remarkable for the strong common sense displayed by the author, his comparative freedom from prejudice, and his firm application of the methods of scientific reasoning to the interpretation of phenomena. Basing his work on the principles of Ptolemy, he brings together illustrations from the most recent travellers, and does not hesitate to take as illustrative examples the familiar city of Oxford and his native county of Devon. He divides geography into *The Spherical Part*, or that for the study of which mathematics alone is required, and *The Topical Part*, or the description of the physical relations of parts of the Earth's surface, preferring this division to that favoured by the ancient geographers—into general and special. It is distinguished from other English geographical books of the period by confining attention to the principles of geography, and not describing the countries of the world.

Varenius.

A much more important work in the history of geographical method is the *Geographia Generalis* of Bernhard Varenius, a German medical doctor of Leyden, who died at the age of twenty-eight in 1650, the year of the publication of his book. It was so highly esteemed that an annotated edition was published in Cambridge in 1672 by Sir Isaac Newton, with the addition of the plates which had been planned by Varenius, but not produced by the original publishers.

"The reason why this great man took so much care in correcting and publishing our author was, because he thought him necessary to be read by his audience, the young gentlemen of Cambridge, while he was delivering lectures on the same subject from the Lucasian Chair."[2]

The treatise of Varenius is a model of logical arrangement and terse expression; it is a work of science and of genius; one of the few of that age which can still be studied with profit. The English translation renders the definition thus: "Geography is that part of *mixed mathematics* which explains the state of the Earth and of its parts, depending on quantity, viz., its figure, place, magnitude, and motion, with the celestial appearances, &c. By some it is taken in too limited a sense, for a bare description of the several countries; and by others too extensively, who along with such a description would have their political constitution."

Varenius was reluctant to include the human side of geography in his system, and only allowed it as a concession to custom, and in order to attract readers by imparting interest to the sterner details of the science. His division of geography was into two parts—(i.) General or universal, dealing with the Earth in general, and explaining its properties without regard to particular countries; and (ii.) Special or particular, dealing with each country in turn from the chorographical or topographical point of view. General geography was divided into—(1) the *Absolute* part, dealing with the form, dimensions, posi-

[1] The period of the early Middle Ages is dealt with in Beazley's *Dawn of Modern Geography*, London, 1897.

[2] From translator's preface to the English version by Mr Dugdale (1733), entitled *A Complete System of General Geography*, revised by Dr Peter Shaw, London, 1756.

tion, and substance of the Earth, the distribution of land and water, mountains, woods, and deserts, hydrography (including all the waters of the Earth), and the atmosphere; (2) the *Relative* part, including the celestial properties, *i.e.*, latitude, climate zones, longitude, &c.; and (3) the *Comparative* part, which "considers the particulars arising from comparing one part with another"; but under this head the questions discussed were longitude, the situation and distances of places, and navigation. Varenius does not treat of special geography, but gives a scheme for it under three heads—(1) *Terrestrial*, including position, outline, boundaries, mountains, mines, woods and deserts, waters, fertility and fruits, and living creatures; (2) *Celestial*, including appearance of the heavens and the climate; (3) *Human*, but this was added out of deference to popular usage.

This system of geography founded a new epoch, and the book—translated into English, Dutch, and French—was the unchallenged standard for more than a century. The framework was capable of accommodating itself to new facts, and was indeed far in advance of the knowledge of the period. The method included a recognition of the causes and effects of phenomena as well as the mere fact of their occurrence, and for the first time the importance of the vertical relief of the land was fairly recognized.

The physical side of geography continued to be elaborated after Varenius's methods, while the historical side was developed separately. Both branches, although enriched by new facts, remained stationary so far as method is concerned until nearly the end of the 18th century. The compilation of "geography books" by uninstructed writers led to the pernicious habit, which is not yet wholly overcome, of reducing the general or "physical" part to a few pages of concentrated information, and expanding the particular or "political" part by including unrevised travellers' stories and uncritical descriptions of the various countries of the world. Such books were in fact not geography, but merely compressed travel.

Bergmann.

The next marked advance in the theory of geography may be taken as the nearly simultaneous studies of the physical Earth carried out by the Swedish chemist, Torbern Bergmann, acting under the impulse of Linnæus, and by the German philosopher, Immanuel Kant. Bergmann's *Physical Description of the Earth* was published in Swedish in 1766, and translated into English in 1772 and into German in 1774. It is a plain, straightforward description of the globe, and of the various phenomena of the surface, dealing only with definitely ascertained facts in the natural order of their relationships, but avoiding any systematic classification or even definitions of terms.

Kant.

The problems of geography had been lightened by the destructive criticism of the French cartographer D'Anville (who had purged the map of the world of the last remnants of traditional fact unverified by modern observations) and rendered richer by the dawn of the new era of scientific travel, when Kant brought his logical powers to bear upon them. Kant's lectures on physical geography were delivered in the University of Königsberg from 1765 onwards.[1] Geography appealed to him as a valuable educational discipline, the joint foundation with anthropology of that "knowledge of the world" which was the result of reason and experience. In this connexion he divided the communication of experience from one person to another into two categories — the narrative or historical and the descriptive or geographical; both history and geography being viewed as descriptions, the former a description in order of time, the latter a description in order of space.

Physical geography he viewed as a summary of nature, the basis not only of history but also of "all the other possible geographies," of which he enumerates five, viz., (1) *Mathematical geography*, which deals with the form, size, and movements of the Earth and its place in the solar system; (2) *Moral geography*, or an account of the different customs and characters of mankind according to the region they inhabit; (3) *Political geography*, the divisions according to their organized governments; (4) *Mercantile geography*, dealing with the trade in the surplus products of countries; (5) *Theological geography*, or the distribution of religions. Here there is a clear and formal statement of the interaction and causal relation of all the phenomena of distribution on the Earth's surface, including the influence of physical geography upon the various activities of mankind from the lowest to the highest. Notwithstanding the form of this classification, Kant himself treats mathematical geography as preliminary to, and therefore not dependent on, physical geography. Physical geography itself is divided into two parts: a general, which has to do with the Earth and all that belongs to it—water, air, and land; and a particular, which deals with special products of the Earth—mankind, animals, plants, and minerals. Particular importance is given to the vertical relief of the land, on which the various branches of human geography are shown to depend.

Humboldt.

Alexander von Humboldt was the first modern geographer to become a great traveller, and thus to acquire an extensive stock of first-hand information on which an improved system of geography might be founded. The impulse given to the study of natural history by the example of Linnæus; the results brought back by Sir Joseph Banks, Dr Solander, and the two Forsters, who accompanied Cook in his voyages of discovery; the studies of De Saussure in the Alps, and the lists of desiderata in physical geography drawn up by that investigator, combined to prepare the way for Humboldt. The theory of geography was advanced by Humboldt mainly by his insistence on the great principle of the unity of nature. He brought all the "observable things," which the eager collectors of the previous century had been heaping together regardless of order or system, into relation with the vertical relief and the horizontal forms of the Earth's surface. Thus he demonstrated that the forms of the land exercise a directive and determining influence on climate, plant life, animal life, and on man himself. This was no new idea; it had been familiar for centuries in a less definite form, deduced from *à priori* considerations, and so far as regards the influence of surrounding circumstances upon man, Kant had already given it full expression. Humboldt's concrete illustrations and the remarkable power of his personality enabled him to enforce these principles in a way that produced an immediate and lasting effect. The treatises on physical geography by Mrs Mary Somerville and Sir John Herschel (the latter written for the eighth edition of the *Encyclopædia Britannica*) showed the effect produced by the stimulus of Humboldt's work in Great Britain.

Ritter.

Humboldt's contemporary, Carl Ritter, extended and disseminated the same views, and in his interpretation of "Comparative Geography" he laid stress on the importance of forming conclusions, not from the study of one region by itself, but from the comparison of the phenomena of many places. Impressed by the influence of terrestrial relief and climate on human movements, Ritter was led deeper and deeper into the study of history and archæology. His monumental "Vergleichende

[1] Printed in *Schriften zur Physischen Geographie*, vol. vi. of Schubert's edition of the collected works of Kant, Leipzig, 1839. First published with notes by Rink in 1802.

Geographie," which was to have made the whole world its theme, died out in a wilderness of detail in twenty-one volumes before it had covered more of the Earth's surface than Asia and a portion of Africa. Some of his followers showed a tendency to look on geography rather as an auxiliary to history than as a study of intrinsic worth.

Geography as a natural science.

During the rapid development of physical geography many branches of the study of nature, which had been included in the cosmography of the early writers, the physiography of Linnæus and even the *Erdkunde* of Ritter, had been so much advanced by the labours of specialists that their connexion was apt to be forgotten. Thus geology, meteorology, oceanography, and anthropology developed into distinct sciences. The absurd attempt was, and sometimes is still, made by geographers to include all natural science in geography; but it is more common for specialists in the various detailed sciences to think, and sometimes to assert, that the ground of physical geography is now fully occupied by these sciences. Political geography has been too often looked on from both sides as a mere summary of guide-book knowledge, useful in the schoolroom, a poor relation of physical geography that it was rarely necessary to recognize.

The science of geography, passed on from antiquity by Ptolemy, re-established by Varenius and Newton, and systematized by Kant, included within itself definite aspects of all those terrestrial phenomena which are now treated exhaustively under the heads of geology, meteorology, oceanography, and anthropology; and the inclusion of the requisite portions of the perfected results of these sciences in geography is simply the gathering in of fruit matured from the seed scattered by geography itself.

The study of geography was advanced by improvements in cartography (see MAPS), not only in the methods of survey and projection, but in the representation of the third dimension by means of contour lines introduced by Buache in 1737, and the more remarkable because less obvious invention of isotherms and isobars introduced by Humboldt in 1817.

The teleological argument in geography.

The "argument from design" had been a favourite form of reasoning amongst Christian theologians, and, as worked out by Paley in his *Natural Theology*, it served the useful purpose of emphasizing the fitness which exists between all the inhabitants of the Earth and their physical environment. It was held that the Earth had been created so as to fit the wants of man in every particular. This argument was tacitly accepted or explicitly avowed by almost every writer on the theory of geography, and Carl Ritter distinctly recognized and adopted it as the unifying principle of his system. As a student of nature, however, he did not fail to see, and as professor of geography he always taught, that man was in very large measure conditioned by his physical environment. The apparent opposition of the observed fact to the assigned theory he overcame by looking upon the forms of the land and the arrangement of land and sea as instruments of Divine Providence for guiding the destiny as well as for supplying the requirements of man. This was the central theme of Ritter's philosophy; his religion and his geography were one, and the consequent fervour with which he pursued his mission goes far to account for the immense influence he acquired in Germany.

The theory of evolution in geography.

The evolutionary theory, more than hinted at in Kant's "Physical Geography," has, since the writings of Charles Darwin, become the unifying principle in geography. The conception of the development of the plan of the Earth from the first cooling of the surface of the planet throughout the long geological periods, the guiding power of environment on the circulation of water and of air, on the distribution of plants and animals, and finally on the movements of man, give to geography a philosophical dignity and a scientific completeness which it never previously possessed. The influence of environment on the organism may not be quite so potent as it was once believed to be, in the writings of Buckle for instance,[1] and certainly man, the ultimate term in the series, reacts upon and greatly modifies his environment; yet the fact that environment does influence all distributions is established beyond the possibility of doubt. In this way also the position of geography, at the point where physical science meets and mingles with mental science, is explained and justified. The change which took place during the 19th century in the substance and style of geography may be best seen by comparing the eight volumes of Malte-Brun's *Géographie Universelle* (Paris, 1812–29) with the twenty-one volumes of Reclus's *Géographie Universelle* (Paris, 1876–95).

In estimating the influence of recent writers on geography it is usual to assign to Peschel the credit of having corrected the preponderance which Ritter gave to the historical element, and restoring physical geography to its old pre-eminence.[2] As a matter of fact, each of the leading exponents of theoretical geography at the present time—such as Richthofen, Wagner, Ratzel, Davis, Penck, De Lapparent, and Reclus—has his individual point of view, one devoting more attention to the results of geological processes, another to anthropological conditions, and the rest viewing the subject in various blendings of the extreme lights.

The two conceptions which may now be said to animate the theory of geography are the genetic, which depends upon processes of origin, and the morphological, which depends on facts of form and distribution.

THE PRINCIPLES OF GEOGRAPHY.

As regards the scope of geography, the order of the various departments and their inter-relation, there is little difference of opinion, and the principles of geography[3] are now generally accepted by modern geographers. The order in which the various subjects are treated in the following sketch is the natural succession from fundamental to dependent facts, which corresponds also to the evolution of the diversities of the Earth's crust and of its inhabitants.

Mathematical geography.

The fundamental geographical conceptions are mathematical, the relations of space and form. The figure and dimensions of the Earth are the first of these. They are ascertained by a combination of actual measurement of the highest precision on the surface and angular observations of the positions of the heavenly bodies. The science of geodesy is part of mathematical geography, of which the arts of surveying and cartography are applications. The motions of the Earth as a planet must be taken into account, as they render possible the determination of position and direction by observations of the heavenly bodies. The diurnal rotation of the Earth furnishes two fixed points or poles, the axis joining which is fixed or nearly so in its direction in space. The rotation of the Earth thus fixes the directions of north and south and defines those of east and west. The angle which the Earth's axis makes with the plane in which the planet revolves round the sun determines the varying seasonal distribution of solar radiation over the surface and the mathematical zones of climate. Another important consequence of rotation is the deviation produced in moving bodies relatively to the surface. In the form known as Ferrell's Law this runs: "If a body moves in any direction on the Earth's surface, there is a deflecting force which arises from the Earth's rotation which tends to deflect it to the right in the northern hemisphere but to the left in the southern hemisphere." The deviation is of importance in the movement of air, of ocean currents, and to some degree of rivers.[4]

Physical geography.

In popular usage the words "physical geography" have come to mean geography viewed from a particular standpoint rather than any special department of the subject. The popular meaning is better conveyed by the word physiography, a term which appears to have been introduced by Linnæus, and was re-invented as a substitute for the cosmography of the Middle Ages by Professor Huxley. Although the term has since been limited by some writers to one particular part of the subject, it seems best to maintain the original and literal meaning. In the stricter sense, physical geography is that part of geography which involves the processes of contemporary change in the crust and the circulation of the fluid envelopes. It thus draws upon physics for the explanation of the phenomena with the space-relations of which it is specially concerned. Physical geography naturally falls into three divisions, dealing respectively with the surface of the lithosphere—geomorphology; the hydrosphere—oceanography; and the atmosphere—climatology. All these rest upon the facts of mathematical geography, and the three are so closely inter-related that they cannot be rigidly separated in any discussion. Oceanography and climatology are treated in some detail in special articles, the latter forming an essential part of meteorology.

Geomorphology.

Geomorphology is the part of geography which deals with terrestrial relief, including the submarine as well as the subaërial portions of the crust. The history of the origin of the various forms belongs to geology, and can be completely studied only by geological methods. But the relief of the crust is not a finished piece of sculpture; the forms are for the most part transitional, owing their characteristic outlines to the process by which they are produced; therefore the

[1] *History of Civilization*, vol. i., 1857.

[2] See H. J. Mackinder in *British Association Report* (Ipswich), 1895, p. 738, for a summary of German opinion, which has been expressed by many writers in a somewhat voluminous literature.

[3] This phrase is old, appearing in one of the earliest English works on geography, William Cuningham's *Cosmographical Glasse conteinyng the pleasant Principles of Cosmographie, Geographie, Hydrographie, or Navigation*, London, 1559.

[4] See also S. Günther, *Handbuch der Mathematischen Geographie*, Stuttgart, 1890.

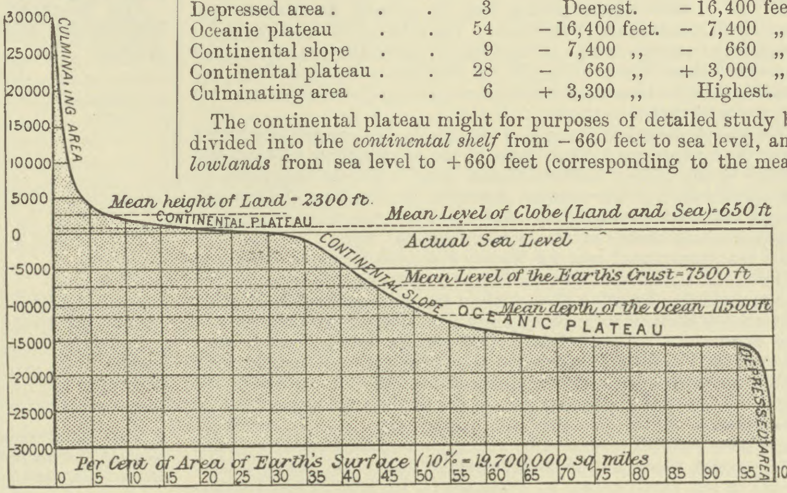
geographer must, for strictly geographical purposes, take some account of the processes which are now in action modifying the forms of the crust. Opinion differs greatly as to the extent to which the geographer's work should overlap that of the geologist.

The primary distinction of the forms of the crust is that between elevations and depressions. Granting that the geoid or mean surface of the ocean is a uniform spheroid, the distribution of land and water approximately indicates a division of the surface of the globe into two areas, one of elevation and one of depression. The increasing number of measurements of the height of land in all continents and islands, and the very detailed levellings in those countries which have been thoroughly surveyed, enable the average elevation of the land above sea level to be fairly estimated, although many vast gaps in accurate knowledge remain, and the estimate is not an exact one. The only part of the sea-bed the configuration of which is at all well known is the zone bordering the coasts where the depth is less than about 100 fathoms or 200 metres, *i.e.*, those parts which sailors speak of as "in soundings." Actual or projected routes for telegraph cables across the deep sea have also been sounded with extreme accuracy in many cases; but beyond these lines of sounding the vast spaces of the ocean remain unplumbed save for the rare researches of scientific expeditions, such as those of the *Challenger*, the *Valdivia*, and the *Albatross*. Thus the best approximation to the average depth of the ocean is little more than an expert guess.

Crustal relief.

The chief element of uncertainty as to the largest features of the relief of the Earth's crust is due to the unexplored area in the Arctic region and the far vaster regions of the Antarctic, of which we know nothing. We know that the Earth's surface if unveiled of water would exhibit a great region of elevation arranged with a certain rough radiate symmetry round the north pole, and extending southwards in three unequal arms which taper to points in the south. A great depression surrounds the unknown south polar region in a continuous ring and extends northwards in three vast hollows lying between the arms of the elevated area. So far it is possible to speak with certainty, but it is permissible to take a few steps into the twilight of dawning knowledge and indicate the chief subdivisions which are likely to be established in the great crust-hollow and the great crust-heap. The boundary between these should obviously be the mean surface of the sphere.

Sir John Murray deduced the mean height of the land of the globe as about 2250 feet above sea level, and the mean depth of the oceans as 2080 fathoms or 12,480 feet below sea level.[1] Calculating the area of the land at 55,000,000 square miles (or 28·6 per cent. of the surface), and that of the oceans as 137,200,000 square miles (or 71·4 per cent. of the surface), he found that the volume of the land above sea level was 23,450,000 cubic miles, the volume of water below sea level 323,800,000, and the total volume of the water equal to about $\frac{1}{666}$th of the volume of the whole globe. From these data, as revised by A. Supan,[2] H. R. Mill calculated the position of mean sphere level at about 10,000 feet or 1700 fathoms below sea level. He showed that an imaginary spheroidal shell, concentric with the Earth and cutting the slope between the elevated and depressed areas at the contour-line of 1700 fathoms, would not only leave above it a volume of the crust equal to the volume of the hollow left below it, but would also divide the surface of the Earth so that the area of the elevated region was equal to that of the depressed region.[3]



Areas of the crust, according to Murray.

A similar observation was made almost simultaneously by Romieux,[4] who further speculated on the equilibrium between the weight of the elevated land mass and that of the total waters of the ocean, and deduced some extremely interesting relations between them. Murray, as the result of his study, divided the Earth's surface into three zones—the *continental area* containing all dry land, the *transitional area* including the submarine slopes down to 1000 fathoms, and the *abysmal area* consisting of the floor of the ocean beyond that depth; and Mill proposed to take the line of mean-sphere level, instead of the empirical depth of 1000 fathoms, as the boundary between the transitional and abysmal areas.

An elaborate criticism of all the existing data regarding the volume relations of the vertical relief of the globe was made in 1894 by Professor Hermann Wagner, whose recalculations of volumes and mean heights—the best results which have yet been obtained—led to the following conclusions.[5]

Areas of the crust, according to Wagner.

The area of the dry land was taken as 28·3 per cent. of the surface of the globe, and that of the oceans as 71·7 per cent. The mean height deduced for the land was 2300 feet above sea level, the mean depth of the sea 11,500 feet below, while the position of mean-sphere level comes out as 7500 feet (1250 fathoms) below sea level. From this it would appear that 43 per cent. of the Earth's surface was above, and 57 per cent. below, the mean level. It must be noted, however, that since 1895 the soundings of Nansen in the north polar area, of the *Valdivia* in the Southern Ocean, and of various surveying ships in the North and South Pacific, have proved that the mean depth of the ocean is very considerably greater than had been supposed, and mean-sphere level must therefore lie deeper than the calculations of 1895 show; possibly not far from the position deduced from the freer estimate of 1888. By the device of a hypsographic curve co-ordinating the vertical relief and the areas of the Earth's surface occupied by each zone of elevation, according to the system introduced by Supan,[6] Wagner showed his results graphically.

This curve with the values reduced from metres to feet is reproduced below.

Wagner subdivides the Earth's surface, according to elevation, into the following five regions:—

WAGNER'S DIVISIONS OF THE EARTH'S CRUST.

Name.	Per cent. of Surface.	From	To
Depressed area . . .	3	Deepest.	−16,400 feet.
Oceanie plateau . . .	54	−16,400 feet.	− 7,400 ,,
Continental slope . . .	9	− 7,400 ,,	− 660 ,,
Continental plateau . . .	28	− 660 ,,	+ 3,000 ,,
Culminating area . . .	6	+ 3,300 ,,	Highest.

The continental plateau might for purposes of detailed study be divided into the *continental shelf* from −660 feet to sea level, and *lowlands* from sea level to +660 feet (corresponding to the mean level of the whole globe).[7] *Uplands* reaching from 660 feet to 2300 (the approximate mean level of the land), and *highlands*, from 2300 upwards, might also be distinguished.

Arrangement of world-ridges and hollows.

A striking fact in the configuration of the crust is that each continent, or elevated mass of the crust, is diametrically opposite to an ocean basin or great depression; the only partial exception being in the case of southern South America, which is antipodal to eastern Asia. Professor Lapworth has generalized the grand features of crustal relief in a scheme of attractive simplicity. He sees throughout all the chaos of irregular crust-forms the recurrence of a certain harmony, a succession of folds or waves which build up all the minor features.[8] One great series of crust waves from east to west is crossed by a second great series of crust waves from north to south, giving rise by their interference to six great elevated masses (the continents), arranged in three groups, each consisting of a northern and a southern member separated by a

[1] "On the Height of the Land and the Depth of the Ocean," *Scot. Geog. Mag.* iv. (1888), p. 1. Estimates had been made previously by Humboldt, De Lapparent, H. Wagner, and subsequently by Penck and Heiderich, and for the oceans by Karstens.

[2] *Petermanns Mitteilungen*, xxv. (1889), p. 17.

[3] *Proc. Roy. Soc. Edin.* xvii. (1890), p. 185.

[4] *Comptes Rendus Acad. Sci.*, Paris, vol. iii. (1890), p. 994.

[5] "Areal und mittlere Erhebung der Landflächen sowie der Erdkruste" in Gerland's *Beiträge zur Geophysik*, ii. (1895), p. 667. See also *Nature*, 54 (1896), p. 112.

[6] *Petermanns Mitteilungen*, xxxv. (1889), p. 19.

[7] The areas of the continental shelf and lowlands are approximately equal, and it is an interesting circumstance that, taken as a whole, the actual coast-line comes just midway on the most nearly level belt of the Earth's surface, excepting the ocean floor. The detailed configuration of some portions of the continental slope has been made the subject of speculation by Hull in *Trans. Victoria Inst.*, London, xxxi. (1899), p. 269, and of discussion by Hudleston in *Geological Mag.* vi. (1899), pp. 97, 145.

[8] *British Association Report* (Edinburgh), 1892, p. 699.

minor depression. These elevated masses are divided from one another by similar great depressions.

Lapworth's fold-theory.

He says :—"The surface of each of our great continental masses of land resembles that of a long and broad arch-like form, of which we see the simplest type in the New World. The surface of the North American arch is sagged downwards in the middle into a central depression which lies between two long marginal plateaux, and these plateaux are finally crowned by the wrinkled crests which form its two modern mountain systems. The surface of each of our ocean floors exactly resembles that of a continent turned upside down. Taking the Atlantic as our simplest type, we may say that the surface of an ocean basin resembles that of a mighty trough or syncline, buckled up more or less centrally in a medial ridge, which is bounded by two long and deep marginal hollows, in the cores of which still deeper grooves sink to the profoundest depths. This complementary relationship descends even to the minor features of the two. Where the great continental sag sinks below the ocean level, we have our gulfs and our Mediterraneans, seen in our type continent, as the Mexican Gulf and Hudson Bay. Where the central oceanic buckle attains the water-line we have our oceanic islands, seen in our type ocean, as St Helena and the Azores. Although the apparent crust-waves are neither equal in size nor symmetrical in form, this complementary relationship between them is always discernible. The broad Pacific depression seems to answer to the broad elevation of the Old World—the narrow trough of the Atlantic to the narrow continent of America."

Suess's theory.

The most thorough discussion of the great features of terrestrial relief in the light of their origin is that by Professor Suess,[1] who points out that the plan of the Earth is the result of two movements of the crust—one, subsidence over wide areas, giving rise to oceanic depressions and leaving the continents protuberant ; the other, folding along comparatively narrow belts, giving rise to mountain ranges. This theory of crust blocks dropped by subsidence is opposed to Lapworth's theory of vast crust-folds, but geology is the science which has to decide between them.

Geomorphology is concerned, however, in the suggestions which have been made as to the cause of the distribution of heap and hollow in the larger features of the crust. Élie de Beaumont, in his speculations on the relation between the direction of mountain ranges and their geological age and character, was feeling towards a comprehensive theory of the forms of crustal relief ; but his ideas were too geometrical, and his theory that the Earth is a spheroid built up on a rhombic dodecahedron, the pentagonal faces of which determined the direction of mountain ranges, could not be proved.[2] The theory brought forward by Lowthian Green[3] that the form of the Earth is a spheroid based on a regular tetrahedron is more serviceable, because it accounts for three very interesting facts of the terrestrial plan—(1) the antipodal position of continents and ocean basins ; (2) the triangular outline of the continents ; and (3) the excess of sea in the southern hemisphere. Recent investigations have recalled attention to the work of Lowthian Green, but the question is still in the controversial stage.[4] The study of tidal strain in the Earth's crust by Professor G. H. Darwin has led that physicist to indicate the possibility of the triangular form and southerly direction of the continents being a result of the differential or tidal attraction of the sun and moon.[5]

In any case it is fully recognized that the plan of the Earth is so clear as to leave no doubt as to its being due to some general cause which should be capable of detection.

The continents.

If the level of the sea were to become coincident with the mean level of the lithosphere, there would result one tri-radiate land-mass of nearly uniform outline and one continuous sheet of water broken by few islands. The actual position of sea level lies so near the summit of the crust-heap that the varied relief of the upper portion leads to the formation of a complicated coast-line and a great number of detached portions of land. The hydrosphere is, in fact, continuous, and the land is all in insular masses : the largest is the Old World of Europe, Asia, and Africa ; the next in size, America ; the third, possibly, Antarctica ; the fourth, Australia ; the fifth, Greenland. After this there is a considerable gap before New Guinea, Borneo,

[1] *Das Antlitz der Erde*, vols. i. and ii., Leipzig, 1885, 1888. Translated under the editorship of E. de Margerie with much additional matter as *La Face de la Terre*, vols. i. and ii., Paris, 1897, 1900.

[2] Élie de Beaumont, *Notice sur les Systèmes de Montagnes*, 3 vols., Paris, 1852.

[3] *Vestiges of the Molten Globe*, London, 1875.

[4] See J. W. Gregory, "The Plan of the Earth and its Causes," *Geog. Journal*, xiii. (1899), p. 225 ; Lord Avebury, *ibid.* xv. (1900), p. 46 ; Marcel Bertrand, "Déformation tétraédrique de la Terre et déplacement du pôle," *Comptes Rendus Acad. Sci.*, Paris, vol. cxxx. (1900), p. 449 ; and A. de Lapparent, *ibid.* p. 614.

[5] *Ency. Brit.*, 9th ed. art. TIDES, x. § 50.

Madagascar, Sumatra, and the vast multitude of smaller islands descending in size by regular gradations to mere rocks. The contrast between island and mainland was natural enough in the days before the discovery of Australia, and the mainland of the Old World was traditionally divided into three continents. These "continents," "parts of the Earth," or "quarters of the globe," proved to be convenient divisions ; America was added as a fourth, and subsequently divided into two, while Australia on its discovery was classed sometimes as a new continent, sometimes merely as an island, sometimes compromisingly as an island-continent, according to individual opinion. The discovery of the insularity of Greenland might again give rise to the argument as to the distinction between island and continent. Although the name of continent was not applied to large portions of land for any physical reasons, it so happens that there is a certain physical similarity or homology between them which is not shared by the smaller islands or peninsulas.

Homology of continents.

The typical continental form is triangular as regards its sea level outline. The relief of the surface typically includes a central plain, sometimes dipping below sea level, bounded by lateral highlands or mountain ranges, loftier on one side than on the other, the higher enclosing a plateau shut in by mountains. South America and North America follow this type most closely ; Eurasia (the land mass of Europe and Asia) comes next, while Africa and Australia are farther removed from the type, and the structure of Antarctica and Greenland is unknown.

If the continuous, unbroken, horizontal extent of land in a continent is termed its *trunk*,[6] and the portions cut up by inlets or channels of the sea into islands and peninsulas the *limbs*, it is possible to compare the continents in an instructive manner.

The following table is from the statistics of Professor H. Wagner,[7] his metric measurements being transposed into British units :—

COMPARISON OF THE CONTINENTS.

	Area (total) mil. sq. m.	Mean height, feet.	Area trunk, mil. sq. m.	Area peninsulas, mil. sq. m.	Area islands, mil. sq. m.	Area limbs, mil. sq. m.	Area limbs, per cent.
Old World .	35·8	2360					
New World .	16·2	2230					
Eurasia . .	20·85	2620	15·42	4·09	1·34	5·43	26
Africa . .	11·46	2130	11·22	...	0·24	0·24	2·1
North America	9·26	2300	6·92	0·78	1·56	2·34	25
South America	6·84	1970	6·76	0·02	0·06	0·08	1·1
Australia .	3·43	1310	2·77	0·16	0·50	0·66	19
Asia . .	17·02	3120	12·93	3·05	1·04	4·09	24
Europe . .	3·83	980	2·49	1·04	0·30	1·34	35

Islands.

The usual classification of islands is into continental and oceanic. The former class includes all those which rise from the continental shelf, or show evidence in the character of their rocks of having at one time been continuous with a neighbouring continent. The latter rise abruptly from the oceanic abysses. Oceanic islands are divided according to their geological character into volcanic islands and those of organic origin, including coral islands. More elaborate subdivisions according to structure, origin, and position have been proposed.[8] In some cases a piece of land is only an island at high water, and by imperceptible gradation the form passes into a peninsula. The typical peninsula is connected with the mainland by a relatively narrow isthmus ; the name is, however, extended to any limb projecting from the trunk of the mainland, even when, as in the Indian peninsula, it is connected by its widest part.

Coasts.

Small peninsulas are known as promontories or headlands, and the extremity as a cape. The opposite form, an inlet of the sea, is known when wide as a gulf, bay, or bight, according to size and degree of inflexion, or as a fjord or ria when long and narrow. It is convenient to employ a specific name for a projection of a coast-line less pronounced than a peninsula, and for an inlet less pronounced than a bay or bight ; outcurve and incurve may serve the turn. The varieties of coast-lines were reduced to an exact classification by Richthofen, who grouped them according to the height and slope of the land into cliff-coasts (*Steilküsten*)—narrow beach coasts with cliffs, wide beach coasts with cliffs, and low coasts, subdividing each group according as the coast-line runs parallel to or crosses the line of strike of the mountains, or is not related to mountain structure.

[6] *Rumpf*, in German, the language in which this distinction was first made.

[7] *Lehrbuch der Geographie*, Hanover and Leipzig, 1900, Bd. i. S. 245, 249.

[8] See, for example, F. G. Hahn's *Insel-Studien*, Leipzig, 1883.

A further subdivision depends on the character of the inter-relation of land and sea along the shore producing such types as a fjord-coast, ria-coast, or lagoon-coast. This extremely elaborate subdivision may be reduced, as Wagner points out, to three types—the continental coast where the sea comes up to the solid rock-material of the land; the marine coast, which is formed entirely of soft material sorted out by the sea; and the composite coast, in which both forms are combined.

Coast-lines. On large-scale maps it is necessary to show two coast-lines, one for the highest, the other for the lowest tide; but in small-scale maps a single line is usually wider than is required to represent the whole breadth of the inter-tidal zone. The measurement of a coast-line is difficult, because the length will necessarily be greater when measured on a large-scale map where minute irregularities can be taken into account. It is usual to distinguish between the general coast-line measured from point to point of the headlands disregarding the smaller bays, and the detailed coast-line which takes account of every inflexion shown by the map employed, and follows up river entrances to the point where tidal action ceases. The ratio between these two coast-lines represents the "coastal development" of any region.

Submarine forms. While the forms of the sea-bed are not yet sufficiently well known to admit of exact classification, they are recognized to be as a rule distinct from the forms of the land, and the importance of using a distinctive terminology is felt. Efforts are being made to arrive at a definite international agreement on this subject.[1]

In our present state of knowledge it would probably be sufficient to use *depression* as the general term for any hollow of the sea-bed, and to distinguish a relatively narrow depression as a *furrow* if the slope of the sides be gentle, and as a *trough* if the slope of the sides be steep. A relatively wide depression might be called a *basin* when the slope is gentle, and a *caldron* when it is abrupt. The word *deep*, often used in the general sense of a deep depression, might be reserved to indicate the deepest portion of a basin or caldron. The nearly flat part of the sea-bed in a depression might be termed a *floor*, and the steeply-sloping side of a depression, or of an elevation, a *wall*. The general term *elevation* might be applied to any inequality rising above the general level of the ocean floor; if relatively narrow it might be termed a *rise*, and if relatively wide a *bank*. For any elevation coming to within five fathoms of the surface, so as to become a danger to navigation, the word *shoal* should be retained. It is convenient to recognize one other form, the *shelf*, a nearly horizontal bank attached to land or to a wall, and bordered on the deeper side by an abrupt descent.

Land forms. The forms of the dry land are of infinite variety, and have been studied in great detail.[2] From the descriptive or topographical point of view, geometrical form alone should be considered; but the origin and geological structure of land forms must in many cases be taken into account when dealing with the function they exercise in the control of mobile distributions. The geographers who have hitherto given most attention to the forms of the land have been trained as geologists, and consequently there is a general tendency to make origin or structure the basis of classification rather than form alone.

The six elementary land forms. The fundamental form-elements may be reduced to the six proposed by Professor Penck as the basis of his double system of classification by form and origin.[3] These may be looked upon as being all derived by various modifications or arrangements of the single form-unit, the *slope* or inclined plane surface. No one form occurs alone, but always grouped together with others in various ways to make up districts, regions, and lands of distinctive characters. They are:—

(1) The *plane* or gently inclined uniform surface.

(2) The *scarp* or steeply inclined slope; this is necessarily of small extent except in the direction of its length.

(3) The *valley*, composed of two lateral parallel slopes inclined towards a narrow strip of plain at a lower level which itself slopes downwards in the direction of its length. Many varieties of this fundamental form may be distinguished.

(4) The *mount*, composed of a surface falling away on every side from a particular place. This place may either be a point, as in a volcanic cone, or a line, as in a mountain range or ridge of hills.

(5) The *hollow* or form produced by a land surface sloping inwards from all sides to a particular lowest place, the converse of a mount.

(6) The *cavern* or space entirely surrounded by a land surface.

Geology and land forms. These forms never occur scattered haphazard over a region, but always in an orderly subordination depending on their mode of origin. The dominant forms result from crustal movements, the subsidiary from secondary reactions during the action of the primitive forms on mobile distributions. The geological structure and the mineral composition of the rocks are often the chief causes determining the character of the land forms of a region. Thus the whole of the scenery of a limestone country depends on the solubility and permeability of the rocks, leading to the typical Karst-formations of caverns, swallow-holes, and underground stream courses, with the contingent phenomena of dry valleys and natural bridges. A sandy beach or desert owes its character to the mobility of its constituent sand-grains, which are readily drifted and piled up in the form of dunes. A region where volcanic activity has led to the embedding of dykes or bosses of hard rock amongst softer strata produces a plain broken by abrupt and isolated eminences.[4]

Classification of mountains. It would be impracticable to go fully into the varieties of each specific form; but, partly as an example of modern geographical classification, partly because of the exceptional importance of mountains amongst the features of the land, one exception may be made. The classification of mountains into types has usually had regard rather to geological structure than to external form, so that some geologists would even apply the name of a mountain range to a region not distinguished by relief from the rest of the country if it bear geological evidence of having once been a true range. A mountain may be described (it cannot be defined) as an elevated region of irregular surface rising comparatively abruptly from lower ground. The actual elevation of a summit above sea level does not necessarily affect its mountainous character; a gentle eminence, for instance, rising a few hundred feet above a tableland, even if at an elevation of say 15,000 feet, could only be called a hill.[5] But it may be said that any abrupt slope of 2000 feet or more in vertical height may justly be called a mountain, while abrupt slopes of lesser height may be called hills. Existing classifications, however, do not take account of any difference in kind between mountain and hills, although it is common in the German language to speak of *Hügelland*, *Mittelgebirge*, and *Hochgebirge* with a definite significance.

The simple classification employed by Professor James Geikie[6] into mountains of accumulation, mountains of elevation, and mountains of circumdenudation, is not considered sufficiently thorough by German geographers, who, following Richthofen, generally adopt a classification dependent on six primary divisions, each of which is subdivided. The terms employed, especially for the subdivisions, cannot be easily translated into other languages, and the English equivalents in the following table are only put forward tentatively:—

RICHTHOFEN'S CLASSIFICATION OF MOUNTAINS.[7]

I. *Tektonische Gebirge*—Tectonic mountains.
 (*a*) *Bruchgebirge oder Schollengebirge*—Block mountains.
  1. *Einseitige Schollengebirge oder Schollenrandgebirge*—Scarp or tilted block mountains.
   (i.) *Tafelscholle*—Table blocks.
   (ii.) *Abrasionsscholle*—Abraded blocks.
   (iii.) *Transgressionsscholle*—Blocks of unconformable strata.
  2. *Flexurgebirge*—Flexure mountains.
  3. *Horstgebirge*—Symmetrical block mountains.
 (*b*) *Faltungsgebirge*—Fold mountains.
  1. *Homöomorphe Faltungsgebirge*—Homomorphic fold mountains.
  2. *Heteromorphe Faltungsgebirge*—Heteromorphic fold mountains.
II. *Rumpfgebirge oder Abrasionsgebirge*—Trunk or abraded mountains.

---

[1] Wagner, Krümmel, and Mill, in *Bericht des VI. Internationalen Geographischen Congresses*, Berlin, 1899. Also see *British Association Report* (Dover), 1899, p. 810.

[2] The most important works on the classification of land forms are F. von Richthofen, *Führer für Forschungsreisende*, Berlin, 1886; G. de la Noë and E. de Margerie, *Les Formes du Terrain*, Paris, 1888; and above all A. Penck, *Morphologie der Erdoberfläche*, 2 vols., Stuttgart, 1894. Compare also A. de Lapparent, *Leçons de Géographie physique*, 2nd ed., Paris, 1898, and W. M. Davis, *Physical Geography*, Boston, 1899.

[3] "Geomorphologie als genetische Wissenschaft," in *Report of Sixth International Geog. Congress*, London, 1895, p. 735 (English Abstract, p. 748).

[4] On this subject see J. Geikie, *Earth Sculpture*, London, 1898; J. E. Marr, *The Scientific Study of Scenery*, London, 1900; Sir A. Geikie, *The Scenery and Geology of Scotland*, London, 2nd ed., 1887; Lord Avebury (Sir J. Lubbock), *The Scenery of Switzerland*, London, 1896.

[5] Some geographers distinguish a mountain from a hill by origin; thus Professor Seeley says "a mountain implies elevation and a hill implies denudation, but the external forms of both are often identical." *Report VI. Int. Geog. Congress*, London, 1895, p. 751.

[6] "Mountains," in *Scot. Geog. Mag.* ii. (1886), p. 145.

[7] *Führer für Forschungsreisende*, pp. 652–685.

III. *Ausbruchsgebirge*—Eruptive mountains.
IV. *Aufschüttungsgebirge*—Mountains of accumulation.
V. *Flachböden*—Plateaux.
   (*a*) *Abrasionsplatten*—Abraded plateaux.
   (*b*) *Marines Flachland*—Plain of marine erosion.
   (*c*) *Schichtungstafelland*—Horizontally stratified tableland.
   (*d*) *Uebergusstafelland*—Lava plain.
   (*e*) *Stromflachland*—River plain.
   (*f*) *Flachböden der atmosphärischen Aufschüttung*—Plains of æolian formation.
VI. *Erosionsgebirge*—Mountains of erosion.

From the morphological point of view it is more important to distinguish the groups of mountain forms, such as the *mountain mass* or group of mountains radiating from a centre, with the valleys furrowing their flanks spreading towards every direction; the *mountain chain* or line of heights, forming a long narrow ridge or series of ridges separated by parallel valleys; the *dissected plateau* or highland, divided into mountains of circumdenudation by a system of deeply-cut valleys; and the *isolated peak*, usually a volcanic cone or a hard rock mass left projecting after the softer strata which embedded it have been worn away (Monadnock of Professor Davis).

Mountain forms.

The geographical distribution of mountains is intimately associated with the great structural lines of the continents of which they form the culminating region. Lofty lines of fold mountains form the "backbones" of North America in the Rocky Mountains and the west coast systems, of South America in the Cordillera of the Andes, of Europe in the Pyrenees, Alps, Carpathians, and Caucasus, and of Asia in the mountains of Asia Minor, converging on the Pamirs and diverging thence in the Himalaya and the vast mountain systems of Central and Eastern Asia. The remarkable line of volcanoes around the whole coast of the Pacific and along the margin of the Caribbean and Mediterranean Seas is one of the most conspicuous features of the globe.

Distribution of mountains.

If land forms may be compared to organs, the part they serve in the economy of the Earth may, without straining the term, be characterized as function. The first and simplest function of the land surface is that of guiding loose material to a lower level. The downward pull of gravity suffices to bring about the fall of such material, but the path it will follow and the distance it will travel before coming to rest depend upon the land form. The loose material may, and in an arid region does, consist only of portions of the higher parts of the surface detached by the expansion and contraction produced by heating and cooling due to radiation. Such broken material rolling down a uniform scarp would tend to reduce its steepness by the loss of material in the upper part and by the accumulation of a mound or scree against the lower part of the slope. But where the side is not a uniform scarp, but made up of a series of ridges and valleys, the tendency will be to distribute the detritus in an irregular manner, directing it away from one place and collecting it in great masses in another, so that in time the land form assumes a new appearance. Snow accumulating on the higher portions of the land, when compacted into ice and caused to flow downwards by gravity, gives rise, on account of its more coherent character, to continuous glaciers, which mould themselves to the slopes down which they are guided, different ice-streams converging to send forward a greater volume. Gradually coming to occupy definite beds, which are deepened and polished by the friction, they impress a characteristic appearance on the land, which guides them as they traverse it, and, although the ice melts at lower levels, vast quantities of clay and broken stones are brought down and deposited in terminal moraines where the glacier ends.

Functions of land forms.

Land waste.

Glaciers.

Rain is by far the most important of the inorganic mobile distributions upon which land forms exercise their function of guidance and control. The precipitation of rain from the aqueous vapour of the atmosphere is dictated by the form and altitude of the land surface and the direction of the prevailing winds, which itself is largely influenced by the land. It is on the windward faces of the highest ground that most rain falls, and all that does not evaporate or percolate into the ground is conducted back to the sea by a route which depends only on the form of the land. More mobile and more searching than ice or rock rubbish, the trickling drops are guided by the deepest lines of the hillside in their incipient flow, and as these lines converge, the stream, gaining strength, proceeds in its torrential course to carve its channel deeper and entrench itself in permanent occupation. Thus the stream-bed, from which at first the water might be blown away into a new channel by a gale of wind, ultimately grows to be the strongest line of the landscape. As the main valley deepens, the tributary stream-beds are deepened also, and gradually cut their way headwards, enlarging the area whence they draw their supplies. Thus new land forms are created—valleys of curious complexity, for example—by the "capture" and diversion of the water of one river by another, leading to a change of watershed.[1] The minor tributaries become more numerous and more constant, until the system of torrents has impressed its own individuality on the mountain side. As the river leaves the mountain, ever growing by the accession of tributaries, it ceases, save in flood time, to be a formidable instrument of destruction; the gentler slope of the land surface gives to it only power sufficient to transport small stones, gravel, sand, and ultimately mud. Its valley banks are cut back by the erosion of minor tributaries, or by rain-wash if the climate be moist, or left steep and sharp while the river deepens its bed if the climate be arid. The outline of the curve of a valley's sides ultimately depends on the angle of repose of the detritus which covers them, if there has been no subsequent change, such as the passage of a glacier along the valley, which tends to destroy the regularity of the cross-section. The slope of the river bed diminishes until the plain compels the river to move slowly, swinging in meanders proportioned to its size, and gradually, controlled by the flattening land, ceasing to transport material, but raising its banks and silting up its bed by the dropped sediment, until, split up and shoaled, its distributaries struggle across its delta to the sea. This is the typical river of which there are infinite varieties, yet every variety would, if time were given, and the land remained unchanged in level relatively to the sea, ultimately approach to the type. Movements of the land either of subsidence or elevation, changes in the land by the action of erosion in cutting back an escarpment or cutting through a col, changes in climate by affecting the rainfall and the volume of water, all tend to throw the river valley out of harmony with the actual condition of its stream. There is nothing more striking in geography than the perfection of the adjustment of a great river system to its valleys when the land has remained stable for a very lengthened period. Before full adjustment has been attained the river bed may be broken in places by waterfalls or interrupted by lakes; after adjustment the bed assumes a permanent outline, the slope diminishing more and more gradually, without a break in its symmetrical descent. Excellent examples of the indecisive drainage of a new land surface, on which the river system has not had time to impress itself, are to be seen in northern Canada and in Finland, where rivers are separated by scarcely perceptible divides, and the numerous lakes frequently belong to more than one river system.

Rain.

River systems.

Adjustment of rivers to land.

The action of rivers on the land is so important that it has been made the basis of a system of physical geography by Professor W. M. Davis, who classifies land surfaces in terms of the three factors—structure, process, and time.[2] Of these time, during which the process is acting on the structure, is the most important. A land may thus be characterized by its position in the "geographical cycle," or cycle of erosion, as young, mature, or old, the last term being reached when the base-level of erosion is attained, and the land, however varied its relief may have been in youth or maturity, is reduced to a nearly uniform surface or peneplain. By a re-elevation of a peneplain the rivers of an old land surface may be restored to youthful activity, and resume their shaping action, deepening the old valleys and initiating new ones, starting afresh the whole course of the geographical cycle. It is, however, not the action of the running water on the land, but the function exercised by the land on the running water, that is considered here to be the special province of geography. At every stage of the geographical cycle the land forms, as they exist at that stage, are concerned in guiding the condensation and flow of water in certain definite ways. Thus, for example, in a mountain range at right angles to a prevailing sea-wind, it is the land forms which determine that one side of the range shall be richly watered and deeply dissected by a complete system of valleys, while the other side is dry, indefinite in its valley systems, and sends none of its scanty drainage to the sea. The action of rain, ice, and rivers conspires with the movement of land waste to strip the layer of soil from steep slopes as rapidly as it forms, and to cause it to accumulate on the flat valley bottoms, in the graceful flattened cones of alluvial fans at the outlet of the gorges of tributaries, or in the smoothly-spread surface of alluvial plains.

The geographical cycle.

The whole question of the régime of rivers and lakes is sometimes treated under the name hydrography, a name used by some writers in the sense of marine surveying, and by others as synonymous with oceanography. For the study of rivers alone the name potamology[3] has been suggested by Penck, and the

[1] See, for a summary of river-action, A. Phillipson, *Studien über Wasserscheiden*, Leipzig, 1886; also I. C. Russell, *River Development*, London, 1898 (published as *The Rivers of North America*, New York, 1898).

[2] W. M. Davis, "The Geographical Cycle," *Geog. Journ.* xiv. (1899), p. 484.

[3] A. Penck, "Potamology as a Branch of Physical Geography," *Geog. Journ.* x. (1897), p. 619.

subject being of much practical importance has received a good deal of attention.[1]

The study of lakes has also been specialized under the name of limnology.[2] The existence of lakes in hollows of the land depends upon the balance between precipitation and evaporation. A stream flowing into a hollow will tend to fill it up, and the water will begin to escape as soon as its level rises high enough to reach the lowest part of the rim. In the case of a large hollow in a very dry climate the rate of evaporation may be sufficient to prevent the water from ever rising to the lip, so that there is no outflow to the sea, and a basin of internal drainage is the result. This is the case, for instance, in the Caspian Sea, the Aral and Balkhash lakes, the Tarim basin, the Sahara, inner Australia, the great basin of the United States, and the Titicaca basin. These basins of internal drainage are calculated to amount to 22 per cent. of the land surface. The percentages of the land surface draining to the different oceans are approximately —Atlantic, 34·3 per cent.; Arctic Sea, 16·5 per cent.; Pacific, 14·4 per cent.; Indian Ocean, 12·8 per cent.[3]

Lakes and internal drainage.

The parts of a river system have not been so clearly defined as is desirable, hence the exaggerated importance popularly attached to "the source" of a river. A well-developed river system has in fact many equally important and widely-separated sources, the most distant from the mouth, the highest, or even that of largest initial volume not being necessarily of greater geographical interest than the rest. The whole of the land which directs drainage towards one river is known as its basin, catchment area, or drainage area—sometimes, by an incorrect expression, as its valley or even its watershed. The boundary line between one drainage area and others is rightly termed the watershed, but on account of the ambiguity which has been tolerated it is better to call it water-parting, or, as in America, divide. The only other important term which requires to be noted here is *thalweg*, a word introduced from the German into French and English, and meaning the deepest line along the valley, which is necessarily occupied by a stream unless the valley is dry.

Terminology of river systems.

The functions of land forms extend beyond the control of the circulation of the atmosphere, the hydrosphere, and the water which is continually being interchanged between them; they are exercised with increased effect in the higher departments of biogeography and anthropogeography.

The sum of the organic life on the globe is termed by some geographers the biosphere, and it has been estimated that the whole mass of living substance in existence at one time would cover the surface of the Earth to a depth of one-fifth of an inch.[4] The distribution of living organisms is a complex problem, a function of many factors, several of which are yet but little known. They include the biological nature of the organism and its physical environment, the latter involving conditions in which geographical elements, direct or indirect, preponderate. The direct geographical elements are the arrangement of land and sea, continents and islands standing in sharp contrast, and the vertical relief of the globe, which interposes barriers of a less absolute kind between portions of the same land area or oceanic depression. The indirect geographical elements, which, as a rule, act with and intensify the direct, are mainly climatic; the prevailing winds, rainfall, mean and extreme temperatures of every locality depending on the arrangement of land and sea and of land forms. Climate thus guided affects the weathering of rocks, and so determines the kind and arrangement of soil. Different species of organisms come to perfection in different climates; and it may be stated as a general rule that a species, whether of plant or animal, once established at one point, would spread over the whole zone of the climate congenial to it unless some barrier were interposed to its progress. In the case of land and fresh-water organisms the sea is the chief barrier; in the case of marine organisms, the land. Differences in land forms do not exert great influence on the distribution of living creatures directly, but indirectly such land forms as mountain ranges and internal drainage basins are very potent through their action on soil and climate. A snow-capped mountain ridge or an arid desert forms a barrier between different forms of life which is often more effective than an equal breadth of sea. In this way the surface of the land is divided into numerous natural regions, the flora and fauna of each of which include some distinctive species not shared by the others. The distribution of life is discussed in the various articles in this Encyclopædia dealing with biological, botanical, and zoological subjects.[5]

Biogeography.

The classification of the land surface into areas inhabited by distinctive groups of plants has been attempted by many phytogeographers, but without resulting in any scheme of general acceptance. The simplest classification is perhaps that of Drude according to climatic zones, subdivided according to continents. This takes account of—(1) the *Arctic-Alpine* zone, including all the vegetation of the region bordering on perpetual snow; (2) the *Boreal* zone, including the temperate lands of North America, Europe, and Asia, all of which are substantially alike in botanical character; (3) the *Tropical* zone, divided sharply into (*a*) the tropical zone of the New World, and (*b*) the tropical zone of the Old World, the forms of which differ in a significant degree; (4) the *Austral* zone, comprising all continental land south of the equator, and sharply divided into three regions the floras of which are strikingly distinct—(*a*) South American, (*b*) South African, and (*c*) Australian; (5) the *Oceanic*, comprising all oceanic islands, the flora of which consists exclusively of forms whose seeds could be drifted undestroyed by ocean currents or carried by birds. To these might be added the antarctic, which is still practically unknown. Many subdivisions and transitional zones have been suggested by different authors.

Floral zones.

From the point of view of the economy of the globe this classification by species is perhaps less important than that by mode of life and physiological character in accordance with environment. The following are the chief areas of vegetational activity usually recognized:—(1) The ice-deserts of the arctic and antarctic and the highest mountain regions, where there is no vegetation except the lowest forms, like that which causes "red snow." (2) The tundra or region of intensely cold winters, forbidding tree-growth, where mosses and lichens cover most of the ground when unfrozen, and shrubs occur of species which in other conditions are trees, here stunted to the height of a few inches. A similar zone surrounds the permanent snow on lofty mountains in all latitudes. The tundra passes by imperceptible gradations into the moor, bog, and heath of warmer climates. (3) The temperate forests of evergreen or deciduous trees, according to circumstances, which occupy those parts of both temperate zones where rainfall and sunlight are both abundant. (4) The grassy steppes or prairies where the rainfall is diminished and temperatures are extreme, and grass is the prevailing form of vegetation. These pass imperceptibly into—(5) the arid desert, where rainfall is at a minimum, and the only plants are those modified to subsist with the smallest supply of water. (6) The tropical forest, which represents the maximum of plant luxuriance, stimulated by the heaviest rainfall, greatest heat, and strongest light. These divisions merge one into the other, and admit of almost indefinite subdivision, while they are subject to great modifications by human interference in clearing and cultivating. Plants exhibit the controlling power of environment to a high degree, and thus vegetation is usually in close adjustment to the bolder geographical features of a region.

Vegetation areas.

The divisions of the Earth into faunal regions by Dr P. L. Sclater have been found to hold good for a large number of groups of animals as different in their mode of life as birds and mammals, and they may thus be accepted as based on nature. They are six in number:—(1) *Palæarctic*, including Europe, Asia north of the Himalaya, and Africa north of the Sahara; (2) *Ethiopian*, consisting of Africa south of the Atlas range, and Madagascar; (3) *Oriental*, including India, Indo-China, and the Malay Archipelago north of Wallace's line, which runs between Bali and Lombok; (4) *Australian*, including Australia, New Zealand, New Guinea, and Polynesia; (5) *Nearctic* or North America, north of Mexico; and (6) *Neotropical* or South America. Each of these divisions is the home of a special fauna, many species of which are confined to it alone; in the Australian region, indeed, practically the whole fauna is peculiar and distinctive, suggesting a prolonged period of complete biological isolation. In some cases, such as the Ethiopian and Neotropical and the Palæarctic and Nearctic regions, the faunas, although distinct, are related, several forms on opposite sides of the Atlantic being analogous, *e.g.*, the lion and puma, ostrich and rhea. Where two of the faunal realms meet there is usually, though not always, a mixing of faunas. These facts have led some naturalists to include the Palæarctic and Nearctic regions in one, termed *Holarctic*, and to suggest transitional regions, such as the *Sonoran*, between North and South America, and the *Mediterranean*, between Europe and Africa, or to create sub-regions, such as Madagascar and New Zealand. Oceanic islands

Faunal realms.

[1] See, for instance, E. Wisotzki, *Hauptfluss und Nebenfluss*, Stettin, 1889. For practical studies, see official reports on the Mississippi, Rhine, Seine, Elbe, and other great rivers.

[2] F. A. Forel, *Handbuch der Seenkunde: Allgemeine Limnologie*, Stuttgart, 1901; F. A. Forel, "La Limnologie, Branche de la Géographie," *Report VI. Int. Geog. Congress*, London, 1895, p. 593; also *Le Léman*, Lausanne, 2 vols., 1892, 1894; H. Lullies, "Studien über Seen," *Jubiläumsschrift der Albertus-Universität*, Königsberg, 1894; and G. R. Credner, "Die Reliktenseen," *Petermanns Mitteilungen*, Erganzungshefte 86 and 89, Gotha, 1887, 1888.

[3] J. Murray, "Drainage Areas of the Continents," *Scot. Geog. Mag.* ii. (1886), p. 548.

[4] Wagner, *Lehrbuch der Geographie*, 1900, i. 586.

[5] For details, see A. R. Wallace, *Geographical Distribution of Animals* and *Island Life*; A. Heilprin, *Geographical and Geological Distribution of Animals*; O. Drude, *Handbuch der Pflanzengeographie*; A. Engler, *Entwickelungsgeschichte der Pflanzenwelt*; also Beddard, *Zoogeography*, Cambridge, 1895; and Sclater, *The Geography of Mammals*, London, 1899.

have, as a rule, distinctive faunas and floras which resemble, but are not identical with, those of other islands in similar positions.

Biological distribution as a means of geographical research. The study of the evolution of faunas and the comparison of the faunas of distant regions have furnished a trustworthy instrument of pre-historic geographical research, which enables earlier geographical relations of land and sea to be traced out, and the approximate period, or at least the chronological order of the larger changes, to be estimated. In this way, for example, it has been suggested that a land, "Lemuria," once connected Madagascar with the Malay Archipelago, and that a northern extension of the antarctic land once united the three southern continents.

The distribution of fossils frequently makes it possible to map out approximately the general features of land and sea in long-past geological periods, and so to enable the history of crustal relief to be traced.[1]

Reaction of organisms on environment. While the tendency is for the living forms to come into harmony with their environment and to approach the state of equilibrium by successive adjustments if the environment should happen to change, it is to be observed that the action of organisms themselves often tends to change their environment. Corals and other quick-growing calcareous marine organisms are the most powerful in this respect by creating new land in the ocean. Vegetation of all sorts acts in a similar way, either in forming soil and assisting in breaking up rocks, in filling up shallow lakes, and even, like the mangrove, in reclaiming wide stretches of land from the sea. Plant life, utilizing solar light to combine the inorganic elements of water, soil, and air into living substance, is the basis of all animal life. This is not by the supply of food alone, but also by the withdrawal of carbonic acid from the atmosphere, by which vegetation maintains the composition of the air in a state fit for the support of animal life. Man in the primitive stages of culture is scarcely to be distinguished from other animals as regards his subjection to environment, but in the higher grades of culture the conditions of control and reaction become much more complicated, and the department of anthropogeography is devoted to their consideration.

Anthropogeography. The first requisites of all human beings are food and protection, in their search for which men are brought into intimate relations with the forms and productions of the Earth's surface. The degree of dependence of any people upon environment varies inversely as the degree of culture or civilization, which for this purpose may perhaps be defined as the power of an individual to exercise control over the individual and over the environment for the benefit of the community. The development of culture is to a certain extent a question of race, and although forming one species, the varieties of man differ in almost imperceptible gradations with a complexity defying classification (see ANTHROPOLOGY). Professor Keane groups man round four leading types, which may be named the black, yellow, red, and white, or the Ethiopic, Mongolic, American, and Caucasic. Each may be subdivided, though not with great exactness, into smaller groups, either according to physical characteristics, of which the form of the head is most important, or according to language.

Types of man. The black type is found only in tropical or sub-tropical countries, and is usually in a primitive condition of culture, unless educated by contact with people of the white type. They follow the most primitive forms of religion (mainly fetishism), live on products of the woods or of the chase, with the minimum of work, and have only a loose political organization. The red type is peculiar to America, inhabiting every climate from polar to equatorial, and containing representatives of many stages of culture which had apparently developed without the aid or interference of people of any other race until the close of the 15th century. The yellow type is capable of a higher culture, cherishes higher religious beliefs, and inhabits as a rule the temperate zone, although extending to the tropics on one side and to the arctic regions on the other. The white type, originating in the north temperate zone, has spread over the whole world. They have attained the highest culture, profess the purest forms of monotheistic religion, and have brought all the people of the black type and most of those of the yellow under their domination.

The actual number of human inhabitants in the world has been calculated as follows :—

	By Continents.[2]
Asia .	875,000,000
Europe .	392,000,000
Africa .	170,000,000
America .	143,000,000
Australia and Polynesia .	7,000,000
Total .	1,587,000,000

	By Race.[3]
White (Caucasic)	770,000,000
Yellow (Mongolic)	540,000,000
Black (Ethiopic)	175,000,000
Red (American)	22,000,000
Total .	1,507,000,000

In round numbers the population of the world is about 1,600,000,000, and, according to an estimate by Ravenstein,[4] the maximum population which it will be possible for the Earth to maintain is 6000 millions, a number which, if the present average rate of increase continues, will be reached within 200 years.

While highly civilized communities are able to evade many of the restrictions of environment, to overcome barriers to intercommunication interposed by land or sea, to counteract the adverse influence of climate, and by the development of trade even to inhabit countries which cannot yield a food supply, the mass of mankind is still completely under the control of those conditions which in the past determined the distribution and the mode of life of the whole human race.

Influence of environment on man. In tropical forests primitive tribes depend on the collection of wild fruits, and in a minor degree on the chase of wild animals, for their food. Clothing is unnecessary ; hence there is little occasion for exercising the mental faculties beyond the sense of perception to avoid enemies, or the inventive arts beyond what is required for the simplest weapons and the most primitive fortifications. When the pursuit of game becomes the chief occupation of a people there is of necessity a higher development of courage, skill, powers of observation and invention ; and these qualities are still further enhanced in predatory tribes who take by force the food, clothing, and other property prepared or collected by a feebler people. The fruit-eating savage cannot stray beyond his woods, which bound his life as the water bounds that of a fish ; the hunter is free to live on the margin of forests or in open country, while the robber or warrior from some natural stronghold of the mountains sweeps over the adjacent plains and carries his raids into distant lands. Wide grassy steppes lead to the organization of the people as nomads whose wealth consists in flocks and herds, and their dwellings are tents. The nomad not only domesticates and turns to his own use the gentler and more powerful animals, such as sheep, cattle, horses, camels, but even turns some predatory creatures, like the dog, into a means of defending their natural prey. They hunt the beasts of prey destructive to their flocks, and form armed bands for protection against marauders or for purposes of aggression on weaker sedentary neighbours. On the fertile low grounds along the margins of rivers or in clearings of forests, agricultural communities naturally take their rise, dwelling in villages and cultivating the wild grains, which by careful nurture and selection have been turned into rich cereals. The agriculturalist as a rule is rooted to the soil. The land he tills he holds, and acquires a closer connexion with a particular patch of soil than either the hunter or the herdsman. In the temperate zone, where the seasons are sharply contrasted, but follow each other with regularity, foresight and self-denial were fostered, because if men did not exercise these qualities seed-time or harvest might pass into lost opportunities and the tribes would suffer. The more extreme climates of arid regions on the margins of the tropics, by the unpredictable succession of droughts and floods, confound the prevision of uninstructed people, and make prudence and industry qualities too uncertain in their results to be worth cultivating. Thus the civilization of agricultural peoples of the temperate zone grew rapidly, yet in each community a special type arose adapted to the soil, the crop, and the climate. On the sea-shore fishing naturally became a means of livelihood, and dwellers by the sea, in virtue of the dangers to which they are exposed from storm and unseaworthy craft, are stimulated to a higher degree of foresight, quicker observation, prompter decision, and more energetic action in emergencies than those who live inland. The building and handling of vessels also, and the utilization of such uncontrollable powers of nature as wind and tide, helped forward mechanical invention. To every type of coast there may be related a special type of occupation and even of character ; the deep and gloomy fjord, backed by almost impassable mountains, bred bold mariners whose only outlet for enterprise was seawards towards other lands—the *viks* created the vikings. On the gently sloping margin of the estuary of a great river a view of tranquil inland life was equally presented to the shore-dweller, and the ocean did not present the only prospect of a career. Finally the mountain valley, with its patches of cultivable soil on the alluvial fans of tributary torrents, its narrow pastures on the uplands only left clear of snow in summer, its intensified extremes of climate and its isolation, almost equal to that of an island, has in all countries produced a special type of brave and hardy people, whose utmost effort may bring them comfort, but not wealth, by honest toil, who know little of the outer world, and to whom the natural outlet for ambition is marauding on the fertile plains. The highlander and viking, products of the valleys raised high amid the mountains or half-drowned in the sea, are everywhere of kindred spirit.

It is in some such manner as these that the natural conditions of regions, which must be conformed to by prudence and utilized

[1] See particularly A. de Lapparent, *Traité de Géologie*, 4th ed. Paris, 1900.
[2] Estimate for 1900. H. Wagner, *Lehrbuch der Geographie*, i. p. 658.
[3] Estimate for year not stated. A. H. Keane in *International Geography*, p. 108.
[4] In *Proc. R. G. S.* xiii. (1891), p. 27.

by labour to yield shelter and food, have led to the growth of peoples differing in their ways of life, thought, and speech. The initial differences so produced are confirmed and perpetuated by the same barriers which divide the faunal or floral regions, the sea, mountains, deserts, and the like, and much of the course of past history and present politics becomes clear when the combined results of differing race and differing environment are taken into account.[1]

Density of population.

The specialization which accompanies the division of labour has important geographical consequences, for it necessitates communication between communities and the interchange of their products. Trade makes it possible to work mineral resources in localities where food can only be grown with great difficulty and expense, or which are even totally barren and waterless, entirely dependent on supplies from distant sources.

The population which can be permanently supported by a given area of land differs greatly according to the nature of the resources and the requirements of the people. Pastoral communities are always scattered very thinly over large areas; agricultural populations may be almost equally sparse where advanced methods of agriculture and labour-saving machinery are employed; but where a frugal people are situated on a fertile and inexhaustible soil, such as the deltas and river plains of Egypt, India, and China, an enormous population may be supported on a small area. In most cases, however, a very dense population can only be maintained in regions where mineral resources have fixed the site of great manufacturing industries. The maximum density of population which a given region can support is very difficult to determine; it depends partly on the race and standard of culture of the people, partly on the nature and origin of the resources on which they depend, partly on the artificial burdens imposed, and very largely on the climate. Density of population is measured by the average number of people residing on a unit of area; but in order to compare one part of the world with another the average should, strictly speaking, be taken for regions of equal size or of equal population; and the portions of the country which are permanently uninhabitable ought to be excluded from the calculation.[2] Considering the average density of population within the political limits of countries, the following list is of some value; the figures for a few smaller divisions of large countries are added (in brackets) for comparison:—

Average Population on 1 Square Mile.

(For 1890 or 1891.)

Country.	Density of population.	Country.	Density of population
(Saxony)	650[3]	Greece	95
Belgium	560[3]	European Turkey	90
Java	510[4]	Spain	90
(England)	500	European Russia	55[4]
(Bengal)	470[4]	Sweden	30
Holland	390	United States	30
United Kingdom	300	Mexico	15
Japan	285	Norway	15
Italy	280	Persia	12 (estimate)
China proper	270[4] (estimate)	New Zealand	7
German Empire	250	Brazil	4·5
Austria	210	Argentina	2·3
Indian Empire	185[4]	Eastern States of Australia	1·7
France	185	Dominion of Canada	1·4
Switzerland	185	Siberia	1
Denmark	140[4]	West Australia	0·17
Hungary	140[4]		
Portugal	135		
Ceylon	120[4]		

Migration.

The movement of people from one place to another without the immediate intention of returning is known as migration, and according to its origin it may be classed as centrifugal (directed *from* a particular area) and centripetal (directed *towards* a particular area). Centrifugal migration is usually a matter of compulsion; it may be necessitated by natural causes, such as a change of climate leading to the withering of pastures or destruction of agricultural land, to inundation, earthquake, pestilence, or to an excess of population over means of support; or to artificial causes, such as the wholesale deportation of a conquered people; or to political or religious persecution. In any case the people are driven out by some adverse change; and when the urgency is great they may require to drive out in turn weaker people who occupy a desirable territory, thus propagating the wave of migration, the direction of which is guided by the forms of the land into inevitable channels. Many of the great historic movements of peoples were doubtless due to the gradual change of geographical or climatic conditions; and the slow desiccation of Central Asia has been plausibly suggested as the real cause of the peopling of modern Europe and of the mediæval wars of the Old World, the theatres of which were critical points on the great natural lines of communication between east and west.

In the case of centripetal migrations people flock to some particular place where exceptionally favourable conditions have been found to exist. The rushes to goldfields and diamond-fields are typical instances; the growth of towns on coalfields and near other sources of power, and the rapid settlement of such rich agricultural districts as the wheat-lands of the American prairies, are other examples.

There is, however, a tendency for people to remain rooted to the land of their birth, when not compelled or induced by powerful external causes to seek a new home.

Political geography.

Thus arises the spirit of patriotism, a product of purely geographical conditions, thereby differing from the sentiment of loyalty, which is of racial origin. Where race and soil conspire to evoke both loyalty and patriotism in a people, the moral qualities of a great and permanent nation are secured. It is noticeable that the patriotic spirit is strongest in those places where people are brought most intimately into relation with the land; dwellers in the mountain or by the sea, and, above all, the people of rugged coasts and mountainous archipelagoes, have always been renowned for love of country, while the inhabitants of fertile plains and trading communities are frequently less strongly attached to their own land.

Amongst nomads the tribe is the unit of government, the political bond is personal, and there is no definite territorial association of the people, who may be loyal but cannot be patriotic. The idea of a country arises only when a nation, either homogeneous or composed of several races, establishes itself in a region the boundaries of which may be defined and defended against aggression from without. Political geography takes account of the partition of the Earth amongst organized communities, dealing with the relation of races to regions, and of nations to countries, and considering the conditions of territorial equilibrium and instability.

Boundaries.

The definition of boundaries and their delimitation is one of the most important parts of political geography. Natural boundaries are always the most definite and the strongest, lending themselves most readily to defence against aggression. The sea is the most effective of all, and an island state is recognized as the most stable. Next in importance comes a mountain range, but here there is often difficulty as to the definition of the actual crest-line, and mountain ranges being broad regions, it may happen that a small independent state, like Switzerland or Andorra, occupies the mountain valleys between two or more great countries. Rivers do not form effective international boundaries, although between dependent self-governing communities they are convenient lines of demarcation. A desert, or a belt of country left purposely without inhabitants, like the mark, marches, or debatable lands of the Middle Ages, was once a common means of separating nations which nourished hereditary grievances. The "buffer-state" of modern diplomacy is of the same ineffectual type. A less definite though very practical boundary is that formed by the meeting-line of two languages, or the districts inhabited by two races. The line of fortresses protecting Austria from Italy lies in some places well back from the political boundary, but just inside the linguistic frontier, so as to separate the German and Italian races occupying Austrian territory. Arbitrary lines, either traced from point to point and marked by posts on the ground, or defined as portions of meridians and parallels, are now the most common type of boundaries fixed by treaty. In Europe and Asia frontiers are usually strongly fortified and strictly watched in times of peace as well as during war. In South America strictly defined boundaries are still the exception, and the claims of neighbouring nations continually give rise to wars or arbitrations.[5]

Forms of government.

The modes of government amongst civilized peoples have little influence on political geography; some republics are as arbitrary and exacting in their frontier regulations as some absolute monarchies. It is, however, to be noticed that absolute monarchies are confined to the east of Europe and to Asia, Japan being the only constitutional monarchy east of the Carpathians. Limited monarchies are (with the exception of Japan) peculiar to Europe, and in these the degree of democratic control may be said to diminish as one passes eastwards from the United Kingdom. Republics, although represented

[1] On the influence of land on people see Shaler, *Nature and Man in America*, New York and London, 1892.

[2] See maps of density of population in Bartholomew's *Atlas of Scotland* and his *Handy Royal Atlas of England*.

[3] Almost exclusively industrial.

[4] Almost exclusively agricultural.

[5] For the history of territorial changes in Europe, see Freeman, *Historical Geography of Europe*, 2 vols., London, 1881; and for the official definition of existing boundaries, see Hertslet, *The Map of Europe by Treaty*, 4 vols., London, 1875, 1891; *The Map of Africa by Treaty*, 3 vols., London, 1896.

in Europe, are the peculiar form of government of America, and are unknown in Asia.

The forms of government of colonies present a series of transitional types from the autocratic administration of a governor appointed by the home Government to complete democratic self-government. The latter occurs only in the temperate possessions of the British empire, in which there is no great preponderance of a coloured native population. New colonial forms have been developed during the partition of Africa amongst European Powers, the sphere of influence being especially worthy of notice. This is a vaguer form of control than a protectorate, and frequently amounts merely to an agreement amongst civilized Powers to respect the right of one of their number to exercise government within a certain area at any future time.

The central governments of all civilized countries concerned with external relations are closely similar in their modes of action, but the internal administration may be very varied. In this respect a country is either centralized, like the United Kingdom or France, or federated of distinct self-governing units like Germany (where the units include kingdoms, at least three minor types of monarchies, municipalities and a crown land under a nominated governor), or the United States, where the units are democratic republics. The ultimate cause of the predominant form of federal government may be the geographical diversity of the country, as in the cantons occupying the once isolated mountain valleys of Switzerland, the racial diversity of the people, as in Austria-Hungary, or merely political expediency, as in republics of the American type.

The minor subdivisions into provinces, counties, and parishes, or analogous areas, may also be related in many cases to natural features or racial differences perpetuated by historical causes. The territorial divisions and subdivisions often survive the conditions which led to their origin; hence the study of political geography is allied to history as closely as the study of physical geography is allied to geology, and for the same reason.

Towns.

The aggregation of population in towns was at one time mainly brought about by the necessity for defence, a fact indicated by the defensive sites of many old towns. In later times, towns have been more often founded in proximity to valuable mineral resources, and at critical points or nodes on lines of communication. These are places where the mode of travelling or of transport is changed, such as seaports, river ports, and railway termini, or natural resting-places, such as a ford, the foot of a steep ascent on a road, the entrance of a valley leading up from a plain into the mountains, or a crossing-place of roads or railways.[1] The existence of a good natural harbour is often sufficient to give origin to a town and to fix one end of a line of land communication.

Lines of communication.

In countries of uniform surface or faint relief, roads and railways may be constructed in any direction without regard to the configuration. In places where the low ground is marshy, roads and railways often follow the ridge-lines of hills, or, as in Finland, the old glacial eskers, which run parallel to the shore. Wherever the relief of the land is pronounced, roads and railways are obliged to occupy the lowest ground winding along the valleys of rivers and through passes in the mountains. In exceptional cases obstructions which it would be impossible or too costly to turn are overcome by a bridge or tunnel, the magnitude of such works increasing with the growth of engineering skill and financial enterprise. Similarly the obstructions offered to water communication by interruption through land or shallows are overcome by cutting canals or dredging out channels. The economy and success of most lines of communication depend on following as far as possible existing natural lines and utilizing existing natural sources of power.[2]

Commercial geography.

Commercial geography may be defined as the description of the Earth's surface with special reference to the discovery, production, transport, and exchange of commodities. The transport concerns land routes and sea routes, the latter being the more important. While steam has been said to make a ship independent of wind and tide, it is still true that a long voyage even by steam must be planned so as to encounter the least resistance possible from prevailing winds and permanent currents, and this involves the application of oceanographical and meteorological knowledge. The older navigation by utilizing the power of the wind demands a very intimate knowledge of these conditions, and it is probable that a revival of sailing ships may in the present century vastly increase the importance of the study of maritime meteorology.

The discovery and production of commodities require a knowledge of the distribution of geological formations for mineral products, of the natural distribution, life-conditions, and cultivation or breeding of plants and animals, and of the labour market. Attention must also be paid to the artificial restrictions of political geography, to the legislative restrictions bearing on labour and trade as imposed in different countries, and, above all, to the incessant fluctuations of the economic conditions of supply and demand and the combinations of capitalists or workers which affect the market.[3] The term "applied geography" has been employed to designate commercial geography, the fact being that every aspect of scientific geography may be applied to practical purposes, including the purposes of trade. But apart from the applied science, there is an aspect of pure geography which concerns the theory of the relation of economics to the surface of the Earth.

Conclusion.

It will be seen that as each successive aspect of geographical science is considered in its natural sequence the conditions become more numerous, complex, variable, and practically important. From the underlying abstract mathematical considerations all through the physical, biological, anthropological, political, and commercial development of the subject runs the determining control exercised by crust-forms acting directly or indirectly on mobile distributions; and this is the essential principle of geography.

Progress of Geographical Discovery.

Recent exploration.

The last quarter of the 19th century witnessed no abatement of the spirit of exploration, almost all the remoter parts of the less known continents having been sought out and investigated. The marked lead taken by British explorers in the first part of the century has not been maintained; for many travellers from Germany, France, the United States, Italy, Austria-Hungary, Russia, and the Scandinavian countries have shared in the triumphs of discovery. The character of the explorations also has largely altered; the work has become more scientific, the surveys more exact, and the collections more systematic. The action of the Royal Geographical Society in supplying practical instruction to intending travellers, in astronomy, surveying, and the various branches of science useful to collectors, has had much to do with bringing about this change. The great development of photography has also been a notable aid, by placing at the disposal of travellers a faithful and ready means of recording the features of a country and the types of inhabitants.

With the exception of the Arctic and the Antarctic regions, very few places now remain absolutely unknown, and these only on account of the severity of natural conditions or the fanaticism of native peoples. The explorer ambitious to fill up a blank space on the map has now to turn his attention to a few comparatively small districts in the sub-arctic lands of Asia and North America, lying remote from the rivers which form the natural lines of communication; or to the highest parts of the great mountain ranges of Asia, the central wilds of the vast tropical forests of the Amazon basin, some corners of the Congo basin, the interior of Borneo and New Guinea; or to the heart of the arid deserts of the tropical continents. Although the greater part of the world has been explored and mapped, the accuracy of the work varies greatly, and only a small fraction of the land-surface has been surveyed with high precision.[4] And after the topographical and hypsometrical surveys are completed, much work remains to be done before statistics are available to enable all the distributions with which geography is concerned to be mapped with approximate completeness.

Geographical societies and publications.

The progress of exploration has been aided by the remarkable development of geographical societies, especially in France and Germany, since the war of 1870. There were in 1896 no fewer than 107 of these societies in the world (83 of them in Europe), with a total membership exceeding 50,000 persons; and in connexion with them, or appearing separately, there were 153 journals or magazines devoted entirely to geographical subjects.[5] In Germany there are professorships of geography in practically all universities, but the higher study of the subject has not been adequately encouraged hitherto in other countries. The superior quality of the exploring work done by recent travellers trained in Germany cannot be denied, where scientific study in the field, as distinct from mere surveying or the collection of specimens, is taken into account.

---

[1] For numerous special instances of the determining causes of town sites, see G. G. Chisholm, "On the Distribution of Towns and Villages in England," *Geographical Journal* (1897), ix. 76, x. 511.

[2] The whole subject of anthropogeography is treated in a masterly way by F. Ratzel in his *Anthropogeographie*, Stuttgart, vol. i., 2nd ed., 1899, vol. ii., 1891, and in his *Politische Geographie*, Leipzig, 1897. The special question of the reaction of man on his environment is handled by G. P. Marsh in *Man and Nature, or Physical Geography as modified by Human Action*, London, 1864.

[3] For commercial geography, see G. G. Chisholm, *Manual of Commercial Geography*, London, 1890.

[4] See J. G. Bartholomew, "The Mapping of the World," *Scottish Geog. Mag.* vi. (1890), 293, 575; vii. (1891), 124, 586.

[5] See H. Wagner, *Geographisches Jahrbuch*, Gotha, 1898. This year-book is the best systematic record of geographical progress in all departments.

Europe.—In Europe the only region where exploration in the ordinary sense of the term has been carried out is Iceland, which has been very carefully studied from every point of view by several travellers, pre-eminent amongst whom is Dr Thorvald Thoroddsen, a native of the island. In all countries the topographical surveys have been pushed forward and, in the United Kingdom, France, Germany, Switzerland, and Austria-Hungary, practically completed by the respective governments. Detailed surveys of the coast have been similarly completed by the hydrographic departments of the maritime states, while private effort has been directed towards the sounding of the smaller lakes, many of the larger ones having been surveyed by national or international organizations. In this respect, Forel in Switzerland, Delebecque and Belloc in France, Ule and Halbfass in Germany, Simony, Penck, and Richter in Austria, Marinelli in Italy, Anuchin in Russia, Mill in England, and Murray and Pullar in Scotland may be mentioned.

Iceland.

Topographical surveys.

Lake surveys.

Detailed exploration of the Alps, Pyrenees, Carpathians, and Norwegian mountains have been made by the members of numerous Alpine clubs (see MOUNTAINEERING); and E. A. Martel in France has initiated the special study of caverns, a fascinating branch of minor exploration, to which the name Speleology has been applied, and to which attention is now directed in all European countries.

Mountain exploration.

Speleology.

The regional description of countries has only been carried out with systematic thoroughness in Finland, where the Geographical Society of Helsingfors has produced a remarkable *Atlas de Finlande*, with a volume of explanatory text, in a French as well as a Swedish edition. In Germany, under the stimulus of the German Geographical Congress (*Deutsche Geographentag*), a series of valuable monographs on different parts of the empire has been produced under the title of *Forschungen zur Deutschen Landes- und Volkskunde*, commenced in 1885 under the editorship of Professor A. Kirchhoff. Similar memoirs abound in the geographical journals of France, Austria, Russia, and in the geological publications of the United States and Canada. A systematic geographical description of the British Isles, based on the one-inch Ordnance Survey map, and utilizing the official statistics of all distributions, was suggested by Dr H. R. Mill in 1896, and a specimen memoir published in 1900.[1] All these are efforts to bring together synthetically the masses of discrete information accumulated by costly public surveys, which at present convey no definite impression to the mind, because the facts of the mobile distributions with which many of them deal are treated without reference to the land-forms.

Regional descriptions.

Asia.—Although made as long ago as 1864, the journey of Prince Peter Kropotkin in the Trans-Baikal province of Siberia and northern Manchuria was not generally known in western Europe until recently. It supplied him with data which led to an entire change in the theory of the mountain system of Asia as a whole, and opened the way to a generation of profitable exploration. Next in importance come the journeys of Baron von Richthofen in China in the years 1868–72, in which the geological structure and the vast mineral wealth of that country were first clearly established. It was a purely scientific journey, and after thirty years led to an important political result, for it was on Richthofen's recommendation that the bay of Kiaochow was selected for the German *pied-à-terre* in China, and the province of Shantung as a German "sphere of influence."

Kropotkin.

Richthofen.

During the whole period under consideration Dr Gustav Radde of the Tiflis Museum has been carrying on a series of exploring journeys in the Caucasus, where also the Russian surveyors have been at work.

Caucasus and Trans-Caspian.

M. Lessar did valuable service on the Turkestan frontier, and General Annenkoff succeeded in bridging the Trans-Caspian deserts by the railway which was opened to Samarcand in 1888, and to Tashkent and Ardijan in 1899, thus furnishing ready access to the borders of Chinese Turkestan.

In 1876 M. Potanin settled the question of the eastern extension of the Altai, and more recently he and other Russian explorers made important researches on the mountain systems of northern China, the northern buttresses of the Tibet plateau, and the Pamirs. The name of Prjevalsky deserves special distinction in this respect. Commencing his serious explorations in 1871, he rediscovered in 1885 the remarkable lake, Lob-nor, in which the Tarim river terminates, and made numerous attempts to penetrate to Lhasa, both from the north and from the east, on one occasion getting to within 160 miles of the forbidden city before being turned back. He had set out on a fresh expedition in 1888 when he died near Issyk-kul. The expedition was carried on by Pyevtsoff, Roborovski, Kosloff, and Bogdanovich, who have since continued to do valuable work in exploring and surveying the borders of Tibet and Mongolia.

Russian explorers in Tibet.

Prjevalsky.

Obrucheff and other Russian explorers in ever-increasing numbers, in the south of the Russian possessions and in north-western China, have cleared up the orography of that region; and the surveys of the Russian railway engineers have carried the line of exact measurements across the whole breadth of Eurasia from sea to sea.

Russian explorers in Siberia.

The Kurile islands in the north-east of Asia have been carefully charted by Captain H. J. Snow, an old sealing skipper, whose knowledge of these little-frequented seas is unique.

Snow.

The problems of Tibet and Central Asia have held the first place in the exploration of Asia, and the former has acquired a romantic interest and a quite fanciful importance on account of the determination of the Tibetan authorities that no European shall be permitted to enter Lhasa. Tibetan exploration was for many years promoted by the Indian Government by the training of native surveyors, amongst whom the names of Nain Singh, Krishna or Kishin Singh (known during his service as A-K), Lama Ugyen Gyacho (known as U-G), and Sarat Chandra Das deserve special distinction. The conscientious surveys of these men in Tibet, in circumstances of the greatest difficulty, have made it possible to prepare fairly accurate general maps of Tibet, and the long stay in Lhasa of Kishin and Chandra Das has given much information as to that city as it was in 1878 and 1882. Exploration by Europeans in Tibet has not been encouraged by the Indian Government, although British officers are permitted to make journeys at their own risk. In this way Captain Bower crossed Tibet from west to east in 1891–92, starting from Leh, and Captain Wellby in 1896 crossed from the same starting-point, but kept farther north. Both made important route surveys through regions which had never previously been traversed by a European. Neither was allowed to enter Lhasa; nor was Mr Littledale more fortunate in 1895, when, after a fine journey across Tibet from the north, he came within 50 miles of the capital, but was obliged to turn westwards and leave the country.

Indian native surveyors in Tibet.

British explorers in Tibet.

M. Bonvalot and Prince Henry of Orleans crossed Tibet from the north by a different route in 1890, but turning eastwards, they terminated their journey (one of the longest land journeys ever made) in French Indo-China. M. Dutreuil de Rhins, after four years spent in the exploration of the northern barrier ranges of Tibet, made a march southwards towards Lhasa, but being turned eastwards, made his way to the neighbourhood of Sining, where he lost his life during an altercation with the Tibetans in 1894.

French explorers in Tibet.

The journeys of Mr W. W. Rockhill, of the American diplomatic service, who entered Tibet from China in 1889, although falling short of Lhasa, have added much to our knowledge of the Tibetan land and people.

Rockhill.

The difficult country of eastern Tibet and western China is still but imperfectly known, although many important expeditions have thinned the veil of darkness which covered it before 1875, when Mr Margary made his way across from China towards Bhamo, but was murdered by the Chinese close to the frontier of Burma. In 1877 Captain W. Gill ascended the Yangtse-kiang, and made his way safely across to the Irrawaddy, and during 1877–78 Mr Colborne Baber pursued extensive explorations throughout the provinces of Szechuen and Yunnan. A finely-equipped expedition under the Hungarian Count Béla Szechenyi investigated the whole west of China and east of Tibet from the upper Yangtse to Koko-nor in 1877–80, and, returning southwards, emerged in Burma with a magnificent collection of scientific specimens. In 1883 Mr A. R. Colquhoun crossed from Canton to Bhamo by a new route, and even as late as 1898 Captain Wingate made a similar journey, in which he crossed several considerable areas of Yunnan where no European had been before. Mrs Bishop's travels in the upper Yangtse district in 1896–97, and Dr Jack's in 1901, also touched new ground. In 1895 M. Bonin, working his way up from the French possessions, was able to rectify the maps of the upper course of the Yangtse; and numerous commercial and missionary journeys have recently contributed to our knowledge.

Exploration in western China.

The problem of the complicated river-system of Indo-China, north-eastern India, and Tibet has been nearly solved by the labours of the native Indian surveyors, the British civil and military officers in Assam and Burma, and by the journeys of several independent travellers. In Indo-China itself the most important recent work is the expedition of M. Pavie to the upper Mekong in 1886–89, when his large scientific staff gave an excellent account of the country.

Indo-China.

The great deserts of Mongolia and eastern Turkestan and the northern edge of the Tibetan plateau, including the mountain range of the Kuen Lun, have held the persistent attention of Russian government explorers, and occasionally attracted

[1] *Geographical Journal*, xv. (1900), 205, 353.

Exploration in inner Asia.

adventurous students and sportsmen of many nationalities. These have mapped the country in a preliminary way from the Pamirs to China, leaving, however, many important blanks between their respective routes. The splendid services of Prjevalsky, who travelled over most of inner Asia and first fixed the source of the Yellow river, have already been referred to. Mr A. D. Carey and Mr Dalgleish, after crossing western Tibet from India in 1885–87, carried their surveys down the Khoten river eastwards, and then south through Tsaidam, and west again to Urumtsi. Captain Frank Younghusband travelled from China to India through Mongolia, Eastern Turkestan, and across the Pamirs in 1886–87, a journey of exceptional interest. In 1896, and again in 1898–99, Captain Deasy conducted an expedition which did much for the exploration of the eastern Pamirs, the Yarkand region, and the regions of the south and south-east as far as the Kuen Lun mountains.

Turfan oasis.

In 1889–90, after an expedition in the Tian Shan, the brothers Grum-Grjmailo described the curious oasis of Turfan, in the very centre of Asia, to which a depth of 100 feet below sea-level was subsequently assigned by Pyevtsoff, and as a result of the long-continued meteorological observations, specially established at Lukchun, in the hollow, the depth has been proved to be 56 feet below sea-level. Drs Futterer and Holderer made an important geological journey across Asia, from the Pamirs to China, in 1898–99, following the northern edge of the Tarim basin, crossing the Gobi desert, and entering China from Koko-nor. The most interesting and most fruitful of recent journeys were undoubtedly those of Dr Sven Hedin, who from 1894 to 1897 was engaged exploring, mapping, collecting natural history specimens, and studying ethnography in the Pamirs, on Mustagh-ata, which he ascended to nearly 20,000 feet, in the Takla-makan desert, which he was the first to cross, and where he discovered ancient ruins of the highest interest, at Lob-nor, and on the northern edge of Tibet, where he traversed an absolutely unknown region south of the Tian Shan. He again (1899–1902) engaged in explorations in the same region.

Sven Hedin.

All recent travellers in Eastern Turkestan have found no small help and encouragement in Kashgar from the British agent, Mr George Macartney, and the Russian consul-general, Petrovsky, who, by their influence and local knowledge, more than once turned an expedition which threatened to be a failure into a success.

The Pamirs.

The Pamirs have been carefully studied by the joint British and Russian Boundary Commissions, by which, from 1872 to 1895, surveys were made by special expeditions, and the actual boundary demarcated on the ground by stone pillars. The region no longer exercises the mysterious fascination which attracted the explorers of the 'seventies and 'eighties. Amongst those the names of Ujfalvy, Bonvalot, and Capus (1877), and Severtsoff (1878), may be specially mentioned; reference must also be made to the later exploring journeys of Mr Littledale, Lord Curzon to the source of the Oxus, Dr Sven Hedin, and the Danish Lieutenant Olufsen.

Kafiristan.

Space fails for a record of the adventurous journeys of British and Russian officers through Afghan territory, but the exploration of the mysterious valleys of Kafiristan by Sir George Robertson in 1890–91 must be mentioned. That region was so rigorously guarded by its pagan mountaineers, who had held out successfully for four hundred years against Mahommedan invasion, that it was believed by Sir Henry Yule to be the last part of the world which should remain unknown. Sir Martin Conway in 1892, and Mr Douglas Freshfield in 1899, broke new ground in the exploration of portions of the higher Himalaya not previously reached.

Himalaya.

Persia.

Persia has been explored in several directions by British officers, with native surveyors supplied by the Government of India. The work of Colonel Sawyer in the Bakhtiari country in 1890, and of Major Sykes in Eastern Persia, may be particularly mentioned; and many others have done good work, which has been ably supplemented by General Houtum Schindler at Tehran and by Russian officers in the north.

Malay Archipelago.

The unknown area in the centre of Borneo has been reduced by expeditions equipped by the Dutch Government, by the British North Borneo Company, and by the Government of Sarawak, in whose service Dr C. Hose has done admirable work in the Baram district. Valuable surveys have been completed in Java by the Dutch Government. A considerable area of unknown country remains in Sumatra, in spite of recent expeditions.

Arabia.

Arabia has been scarcely touched since the travels of Mr Doughty in the north in 1876–77. The journeys of the French Orientalist M. Huber in the north, and those of Dr E. Glaser, Dr L. Hirsch, and Mr and Mrs Theodore Bent in the Hadramut in the south, are the most important in recent years.

Palestine.

The labours of the Palestine Exploration Fund have resulted in the detailed survey of the whole of Palestine on the scale of one inch to a mile by the British Ordnance Survey.

Africa.—The last quarter of the 19th century has filled the map of Africa with authentic topographic details, and left few blanks of any size, while surveys of high accuracy have been commenced at several points. Practically the whole continent has been parcelled out since 1884 amongst the European Powers as colonies, protectorates, or spheres of influence, within each of which the dominant Power treats exploration as a duty. As the work of exploration and survey has become closer and more detailed, journeys of startling novelty have become less frequent, and the most solid of the recent accessions to knowledge have resulted from the labours of a succession of hard-working colonial officials toiling individually in obscurity.

Congo basin.

The great journey of Sir H. M. Stanley along the Congo from Lake Tanganyika to the sea in 1875–76 initiated a new era in African exploration. The number of travellers soon became so great that the once marvellous feat of crossing the continent from sea to sea has been performed by more than twenty expeditions, some of which have scarcely added to the knowledge possessed before they set out. The branches of the Congo were gradually explored by scientific investigators, missionaries, and the officers of the Congo Free State, which was founded under the sovereignty of the king of the Belgians in 1879. The relation of the Congo basin to the neighbouring river systems was brought out by the journeys of many travellers. Chief among these were the Portuguese Serpa Pinto, who crossed Africa from St Paul de Loando to the east coast in 1877–79; Capello and Ivens, who a few years later (1884–86) traced out a great part of the Congo-Zambezi watershed; the English missionary Grenfell, who discovered the Ubangi in 1884–85; the German Major von Wissmann, who explored the Kasai river and made his way across Africa more than once (1881–82); the Russian Junker, who, in the course of a long sojourn (1879–87) in the Sudan, thoroughly explored the Bahr-el-Ghazal province and the basin of the Welle, a river the relation of which to the Congo drainage was long a subject of controversy—settled finally by Van Gèle in 1887. Stanley's Emin Pasha Relief Expedition of 1889 also helped to fill up the map of the northern slopes of the Congo basin by the exploration of the Aruwimi. In 1893–94 Count Götzen, in the course of a journey across Central Africa, defined the eastern edge of part of the Congo basin, and discovered Lake Kivu in the great rift between Lakes Tanganyika and Albert Edward. The journeys of MM. de Brazza, Crampel, Maistre, Fourneau, and many other officials of French Congo have determined the relations between the Congo, Lake Chad, and the Niger drainage areas. The only portion of the Congo basin which still affords scope for pioneer exploration is in the south-west, where the upper streams descending from the watershed with the Zambezi have not been fully mapped. Some light has been thrown on the south-eastern part of the basin by the Katanga expeditions of Captains Bia, Delcommune, and Stairs, and by the missionaries Arnot and Coillard; while in the source-region of the Congo about Lakes Mweru and Bangweolo those of Lieutenant V. Giraud in 1883–84 and of Mr Poulett Weatherley in 1899 have been important. The whole watershed of the Congo-Zambezi was traced in 1899–1900 by Major Gibbons, who had previously explored the upper Zambezi, and Captain Lemaire, who had ascended one of the upper tributaries of the Kasai.

East Africa.

In East Africa the period of surveys following on exploration has been fairly inaugurated, and the Uganda railway line united Victoria Nyanza and the coast in 1902, not only facilitating access to the interior, but supplying an invaluable base for surveys to the north and south of the route. In 1879–80 Mr Joseph Thomson crossed East Africa to Lakes Tanganyika and Nyasa, and in 1883 he made a daring journey across the country of the dangerous Masai tribe to Victoria Nyanza, rediscovering Mount Kenya, and getting the first information as to the great Rift Valley containing Lake Naivasha, perhaps the most remarkable feature in the geography of Africa.

The Somali peninsula and its hinterland towards Abyssinia and Uganda was the last part of East Africa to yield up its secrets. It was penetrated from the south by Count Teleki and Lieutenant von Höhnel in 1887–88, when Lakes Rudolf and Stefanie were discovered, and from the north in 1885 by the brothers James, who reached the river Webi, and by Dr Donaldson Smith, who passed right through to Uganda in 1894. Italian explorers, amongst whom Bottego (who traced the Omo to Lake Rudolf in 1897) may be specially mentioned, did much valuable exploring work in this region, and the final problems of its hydrography have been practically solved by the journeys of Mr H. S. H. Cavendish in 1898, Captain Wellby, Messrs Grogan and Sharp, and Dr Donaldson Smith in 1899. Mr Grogan's expedition was the first to traverse the whole length of Africa from Cape Town to the Mediterranean by land.

East African mountains.

The lofty mountains of East Africa have naturally attracted a good deal of attention. Kilimanjaro, which is included in German East Africa, was ascended to above the snow-line by Sir H. H. Johnston in 1884, and since 1887 it has been repeatedly climbed and the summit attained by Professor Hans Meyer, who has made it the subject of a valuable monograph. Kenya, lying farther north, on the equator, in the British sphere, has also been successfully ascended. Count Teleki was the first to get above the forest zone; Dr J. W. Gregory, in 1894, made a more complete study, and passed the snow-line; while Mr H. J. Mackinder, in 1899, reached the summit. The snowy peaks of Ruwenzori, discovered by Sir H. M. Stanley in 1889, have not yet been scaled, although the explorations of this mountain group by Mr Scott Elliot in 1894, by Mr J. E. S. Moore in 1900, and especially by Sir H. H. Johnston, who ascended to 14,800 feet in 1900, have added much to our knowledge. The region of the great central lakes, Tanganyika and Nyasa, has been thoroughly explored; the latter, from the time of Dr Stewart's journey in 1877, has been studied by the missionaries of Nyasaland and the Government of British Central Africa. The survey of Tanganyika by Mr E. C. Hore in 1878–80 has been completed and extended by subsequent work, the position of the lake in longitude having been rectified by Mr Fergusson on Mr Moore's expedition.

The French, whose sphere of influence in Africa is larger than that of any other Power, have justified their claim to extensive territory by their diligence in exploration. While the Austrian traveller Oscar Lenz was successful in crossing the Sahara from Marocco to Timbuktu in 1880, the French Commandant Monteil made the more difficult journey from the Niger to Tripoli in 1894, and in 1899 M. Fourcau, after twelve years' experience of exploration in the Sahara, succeeded in crossing the desert from Algeria to Lake Chad, after great danger from the Tuareg tribes, who had massacred Colonel Flatters at the oasis of Aïr in 1880. The western portion of the Sudan, especially the district between the great bend of the Niger and the Gulf of Guinea, has been thoroughly explored by Captain Binger and other French officials. The lower course of the Niger and its neighbouring lands in the British sphere of influence have also been fully explored by officials of the Royal Niger Company, and later by those of British Nigeria.

French explorers in West Africa.

The most extensive journey ever made by any French traveller in Africa was that of Commandant Marchand in 1898 from French Congo through the Central Sudan and the Bahr-el-Ghazal province to the upper Nile, and thence through Abyssinian territory to the French Red Sea colony of Jibuti.

In South Africa the most important work has been the extension northwards of accurate triangulations by the Cape Government, and the opening up of the plateau region between the Limpopo and the Zambezi by the British South Africa Company, a work in which the explorations carried on for many years by Mr F. C. Selous were of the greatest value.

South Africa.

Australia.—During the last quarter of the 19th century exploration on a large scale in Australia was only possible in the two western states, but surveying has been proceeding steadily in the three eastern states. The chief difficulty explorers have had to contend with has been the extremely arid and capricious climate of the interior, and in a less degree the fierceness of some of the native tribes. The introduction of camels, however, has facilitated desert expeditions.

On the establishment of the overland telegraph from the south to the north coast in 1872, Mr Ernest Giles made an unsuccessful attempt to penetrate to the west coast from near Charlotte Waters telegraph station; and in the following year, starting farther south, he got half-way to the west coast. He repeated the attempt in 1875, and then succeeded in passing from the head of St Vincent Gulf to Perth. In 1876 he returned by a still more remarkable journey north of the tropic, again crossing the whole breadth of West Australia. West Australia had been crossed twice before this, once in 1873 by Colonel Warburton travelling with camels from Alice Springs on the telegraph line to Oakover river on the west coast, and again in 1874 by Sir John Forrest with horses only, from the Murchison river to near Peake station on the telegraph line. Between 1885 and 1887 Mr D. Lindsay explored the interior of South Australia, crossing the continent twice, from south to north and from north to south. Again in 1891–92, as leader of the exploring expedition fitted out by Sir Thomas Elder, he carried out additional work in the interior. Mr E. Favenc in 1888, and Mr Tietkins in 1889, made important journeys in the interior of West Australia. In 1896–97 Mr David Carnegie, starting from Coolgardie, traversed the deserts northwards to Hall's Creek in the north, and returned by a different route, accomplishing important surveys of a very desolate country. The development of the gold-fields of West Australia has led to innumerable journeys of great difficulty, comparatively few of which have been described. The scientific exploring expedition fitted out by Mr W. A. Horn in 1894 included in its staff several biological and geological professors of Australian universities, and by its thorough exploration of a considerable area about the MacDonnell Ranges, almost in the centre of the Australian continent, added much to the accurate knowledge of the desert region.

Giles.

Warburton.

Forrest.

Lindsay.

Elder expedition.

Carnegie.

Horn expedition.

In New Guinea the most valuable explorations have probably been those made by Sir William Macgregor, when governor of British New Guinea, who, in addition to the survey of parts of the coast, made several expeditions into the interior, in the course of one of which, in 1889, he ascended and named Mount Victoria, the highest summit of the Owen Stanley range. Important journeys have also been made by Messrs Macfarlane, Chalmers, and other missionaries. Dr Otto Finsch made a journey both in British and German New Guinea in 1884–85, for the purpose of scientific exploration, and in the German colony the officials have made several difficult journeys of exploration, the chief being perhaps that by Tappenbeck and Lauterbach on the Ramu or Ottillien river. Few parts of the world outside the polar circles, however, remain so little known as the interior of New Guinea.

British New Guinea.

German New Guinea.

North America.—All the great features of this continent were known before 1875, and the explorations since that time have been mainly carried out by the Geological and Land Survey Departments of Canada and the United States. The construction of the Canadian Pacific Railway, which was opened from sea to sea in 1886, rendered necessary a careful study of the difficult country between the Rocky Mountains and the Pacific in the search for a practicable route. The geological surveyors of Canada have been unceasingly at work in the detailed mapping of the settled districts, and they have also made many exploring journeys of great magnitude. Thus, the late Dr G. M. Dawson explored the upper course of the Yukon in 1887, ten years before the gold discoveries at Klondike attracted the attention of the world to that difficultly accessible region. Mr MacConnel of the Geological Survey and Mr W. Ogilvie of the Dominion Land Survey extended the work of exploration and survey during the height of the gold fever. Dr R. Bell and the brothers Tyrrell mapped the shores of Hudson Bay and the desolate stretches of the barren grounds between that sea and the Mackenzie river, and Mr A. P. Low made important journeys in the interior of the great peninsula of Labrador.

Exploration by Canadian geological surveyors.

Conjointly with delegates from the United States, the Dominion land surveyors have mapped the disputed boundary belt between Alaska and British Columbia. The long-doubtful height of Mount St. Elias has been definitely fixed, and the mountain itself was climbed by the duke of the Abruzzi in 1897. The still higher summit of Mount Logan has been trigonometrically measured as 19,500 feet. Many expeditions in Alaska have been sent out by the United States Government, and the geography of the interior of the peninsula has been fairly well sketched in as regards its main features.

Alaska boundary surveys.

The Coast and Geodetic Survey, the United States Geological Survey, and the surveys of many of the individual states, have made great progress in mapping the country. The names of Professor Mendenhall of the Coast and Geodetic Survey, and of Mr Clarence King, Major J. W. Powell, and Mr I. C. Russell of the Geological Survey, may be specially associated with recent progress.

Exploration by United States surveyors.

The peninsula of Lower California was explored between 1885 and 1894 under the auspices of the Californian Academy of San Francisco, and American travellers, including Drs Lenk and Felix and Professor A. Heilprin, helped forward the exploration of the less known parts of Mexico. In the south of that country, and in northern Guatemala, scientific and archæological studies were carried out by Messrs Salvin, Godman, and Maudslay, whose results are being published in the magnificent volumes entitled *Biologia Centrali-Americana.*

Mexico.

Central and South America.—South America has always been a continent of uncertain boundaries, and many recent exploring journeys promoted by the governments of South American republics have been carried out with the direct purpose of defining or demarcating frontiers.

In Central America minute surveys were made for the Panama Canal and also for the projected Nicaragua Canal. The independent researches made since 1888 by Dr Carl Sapper of the Guatemala Geological Survey cleared up the complex and ill-understood orography of Central America, and definitely proved that neither the Rocky Mountains nor any other North American range is continuous with the Andes. Dr Pittier of Costa Rica extended these researches to the borders of South America.

Central America.

In the West Indies the researches of North American geologists, especially Professor J. W. Spencer and Dr R. T. Hill, enabled the true relation of the island chain to the two continents to be determined.

West Indies.

On the mainland the Sierra Nevada de Santa Marta and the Goajir peninsula were explored for the first time by Mr F. A.

A. Simons in 1878–80, and again by Professor W. Sievers in 1886, this geologist having already studied and elucidated the orography of the Venezuelan Coast Range in 1884–85.

Venezuela.

In the uplands of Guiana Mr Everard F. im Thurn succeeded in reaching the previously inaccessible summit of Roraima in 1884, and the long-continued journeys of M. Coudreau and M. Créveau in French Guiana and the adjacent parts of Brazil have fully delineated the territory which was long contested by the two countries.

Guiana.

The great river Amazon and its branches flow through the least-known part of South America, and although many expeditions have been engaged in tracing the rich ramifications of the river system, the wild woodlands between the converging streams are still in large part untrodden by any white man. The earlier work of exploration in the western republics by Drs Reiss and Stübel was continued by the latter in the Amazon basin in 1876–77. In 1881 M. Charles Wiener explored the upper tributaries with the view of finding the best routes across the Andes to navigable waters. Dr A. Hettner between 1882 and 1890 carried on extensive travels in the Andean and Amazonian region of Peru, Bolivia, and Brazil. The problem of the boundary between the Amazonian provinces of Peru and Bolivia has given prominence to the Inambari question, to the solution of which the Bolivian geographers Pando and Ballivian have devoted many journeys on the Madre de Dios and Inambari rivers. Amongst the explorers of South America Colonel G. E. Church takes a high place, his travels in connexion with railway surveys touching almost every country in the continent. M. Coudreau travelled and mapped new routes in the Rio Negro basin in 1884–85, and the Xingu region was entered by him from the north in 1897, when he was the first to explore the district between the Tocantins and Xingu; he died on a journey in the Trombetas basin in 1899.

Amazon basin.

The trackless province of Matto Grosso was explored from the south through the tributaries of the Xingu river by Dr Karl von den Steinen in 1884–88, then by Dr Ehrenreich, and in continuation of the same series of researches by Dr Herrmann Meyer in 1896 and again in 1899. The result has been not only of geographical importance, but has brought in a harvest of new knowledge in all departments of science, especially in ethnography.

The Andes have always invited exploration, but until the assistance of professional Alpine guides was called in the highest peaks proved effective obstacles to the mountaineer. In 1880 Mr Edward Whymper climbed Chimborazo and other great peaks in Ecuador; in 1897 two members of Mr E. A. Fitzgerald's expedition reached the summit of Aconcagua, the highest point on the American continents, and in 1898 Sir Martin Conway climbed the highest of the Bolivian Andes, Illimani and Illampu (Sorata). The main geographical interest presented by the Andes in recent years is the definition of the word *Cordillera* as applied to them. By the terms of the treaty of 1881 the boundary between Chile and the Argentine Republic is defined as "the line of the highest crests of the Cordillera of the Andes which divide the waters." But since the watershed does not coincide with the highest line of the Andes in Patagonia, it has been necessary to make careful surveys of the almost unknown country in the disputed zone. On the Argentine side the work of Dr Francisco Moreno from 1875 onwards has been of the highest importance, including the discovery of several of the great lakes of the Patagonian lake-district; and on the Chilean side the explorations of Professor A. Bertrand, Dr H. Steffen, and Dr Paul Krüger have greatly elucidated the difficult orography of the forest-clad and rain-drenched western slopes of the Patagonian Andes. The mapping of the disputed area was undertaken in 1902 by a British commission under Sir Thomas Holdich.

Andes.

Patagonia.

The coasts of southern Chile and Magellan Strait have been surveyed in parts by the Chilean navy, and various short journeys have been made in Tierra del Fuego by travellers of all nationalities, amongst whom may be mentioned the French circumpolar observers in 1882, Dr Otto Nordenskjöld in 1895–96, and the scientific staff of the *Belgica* in 1897–98.

Tierra del Fuego.

Arctic Regions.—The last great polar expedition on the old lines was that under Sir George Nares in the *Alert* and *Discovery* in 1875–76, on which Lieutenant (afterwards Admiral) A. H. Markham reached the farthest north in 83° 20′. Since then small parties, whose leader had generally a special plan of his own to carry out, have been the rule. The voyage of the *Vega*, under Baron A. E. Nordenskiöld, along the north coast of Asia, which was arrested in 1878 not far from Bering Strait, was successfully completed in 1879; the North-East Passage was made for the first time, and Europe and Asia were circumnavigated. Since this achievement scarcely a year has elapsed in which several trading steamers did not make the voyage through the Kara Sea to the mouths of the Ob and Yenisei.

Nares.

Nordenskiöld in the "Vega."

In 1879 the *New York Herald* sent out an expedition under Captain W. G. de Long on the *Jeannette* (the *Pandora* of Sir Allen Young's voyage), which entered Bering Sea and tried to reach a high latitude. She was, however, caught in the ice-pack, and after drifting helplessly west and north for 21 months, she was crushed and sunk in 77° 15′ N. Her company escaped with difficulty to the New Siberian Islands, and thence to the coast of Siberia, where most of them perished. Some objects from the *Jeannette* were picked up on an ice-floe off Julianehaab in Western Greenland three years later, a circumstance which led to some controversy and to a great generalization.

The "Jeannette."

In 1879 Lieutenant Schwatka, of the United States army, made a remarkable sledge journey from the shore of Hudson Bay to King William Land, and returned in 1880 with a collection of relics of Franklin's expedition recovered from the Eskimo.

Schwatka's search.

Professor A. G. Nathorst and Baron de Geer commenced in 1882 a series of studies of Spitsbergen and other Arctic islands, which is still being continued by Swedish observers. Sir Martin Conway and Mr Garwood crossed Spitsbergen for the first time in 1897, and Professor Nathorst circumnavigated that island group and settled its true extent in 1898.

Spitsbergen.

Mr B. Leigh Smith, after several voyages to the far north in his Arctic yacht *Eira*, had the misfortune in 1881 to lose his vessel, which was nipped in the ice off Cape Flora, Franz Josef Land. His ship's company passed the winter in a hastily-constructed hut without casualty, and returned in the following year by boat to Novaya Zemlya, as remarkable and successful a journey as any in Arctic annals. Franz Josef Land was made the base of the Jackson-Harmsworth Polar Expedition in 1894–97, and although no high latitude was attained, fresh light was thrown on the geography of the Archipelago and valuable scientific observations were secured. Mr Jackson having indicated the impracticability of advancing north by land, the duke of the Abruzzi, on board the *Stella Polare*, started in 1899 to endeavour to push his way northwards from Franz Josef Land by sea. The ship was stopped in 82°, and Captain Cagni with two other Italians pushed northwards over the ice with dog-sledges, reaching 86° 33′ in 65° E. on 23rd April 1900, the farthest north point yet attained. It was proved that Petermann Land is non-existent. Mr E. B. Baldwin set out in 1901 with a lavishly-equipped American expedition to follow the same route northward.

Franz Josef Land. Leigh Smith.

Jackson.

Duke of the Abruzzi.

The year 1882 saw the most strenuous international efforts to obtain trustworthy data as to the meteorology and magnetic conditions of the North Polar area. On the initiative of Payer, and by the direct action of the German Government, twelve stations round the North Pole in high latitudes were occupied from July 1882 to August 1883 by British, United States, German, Russian, Austro-Hungarian, Swedish, Norwegian, Danish, and Finnish observers. Of these the most remarkable was the American station under Lieutenant (afterwards General) Greely in Grinnell Land, from which Lieutenant Lockwood succeeded in reaching a point in 83° 24′ N., about four miles beyond Admiral Markham's farthest.

International circumpolar stations.

Greely.

Dr A. Bunge and Baron Toll visited and explored the New Siberian Islands in 1886, and in 1900–02 Baron Toll again undertook a journey thither in the hope of passing beyond them and reaching Sannikoff Land, and also of repeating the North-East Passage.

Toll.

Baron Nordenskiöld in 1883 made a determined effort to penetrate the interior of Greenland from the west coast, but the two Lapps whom he sent on in advance on ski had to turn at 120 miles from the sea. In 1888 Dr Fridtjof Nansen was landed on the east coast of Greenland with the object of crossing the Inland Ice, he having conceived the idea of making a retreat unnecessary by keeping the one chance of safety in front. He successfully crossed the ice with a small party, the distance by his route being 260 miles.

Greenland.

Nansen.

The next journey of this explorer was the most remarkable polar voyage yet achieved. Dr Nansen again resolved to make a journey on which there should be no question of any line of retreat. From the drift of the *Jeannette* relics, and much other evidence which he had carefully collected and weighed, he was led to believe that a current flowed from the neighbourhood of the New Siberian Islands nearly over the Pole towards Greenland, and that a strongly-built ship frozen in at the proper place would be carried into a high latitude by the drifting ice. In June 1893 he set out, allowed his vessel, the *Fram*, to be frozen in the pack off the New Siberian Islands, and every point of his forecast as to the drift of the ship was literally verified. With one companion he left the ship in 84° N. and travelled on snow-shoes to 86° 14′, nearly 3° beyond any previous explorer. They returned on foot to Franz Josef Land, wintered in a hut, met Mr Jackson in the spring of 1896, and arrived in Europe simultaneously with the *Fram*, a coincidence probably without parallel.

The drift of the "Fram."

In northern Greenland Mr Peary set himself in 1891 to a task which he has pursued steadily for ten years in spite of almost overwhelming difficulties. In 1892 he sledged across the northern ice-cap from Inglefield Gulf to Independence Bay on the east coast, a distance of 600 miles, and back again; but though he repeated this achievement on subsequent occasions, he could not advance upon it. In 1898, and again in 1900, accompanied by some Eskimo, he endeavoured to reach the Pole by travelling over the ice and living in ice-huts, but he was forced to return to his base both times. He was still confident that the plan was practicable, and prepared to start again, resolved not to leave the work until it was accomplished. Captain Sverdrup, Nansen's captain in the *Fram*, took out that vessel in 1898 up Smith Sound, in the hope of being able to explore by sea to the north of Greenland, a voyage very frequently attempted before, and always in vain. No news of Sverdrup was received in 1900 or 1901.

Peary.

Sverdrup.

Dr Erich von Drygalski studied the glaciers of Umanak fjord in western Greenland in 1891 and 1892–93, and the Danish authorities have for many years sent vessels to explore and map portions of the still unknown East Greenland coast, Lieutenants Ryder and Amdrup having particularly distinguished themselves in this work.

Drygalski.

From the northern point of Spitsbergen the Swedish engineer Andrée with two companions started in a balloon of novel design on 11th July 1897, with the hope of being drifted by the wind over the Pole. Messages dated two days later were recovered, and several buoys were found which had been carried in the balloon, but nothing further has been heard of the explorers, whose fate does not admit of doubt.

Andrée.

In 1899 the Russian Admiral Makaroff took the great ice-breaking steamer *Yermak* on a trial trip to the Arctic Sea north of Spitsbergen, and the results confirmed his belief that a vessel of this kind can force a way through any floe-ice known to exist, although subsequent experiments have produced little result.

Exploration by ice-breaker.

Antarctic Regions.—The greatest unknown area of the Earth lies in the Antarctic regions, access to which is both difficult and dangerous. After the voyage of Sir James Ross, thirty years elapsed before a further step was taken. Then in 1873–74 the German Captain Dallman visited the neighbourhood of Grahamland. In 1874 H.M.S. *Challenger* was the first steam vessel to cross the Antarctic circle, which she did south of Kerguelen Island, but, not being protected against ice, she could not enter the pack. In the southern summer of 1892–93 several Scottish and Norwegian whalers visited the seas about Grahamland and, though they did but little exploration, brought back some definite additions to knowledge. In 1895 the Norwegian whaler *Antarctic* was the first steamer to push through the Antarctic pack, and Captain Kristensen with Mr Borchgrevink, who had shipped as a sailor, were the first men to land on the supposed Antarctic continent, which they did at Cape Adare. In 1897 a Belgian expedition under Captain de Gerlache, with a cosmopolitan scientific staff, sailed in the *Belgica*, and early in 1898 were caught in the ice-pack west of Grahamland, remaining fast, drifting in the ice for rather more than a year. The members of this expedition were the first to winter within the Antarctic circle, although the farthest point of the drift was only 71° 36′ S.

"Challenger."

Whalers.

"Belgica."

In 1898 Mr C. E. Borchgrevink was sent out by Sir George Newnes as commander of an expedition in the *Southern Cross*, and succeeded in landing early in 1899 with a competent scientific staff at Cape Adare, where they spent a whole year. On the return of the ship to Cape Adare in 1900 Mr Borchgrevink proceeded south to the ice-barrier, saw Mount Erebus, and was able to land on the ice in long. 165° W. and march a few miles inland to 78° 50′ S., a little beyond Ross's farthest point.

Borchgrevink.

A British expedition under Commander R. F. Scott, R.N., sailed in the *Discovery* in 1901, leaving New Zealand in December for Victoria Land. A German expedition under Professor E. von Drygalski in the *Gauss* made its departure southward simultaneously from Kerguelen, and a Swedish expedition under Dr Otto Nordenskjöld in the *Antarctic* left Buenos Aires for Weddell Sea. In 1902 Mr W. S. Bruce sails in command of a Scottish expedition to Weddell Sea; and the *Morning* takes out a relief party for the *Discovery*.

New expeditions.

The Oceans.—The exploration of the oceans has gone on without intermission since the great circumnavigation of H.M.S. *Challenger* in 1872–76, and the simultaneous voyage of the German man-of-war *Gazelle*. Much valuable information has been obtained in the cable-laying expeditions of telegraph ships, much also from the work of government surveying vessels, especially those of the British Navy, one of which, H.M.S. *Penguin*, obtained in 1896 the remarkable sounding of 5155 fathoms in the South Pacific to the east of the Kermadec Islands, a depth only exceeded by 5269 fathoms found by the U.S. telegraph ship *Nero* to the east of Guam in 1900. The Norwegian Government sent out an expedition to the North Atlantic on the *Voringen* in 1876–78, and the Russian frigate *Vityaz*, in her circumnavigation of the world in 1886–89, carried on much oceanographical work under Admiral Makaroff in the North Pacific.

The prince of Monaco, at first in his sailing yacht *Hirondelle*, and later in the fine steam yacht *Princesse Alice*, specially built for oceanographical work, has investigated the currents of the North Atlantic and the physical and biological conditions of several parts of that ocean. The Austrian ship *Pola*, under the direction of the Vienna Academy of Sciences, explored the Eastern Mediterranean, the Black Sea, and the Red Sea from 1890 to 1896.

The cruise of the German merchant steamer *Valdivia* in 1898–99, under the scientific direction of Professor Chun, was of more than ordinary importance, and although without the discipline of naval service, and under the sole charge of a scientific man, the expedition led to results greater than had ever before been obtained in so short a time and at such small expense. The voyage was merely a circumnavigation of Africa, but with wide loops, one of which led to the rediscovery of the long-lost Bouvet Island; another greatly extended our knowledge of the depths of the Southern Ocean towards the Antarctic Circle, and the third enabled a line of soundings to be run across a part of the Indian Ocean hitherto blank on the charts. The Pacific Ocean was the field of Professor A. Agassiz's researches in the United States Fish Commission steamer *Albatross* in 1899–1900, and the Dutch Government vessel *Siboga* was engaged at the same time in the little-known seas of the Malay Archipelago. (H. R. M.)

GEOLOGY.

During the years which have elapsed since the publication of the article on geology in the ninth edition of this Encyclopædia, the science has continued to make advances in every department of its domain, but its principles and broad conclusions remain with but little change. That article, therefore, still gives a fairly accurate and complete presentation of its subject. Innumerable fresh illustrations might now be inserted of the principles of the science, vast numbers of new facts might be cited which have come to light in the interval, many departments of the subject might be greatly expanded in the light of recent research. But in this supplementary article it will be sufficient to call attention only to the more important changes of view and additions to our knowledge of the larger questions with which geology deals.

1. Cosmical Aspects of Geology.

The astronomical relations of the Earth and their bearings on geological speculation have been much discussed in recent years. Of these questions, more particular reference may here be made to two—Croll's doctrines as to the origin of climates in the past, and the controversy as to the age of the Earth. The ingenious views propounded by James Croll (1821–90) regarding the influence of astronomical causes in determining variations of terrestrial climate were fully stated in the ninth edition article. His teaching was widely accepted by geologists, inasmuch as it seemed to offer a solution of one of the most difficult problems of geology, and to provide a possible basis for computing the absolute value of geological time. More recently his views were adopted with certain modifications, and enforced by Sir Robert Ball with his accustomed vigour.[1]

Origin of climates.

[1] Croll's original papers will be found chiefly in the *Philosophical Magazine* between the years 1864 and 1874. They were collected and incorporated with modifications in his volume *Climate and Time in their Geological Relations*, London, 1875. His views were also elaborated by him in his subsequently published *Discussions on Climate and Cosmology*, Edinburgh, 1885. Sir Robert Ball's work, *The Cause of an Ice-Age*, was published in London, 1891.

During his lifetime Croll's doctrine, though it commended itself to geologists, did not make way among physicists and astronomers. In particular, it was criticized by Professor Simon Newcomb, and defended by its author.[1] More recently it has been critically examined by Mr E. P. Culverwell, who regards it as "a vague speculation, clothed indeed with a delusive semblance of severe numerical accuracy, but having no foundation in physical fact, and built up of parts which do not dovetail one into the other."[2] This writer affirms that Croll's fundamental assumption that the midsummer and midwinter temperatures are directly proportional to the sun's heat at those seasons is not borne out by an appeal to observation. At Yakutsk, for example, which may be taken as an extreme case of range of temperature, if the excess of its midwinter temperature above that of space were due entirely to the midwinter sun-heat, then the midsummer temperature, also arising solely from direct sun heat, should be 5800° Fahr. above that of space, or if the midsummer excess were due only to the midsummer sun-heat, then the midwinter temperature ought to be – 228° Fahr. Mr Culverwell has calculated what parallels of latitude now receive the same amount of winter sun-heat as the parallels of 40°, 50°, 60°, 70°, 80°, and 90° received during a time of high eccentricity when winter occurred in aphelion. He finds that the daily average sun-heat received during the winter of high eccentricity by the parallel of 40° is now received by that of 42·2°, and that the parallel of 54° at the present time receives the same amount as that of 50° did then. He concludes that the lowering of the midwinter temperature from lat. 50° N. to 70° N., due to diminished winter sun-heat in the epoch of great eccentricity, cannot have been as much as from 3° to 5° Fahr. Such a small decrease could not have been sufficient to produce a glacial period within these latitudes. But it is not certain that the midwinter temperature did really fall during the epoch of maximum eccentricity. This temperature, in the case of the British Isles, depends not on direct sun-heat so much as on the heat transported by the Gulf stream. But during the time of high eccentricity the summer temperature of the regions whence the Gulf stream derives its warmth was far greater than it is now, so that it is conceivable that, instead of being colder in winter, the British climate may actually have been milder than it is now. The failure of the astronomical theory to afford a solution of the problem of the Ice Age leaves geologists once more face to face with one of the most perplexing questions with which they have to deal. At present no satisfactory explanation of it has been offered.

Age of the Earth.

Though the question of the *Age of the Earth* has continued to engage the attention of physicists, geologists, and palæontologists since 1880, no general agreement has been reached in regard to it. On the physical side the same three arguments are still adduced which were stated in the ninth edition article (p. 227), viz., the secular cooling of the Earth, the retardation of our planet's rotation by tidal friction, and the age of the sun's heat. But whereas Lord Kelvin (then Sir William Thomson) was formerly disposed to allow a period of 100 millions of years for the evolution of geological history, he has since maintained that the time "was more than 20 and less than 40 millions of years, and probably much nearer 20 than 40."[3] On the other hand, several physicists and mathematicians of eminence have expressed themselves less confidently on the validity of these arguments and conclusions, and with more appreciation of the importance of the views brought forward on the side of geology and palæontology. In an address from the chair of the Mathematical Section of the British Association in 1886, Professor George Darwin reviewed the controversy, and pronounced the following deliberate judgment in regard to it: "In considering these three arguments I have adduced some reasons against the validity of the first [tidal friction], and have endeavoured to show that there are elements of uncertainty surrounding the second [secular cooling of the Earth]; nevertheless, they undoubtedly constitute a contribution of the first importance to physical geology. Whilst, then, we may protest against the precision with which Professor Tait seeks to deduce results from them, we are fully justified in following Sir William Thomson, who says that 'the existing state of things on the Earth, life on the Earth—all geological history showing continuity of life—must be limited within some such period of past time as 100 million years.'"[4] Lord Kelvin has never dealt with the geological and palæontological objections against the limitation of geological time to a few millions of years. But Professor Darwin, in the address just cited, uttered the memorable warning: "At present our knowledge of a definite limit to geological time has so little precision that we should do wrong summarily to reject theories which appear to demand longer periods of time than those which now appear allowable" (*ibid.* p. 518).

In an address to the Mathematical Section of the American Association for the Advancement of Science in 1889, the vice-president of the Section, Mr R. S. Woodward, thus expressed himself with regard to the physical arguments brought forward by Lord Kelvin and Professor Tait in limitation of geological time. "Having been at some pains to look into this matter, I feel bound to state that, although the hypothesis appears to be the best which can be formulated at present, the odds are against its correctness. Its weak links are the unverified assumptions of an initial uniform temperature and a constant diffusivity. Very likely these are approximations, but of what order we cannot decide. Furthermore, if we accept the hypothesis, the odds appear to be against the present attainment of trustworthy numerical results, since the data for calculation, obtained mostly from observations on continental areas, are far too meagre to give satisfactory average values for the entire mass of the Earth."[5]

Still more emphatic is the protest made from the physical side by Professor John Perry. He has attacked each of the three lines of argument of Lord Kelvin, and has impugned the validity of the conclusions drawn from them. The argument from tidal retardation he dismisses as fallacious, following in this contention the previous criticism of the Rev. Maxwell Close and Professor George Darwin. In dealing with the argument based on the secular cooling of the Earth, he holds it to be perfectly allowable to assume a much higher conductivity for the interior of the globe, and that such a reasonable assumption would enable us greatly to increase our estimate of the Earth's antiquity. As for the third argument, from the age of the sun's heat, he points out that the sun may have been repeatedly fed by a supply of meteorites from outside, while the Earth may have been protected from radiation, and been able to retain much of its heat by being enveloped in a dense atmosphere. Remarking that "almost anything is possible as to the present internal state of the Earth," he concludes thus: "To sum up, we can find no published record of any lower maximum age of life on the Earth, as calculated by physicists, than 400 millions of years. From the three physical arguments Lord Kelvin's higher limits are 1000, 400 and 500 million years. I have shown that we have

[1] See *Phil. Mag.* for the years 1876, 1883, and 1884.
[2] *Geological Magazine*, 1895, pp. 3, 55; *Phil. Mag.*, 1894, p. 541.
[3] *Phil. Mag.*, January 1899.
[4] *Brit. Assoc. Report*, 1886, p. 517.
[5] *Smithsonian Report for 1890*, p. 194.

reasons for believing that the age, from all these, may be very considerably under-estimated. It is to be observed that if we exclude everything but the arguments from mere physics, the *probable* age of life on the Earth is much less than any of the above estimates; but if the palæontologists have good reasons for demanding much greater times, I see nothing from the physicist's point of view which denies them four times the greatest of these estimates."[1]

The arguments from the geological side against the physical contention that would limit the age of our globe to some 10 or 20 millions of years have been repeatedly stated.[2] They are based on the observed rates of geological and biological changes at the present time upon land and sea, and on the nature, physical history, and organic contents of the stratified crust of the Earth. Unfortunately, actual numerical data are not obtainable in many departments of geological activity, and even where they can be procured they have not yet been based on a sufficiently wide collection of accurate and co-ordinated observations. But in some branches of dynamical geology materials exist for at least a preliminary computation of the rate of change. This is more especially the case in respect of the wide domain of denudation. The observational records of the action of the sea, of springs, rivers, and glaciers are becoming gradually fuller and more trustworthy. A method of making use of these records for estimating the rate of denudation of the land was referred to in the ninth edition article (p. 278). Taking the Mississippi as a general type of river-action, it was shown that the amount of material conveyed by this stream into the sea in one year was equivalent to the lowering of the general surface of the drainage-basin of the river by $\frac{1}{6000}$ of a foot. This would amount to one foot in 6000 years, and 1000 feet in 6 million years. So that at the present rate of waste in the Mississippi basin a whole continent might be worn away in a few millions of years.

It is evident that as deposition and denudation are simultaneous processes, the ascertainment of the rate at which solid material is removed from the surface of the land supplies some necessary information for estimating the rate at which new sedimentary formations are being accumulated on the floor of the sea, and for a computation of the length of time that would be required at the present rate of change for the deposition of all the stratified rocks that enter into the composition of the crust of our globe. If the thickness of these rocks be assumed to be 100,000 feet, and if we could suppose them to have been laid down over as wide an area as that of the drainage basins from the waste of which they were derived, then at the present rate of denudation their accumulation would require some 600 millions of years. But, as Dr A. R. Wallace has justly pointed out, the tract of sea-floor over which the material derived from the waste of the terrestrial surface is laid down is at present much less than that from which this material is worn away. We have no means, however, of determining what may have been the ratio between the two areas in past time. Certainly ancient marine sedimentary rocks cover at the present day a much more extensive area than that in which they are now being elaborated. If we take the ratio postulated by Dr Wallace—1 to 19—the 100,000 feet of sedimentary strata would require 31 millions of years for their accumulation. It is quite possible, however, that this ratio may be much too high. There are reasons for believing that the proportion of coast-line to land area has been diminishing during geological time; in other words, that in early times the land was more insular, and is now more continental. So that the 31 millions of years may be much less than the period that would be required, even on the supposition of continuous uninterrupted denudation and sedimentation, during the whole of the time represented by the stratified formations.

But no one who has made himself familiar with the actual composition of these formations and the detailed structure of the terrestrial crust can fail to recognize how vague, imperfect, and misleading are the data on which such computations are founded. It requires no prolonged acquaintance with the Earth's crust to impress upon the mind that one all-important element is omitted, and indeed can hardly be allowed for from want of sufficiently precise data, but the neglect of which must needs seriously impair the value of all numerical calculations made without it. The assumption that the stratified formations can be treated as if they consisted of a continuous unbroken sequence of sediments, indicating a vast and uninterrupted process of waste and deposition, is one that is belied on every hand by the actual structure of these formations. It can only give us a minimum of the time required; for, instead of an unbroken series, the sedimentary formations are full of "unconformabilities"—gaps in the sequence of the chronological records—as if whole chapters and groups of chapters had been torn out of a historical work. It can often be shown that these breaks of continuity must have been of vast duration, and actually exceeded in chronological importance thick groups of strata lying below and above them. Moreover, even among the uninterrupted strata, where no such unconformabilities exist, but where the sediments follow each other in apparently uninterrupted sequence, and might be thought to have been deposited continuously at the same general rate, and without the intervention of any pause, it can be demonstrated that sometimes an inch or two of sediment must, on certain horizons, represent the deposit of an enormously longer period than a hundred or a thousand times the same amount of sediment on other horizons. A prolonged study of these questions leads to the profound conviction that in many parts of the geological record the time represented by sedimentary deposits must be vastly less than the time which is not so represented.

It has often been objected that the present rate of geological change ought not to be taken as a measure of the rate in past time, because the total sum of terrestrial energy has been steadily diminishing, and geological processes must consequently have been more vigorous in former ages than they are now. Geologists do not pretend to assert that there has been no variation or diminution in the activities of the various processes which they have to study. What they do insist on is that the present rate of change is the only one which we can watch and measure, and which will thus supply a statistical basis for any computations on the subject. But it has been dogmatically asserted that because terrestrial energy has been diminishing, therefore all kinds of geological work must have been more vigorously and more rapidly carried on in former times than now; that there were far more abundant and more stupendous volcanoes, more frequent and more destructive earthquakes, more gigantic upheavals and subsidences, more powerful oceanic waves and tides, more violent atmospheric disturbances with heavier rainfall, and more active denudation.

It is easy to make these assertions, and they look plausible; but, after all, they rest on nothing stronger than assumption. They can be tested by an appeal to the crust of the Earth, in which the geological history of our

[1] *Nature*, vol. li. p. 585 (18th April 1895).

[2] They are briefly given in the original article (pp. 226, 227). See, however, the presidential address to the British Association at the Edinburgh Meeting in 1892, pp. 15–21, and the President's Address to Section C of the Association at the Dover Meeting of 1899.

planet has been so fully recorded. Had such portentous manifestations of geological activity ever been the normal condition of things since the beginning of that history, there ought to be a record of them in the rocks. But no evidence for them has been found there, though it has been diligently sought for in all quarters of the globe. We may confidently assert that while geological changes may quite possibly have taken place on a gigantic scale in the earliest ages of the Earth's existence, of which no geological record remains, there is no proof that they have ever done so since the time when the very oldest of the stratified formations were deposited. There is no need to maintain that they have always been conducted precisely on the same scale as now, or to deny that they may have gradually become less vigorous as the general sum of terrestrial energy has diminished. But we may unhesitatingly affirm that no actual evidence of any such progressive diminution of activity has been adduced from the geological record in the crust of the Earth: that, on the contrary, no appearances have been detected there which necessarily demand the assumption of those more powerful operations which physicists have postulated, or which are not satisfactorily explicable by reference to the existing scale of nature's processes.

That this conclusion is warranted even with regard to the innate energy of the globe itself will be seen if we institute a comparison between the more ancient and the more recent manifestations of that energy. Take, for example, the proofs of gigantic plication, fracture, and displacement within the terrestrial crust. These, as they have affected the most ancient rocks of Europe, have been worked out in great detail in the north-west of Scotland. But they are not essentially different from or on a greater scale than those which have affected the Alps, and have involved strata of so recent a date as the older Tertiary formations. On the contrary, it may be doubted whether any denuded core of an ancient mountain-chain reveals traces of such stupendous disturbances of the crust as those which have given rise to the younger mountain-chains of the globe. It may, indeed, quite well have been the rule that instead of diminishing in intensity of effect, the consequences of terrestrial contraction have increased in magnitude, the augmenting thickness of the crust offering greater resistance to the stresses, and giving rise to vaster plications, faults, thrust-planes, and metamorphism, as this growing resistance had to be overcome.

The assertion that volcanic action must have been more violent and more persistent in ancient times than it is now has assuredly no geological evidence in its support. It is quite true that there are vastly more remains of former volcanoes scattered over the surface of the globe than there are active craters now, and that traces of copious eruptions of volcanic material can be followed back into some of the oldest parts of the geological record. But we have no proof that ever at any one time in geological history there have been more or larger or more vigorous volcanoes than those of recent periods. It may be said that the absence of such proof ought not to invalidate the assertion until a far wider area of the Earth's surface has been geologically studied. But most assuredly, as far as geological investigation has yet gone, there is an overwhelming body of evidence to show that from the earliest epochs in geological history, as registered in the stratified rocks, volcanic action has manifested itself very much as it does now, but on a less rather than on a greater scale. Nowhere can this subject be more exhaustively studied than in the British Isles, where a remarkably complete series of volcanic eruptions has been chronicled ranging from the earliest Palæozoic down to older Tertiary time. The result of a prolonged study of British volcanic geology (of which a summary will be given in pages 641–646) has demonstrated that, even to minute points of detail, there has been a singular uniformity in the phenomena from beginning to end. The oldest lavas and ashes differ in no essential respect from the youngest. Nor have they been erupted more copiously or more frequently. Many successive volcanic periods have followed each other after prolonged intervals of repose, each displaying the same general sequence of phenomena and similar evidence of gradual diminution and extinction. The youngest, instead of being the feeblest, were the most extensive outbursts in the whole of the prolonged series (see p. 638).

If now we turn for evidence of the alleged greater activity of all the epigene or superficial forces, and especially for proofs of more rapid denudation and deposition on the Earth's surface, we search for it in vain among the stratified formations of the terrestrial crust. Had the oldest of these rocks been accumulated in a time of great atmospheric perturbation, of torrential rains, colossal tides, and violent storms, we might surely expect to find among the sediments some proof of such disturbed meteorological and geographical conditions. We should look, on the one hand, for tumultuous accumulations of coarse unworn detritus, rapidly swept by rains, floods, and waves from land to sea, and on the other hand, for an absence of any evidence of the tranquil and continuous deposit of such fine laminated silt as could only settle in quiet water. But an appeal to the geological record is made in vain for any such proofs. The oldest sediments, like the youngest, reveal the operation only of such agents and such rates of activity as are still to be witnessed in the accumulation of the same kind of deposits. If, for instance, we search the most ancient thick sedimentary formation in Britain—the Torridon Sandstone of north-west Scotland, which is older than the oldest fossiliferous deposits—we meet with nothing which might not be found in any Palæozoic, Mesozoic, or Cainozoic group of similar sediments. We see an accumulation, at least 8000 or 10,000 feet thick, of sand, gravel, and mud, such as may be gathering now on the floor of any large mountain-girdled lake. The conglomerates of this ancient series are not pell-mell heaps of angular detritus, violently swept away from the land and huddled promiscuously on the sea-floor. They are built up of pebbles that have been worn smooth, rounded and polished by prolonged attrition in running water, and they follow each other on successive platforms with intervening layers of finer sediment. The sandstones are composed of well-waterworn sand, some of which has been laid down so tranquilly that its component grains have been separated out in layers according to their specific gravity, in such manner that they now present dark layers in which particles of magnetic iron, zircon, and other heavy minerals have been sifted out together, just as iron-sand may be seen gathered into thin sheets on sandy beaches at the present day. Again, the same series of primeval sediments includes intercalations of fine silt, which has been deposited as regularly and intermittently there as it has been among the most recent formations. These bands of shale have been diligently searched for fossils, as yet without success; but they may eventually disclose organic remains older than any hitherto found in Europe.

We now come to the consideration of the Palæontological evidence as to the value of geological time. Here the conclusions derived from a study of the structure of the sedimentary formations are vastly strengthened and extended. In the first place, the organization of the most ancient plants and animals furnishes no indication that they had to contend with any greater violence of storm, flood, wave, or ocean-current than is familiar to their modern descendants. The oldest trees, shrubs, ferns, and club-mosses display no special structures that suggest a difference in the general conditions of their environment. The most ancient crinoids, sponges, crustaceans, arachnids, and molluscs were as delicately constructed as those of to-day, and their remains are often found in such perfect preservation as to show that neither during their lifetime nor after their death were they subject to any greater violence of the elements than their living representatives now experience. Of much more cogency, however, is the evidence supplied by the grand upward succession of organic forms, from the most ancient stratified rocks up to the present day. No biologist now doubts for a moment that this marvellous succession is the result of a gradual process of evolution from lower to higher types of organization. There may be differences of opinion as to the causes which have governed this process and the order of the steps through which it has advanced, but no one who is conversant with the facts will now venture to deny that it has taken place, and that, on any possible explanation of its progress, it must have demanded an enormous lapse of time. In the Cambrian or oldest fossiliferous formations there is already a large and varied fauna, in which the leading groups of invertebrate life are represented. On no tenable hypothesis can these be regarded as the first organisms that came into being on our planet. They must have had a long ancestry, and as Darwin first maintained, the time required for their evolution may have been "as long as, or probably far longer than, the whole interval from the Silurian [Cambrian] age to the present day." The records of these earliest eras of organic development have unfortunately not survived the geological revolutions of the past; at least, they have not yet been recovered. But it cannot be doubted that they once existed and registered their testimony to the prodigious lapse of time prior to the deposition of the most ancient fossiliferous formations which have escaped destruction.

The impressive character of the evidence furnished by the sequence of organic forms throughout the great series of fossiliferous strata can hardly be fully realized without a detailed and careful study of the subject. Professor Poulton, in an address to the Zoological Section of the British Association at the Liverpool Meeting in 1896, showed how overwhelming are the demands which this evidence makes for long periods of time, and how impossible it is of comprehension unless these demands be conceded. The history of life upon the Earth, though it will probably always be surrounded with great and even insuperable difficulties, becomes broadly comprehensible in its general progress when sufficient time is granted for the evolution which it records; but it remains unintelligible on any other conditions.

Taken then as a whole, the body of evidence, geological and palæontological, in favour of the high antiquity of our globe is so great, so manifold, and based on such an ever-increasing breadth of observation and reflexion, that it may be confidently appealed to in answer to the physical arguments which would seek to limit that antiquity to ten or twenty millions of years. In the present state of science it is out of our power to state positively what must be the lowest limit of the age of the Earth. But we cannot assume it to be much less, and it may possibly have been much more, than the 100 millions of years which Lord Kelvin was at one time willing to concede.[1]

2. Geognosy.

In this department of geological inquiry petrographical research has been greatly pursued and extended. The methods of determining the microscopic structure of rocks have been considerably improved. Fresh light has been thrown on the composition, structure, and probable history of many rocks. A considerable number of new varieties of rocks has been added to the already sufficiently numerous list. Various schemes of classification have been proposed, but petrographers are still far from any general agreement as to a scheme that shall be at once natural and convenient. This subject has engaged the attention of the International Geological Congress, of which a special committee has been formed for the purpose of considering the question of petrographical nomenclature and classification.

The voluminous recent literature of this branch of geology will be found partly in the form of papers in the scientific serials and in the proceedings of scientific societies, and partly as independent general treatises or text-books. Of the latter the most important are:—F. Zirkel, *Lehrbuch der Petrographie*, 3 vols., 2nd edit., Leipzig, 1893–94: this is the most comprehensive treatise on rocks; H. Rosenbusch, *Mikroskopische Physiographie der Mineralien und Gesteine*, 3rd edit., Stuttgart, 1892–96: translated by Iddings, London, 1888; H. Rosenbusch, *Elemente der Gesteinslehre*, Stuttgart, 1898; A. Harker, *Petrology for Students*, 2nd edit., Cambridge, 1897.

3. Dynamical Geology.

The hypogene action whereby changes are effected within the crust of the earth manifests itself in volcanoes, earthquakes, secular movements of upheaval and depression, and in alterations of the texture, structure, and composition of rocks. In each of these sections of inquiry progress has been made in the accumulation of fresh facts, if not in the elaboration of a satisfactory hypothesis to account for them. To a few of the more important additions to our knowledge in some of these departments reference will here be made.

Volcanoes.—A large amount of observation has been devoted to the phenomena of volcanoes. The daily operations of such constantly active vents as Etna, Stromboli, Vesuvius, and Hawaii have been watched and recorded.[2]

Several important volcanic eruptions in various parts of the world have been investigated by competent observers, notably the stupendous catastrophe of Krakatoa in 1883 and that of Bandai-san, Japan, in 1888. The circumstances accompanying volcanic explosions have been more fully studied. Attention has been given to the

[1] The subject of the age of the Earth has also been discussed by Professor Joly and Professor Sollas. The former geologist, approaching the question from a novel point of view, has estimated the total quantity of sodium in the water of the ocean and the quantity of that element received annually by the ocean from the denudation of the land. Dividing the one sum by the other, he arrives at the result that the probable age of the Earth is between 90 and 100 millions of years (*Trans. Roy. Dublin Soc.*, ser. ii. vol. vii., 1899, p. 23; *Geol. Mag.*, 1900, p. 220). Professor Sollas believes that this limit exceeds what is required for the evolution of geological history, that the lower limit assigned by Lord Kelvin falls short of what the facts demand, and that geological time will probably be found to have been comprised within some indeterminate period between these limits. (Address to Section C, *Brit. Assoc. Report*, 1900.)

[2] For recent accounts of Vesuvius see:—H. J. Johnstone-Lavis, *Spettatore del Vesuvio*, Naples, 1887; *Nature*, vols. xxvi., xliv. pp. 160, 320, 352, lii. p. 342; G. Mercalli, *Vulcani e Fenomeni Vulcanici in Italia*, Milan, 1883; R. V. Manteucci, *Rend. R. Accad. Napoli*, 1897, 1898, 1899; *Boll. Soc. Geol. Ital.* vol. xvi. (1898); *Boll. Soc. Sismolog. Ital.* v. (1899–1900); *Rend. Accad. Lincei. Roma*, viii. (1899). On Etna:—S. von Waltershausen, *Der Etna*, Leipzig, 1880; Mercalli in the work just cited and notices of recent eruptions in *Nature*, vols. xix. xx. xxi. xxii. xxv. xxvii. xlvi. xlvii. and lv. On Stromboli:—Mercalli, *Vulcani, &c.*, p. 135; *Atti. Soc. Ital. Sci. Nat.*, vols. xxii. xxiv. xxvii. xxix. xxxi.; and notes in *Nature*, xliv. (1891), p. 280, xlvii. pp. 89, 453. On Hawaii:—J. D. Dana, *Characteristics of Volcanoes*, p. 125, London, 1890; and *Amer. Journ. Sci.* vols. xxxiii.–xxxvii. (1887–89); C. E. Dutton, *Amer. Journ. Sci.* vol. xxv. (1883), p. 219; *Ann. Rep. U.S. Geol. Survey* (1882–83); also notices in *Nature*, vols. xlvii. (1893), p. 499; l. (1894), pp. 91, 483; liii. (1896) p. 490.

phase of fissure eruptions, especially as manifested in recent times in Iceland and in more remote ages in Britain, India, and the western portions of the United States. A large body of evidence has been gathered bearing on the history of vulcanism in the geological past, and many features of the inner mechanism of volcanic vents, as well as of the phenomenon of the subterranean intrusions of igneous material, have been ascertained with a clearness which no modern volcano could supply.

Volcanic Explosions.—Of recent volcanic eruptions by far the most stupendous was the outburst of Krakatoa in Sunda Strait. It has thrown fresh light on the nature and the occurrence of the explosions which form so characteristic a feature in the régime of volcanoes. These phenomena have from the earliest times powerfully impressed the human imagination. In a few hours or days a great mountain is eviscerated with the most violent commotion, vast clouds of dust are projected high into the air and cover the noonday sky with the darkness of night, while terror, wounds, and death befall vast numbers of the population around. Such catastrophes have taken place at wide intervals since prehistoric times. It was by one of them that the crater of the islands which now form the Santorin group in the Grecian Archipelago was blown out after a human colony had settled around its flanks. Another, likewise older than the times of history, produced the vast chasm of the Val del Bove on the east side of Etna. The first of which any account has been handed down was that which destroyed the southern half of Monte Somma and buried the towns on the shores of the Bay of Naples in A.D. 79. Since that time other examples of the phenomenon in different degrees of intensity have been experienced in various parts of the world. But probably none of them has equalled in violence the great explosion of Krakatoa. Fortunately the events that preceded, accompanied, and followed that catastrophe were witnessed by many observers whose testimony has been collected and collated, so that the nature and sequence of these events have been recorded with a fulness previously unknown.

Eruption of Krakatoa.

At some early period a large volcano rose in the centre of the tract where now runs the Sunda Strait between Sumatra and Java. Long before any European had entered these waters a gigantic explosion took place by which the mountain was so completely blown away that only the outer portions of its base were left as a broken ring of islands. Subsequent eruptions gradually built up a new series of small cones within the great crater ring. Of these the most important rose to a height of 2623 feet above the sea and formed the peak of the volcanic island of Krakatoa. But compared with the great neighbouring volcanoes of Java and Sumatra, the islets of the Sunda Strait were comparatively unknown and neglected. Though densely wooded, Krakatoa was uninhabited, and no satisfactory map or chart of it had been made. In the year 1680 it appears to have suffered from a volcanic eruption, when great earthquakes took place and large quantities of pumice were ejected. But the effects of this disturbance had been so concealed by the subsequent spread of tropical vegetation that the very occurrence of the eruption has sometimes been called in question. At last, about the year 1877, earthquakes began to be of frequent occurrence in the Sunda Strait and continued for the next few years, as an indication that the volcanic energy which had been dormant for at least 200 years was once more waking into life. In 1883 the manifestations of subterranean commotion began to be more decided, for in the month of May of that year Krakatoa broke out in eruption. For some time the efforts of the volcano appear to have consisted mainly in the discharge of pumice and dust, with the usual accompaniment of detonations, tremors, and earthquakes. And so far the type of activity resembled that which had characterized the volcano ever since the time of the great explosion. But at last, on 26th August, a succession of paroxysmal explosions began which lasted till the morning of the 28th, but of which the four most violent took place on the morning of the 27th. The whole of the northern and lower portion of the island of Krakatoa, lying within the original crater ring of prehistoric times, was blown away; the northern part of the cone of Rakata almost entirely disappeared, leaving a vertical cliff which laid bare the inner structure of that volcano. Instead of the volcanic island which had previously existed, and rose from 300 to 1400 feet above the sea, there was now left a submarine cavity the bottom of which is here and there more than 1000 feet below the sea-level. This prodigious evisceration was the result of successive violent explosions of the superheated vapour and gas absorbed in the molten magma within the crust of the earth. The vigour and repetition of these explosions, it has been suggested, may have been caused by sudden inrushes of the water of the ocean as the throat of the volcano was cleared and the crater-ring was lowered and ruptured. The access of large bodies of cold water to the top of the column of molten lava would probably give rise at once to some minor explosions and then to a chilling of the surface of the lava and a consequent temporary diminution or even cessation of the volcanic eructations. But until the pent-up water-vapour in the lava below had found relief it would only gather strength until it was able with explosive energy to burst through the chilled crust and overlying water, and to hurl a vast mass of cooled lava, pumice, and dust into the air.

The amount of material discharged during the two days of paroxysmal energy was enormous, though there are no satisfactory data for even approximately estimating it. A large cavity was formed where the island had previously stood, and the sea-bottom around this crater was covered with a wide and thick sheet of fragmentary materials. Some of the surrounding islands received such a thick accumulation of ejected stones and dust as to bury their forests and greatly to increase the area of the land. So much was the sea filled up that a number of new islands rose above its level. But a vast body of the fine dust was carried far and wide by aërial currents, while the floating pumice was transported for many hundreds of miles on the surface of the ocean. At Batavia, 100 miles from the centre of eruption, the sky was darkened by the quantity of ashes borne across it, and lamps had to be used in the houses at mid-day. The darkness even reached as far as Bandong, a distance of nearly 150 miles. It was computed that the column of stones, dust, and ashes projected from the volcano shot up into the air for a height of seventeen miles or more. The finer particles coming into the higher layers of the atmosphere were diffused over a large part of the surface of the earth, and showed their presence by the brilliant sunset glows to which they gave rise. It was computed that within the tropics they were at first borne along by air-currents at the rate of about seventy-three miles an hour from east to west until within a period of six weeks they were diffused over nearly the whole space between the latitudes 30° N. and 45° S. Eventually they spread northwards and southwards and were carried over North and South America, Europe, Asia, South Africa, and Australasia. In the Old World they spread from the north of Scandinavia to the Cape of Good Hope.

Another remarkable feature of this stupendous volcanic event was the world-wide disturbance of the atmosphere. The culminating paroxysm of Krakatoa on the morning of

27th August gave rise to an atmospheric wave or oscillation, which, travelling outwards from the volcano as a centre, became a great circle at 180° from its point of origin, whence it continued travelling onwards and contracting till it reached a node at the antipodes to Krakatoa. It was then reflected or reproduced, travelling backwards again to the volcano, whence it once more returned in its original direction. "In this manner its repetition was observed not fewer than seven times at many of the stations, four passages having been those of the wave travelling from Krakatoa, and three those of the wave travelling from its antipodes, subsequently to which its traces were lost" (Sir R. Strachey).

The actual sounds of the volcanic explosions were heard over a vast area of the earth's surface, especially towards the west. Thus they were noticed at Rodriguez, nearly 3000 English miles away, at Bangkok in Siam (1413 miles), in the Philippine Islands (about 1450 miles), in Ceylon (2058 miles), and in West and South Australia (from 1300 to 2250 miles). On no other occasion have sound-waves ever been perceived at anything like the extreme distances to which the detonations of Krakatoa reached.

Not less manifest and far more serious were the effects of the successive explosions of the volcano upon the waters of the ocean. A succession of waves were generated which appear to have been of two kinds, long waves with periods of more than an hour, and shorter but higher waves, with irregular and much briefer intervals. The greatest disturbance, probably resulting from a combination of both kinds of waves, reached a height of about 50 feet. The destruction caused by the rush of such a body of sea-water along the coasts and low islands was enormous. All vessels lying in harbour or near the shore were stranded, the towns, villages, and settlements close to the sea were either at once, or by successive inundations, entirely destroyed, and more than 36,000 human beings perished. The sea-waves travelled to vast distances from the centre of propagation. The long wave reached Cape Horn (7818 geographical miles) and possibly the English Channel (11,040 miles). The shorter waves reached Ceylon and perhaps Mauritius (2900 miles).[1]

Eruption of Bandai-san.

The eruption of Bandai-san in the north of Japan in the year 1888 was likewise witnessed and chronicled by intelligent observers, whose evidence brings before us some additional particulars regarding the phenomena attendant on volcanic explosions. The ground rocks of the region are various granites, gneisses, and crystalline schists through which in Tertiary time a series of volcanic eruptions took place. The volcanic energy is said to have gradually declined down to the present day. A line of volcanic mountains runs in a general north and south direction along the axis of the island. Most of them are now extinct. But a few have remained in the solfataric stage; that is, they have from time to time given vent to explosions of vapour with more or less violence, but without the discharge of true ashes or lava. During a long period of comparative quiescence the cones have been deeply trenched by denudation and thickly clothed with forest. Hot springs still rise at many points, but except to a geological eye there is little in the general aspect of the country to suggest that its contours have resulted from former volcanic activity, or that they may be again modified by the same cause. Tradition tells that the volcanic mountain of Bandai-san had its summit burst open by an eruption, which, sending forth fire and smoke, split it into several peaks. The event was accompanied by a memorable catastrophe to the inhabitants, whereby fifty villages were buried under the waters which gathered in the hollow now occupied by Lake Inawishiro. But for ten centuries the volcano appears to have remained on the whole in a dormant condition. At last, on the morning of 15th July 1888, rumbling noises like distant thunder began to be heard by the inhabitants, until a tolerably severe earthquake took place that lasted more than twenty seconds and affected an area with a radius of about thirty miles. A quarter of an hour later, after further violent shaking of the ground, and while the commotion was still going on, a great explosion took place on the old volcanic cone of Bandai-san (6036 feet) followed by fifteen or twenty more during nearly two hours. Each of these paroxysms was accompanied by deafening detonations, while steam and dust were shot up into the air to a height of more than 4000 feet. By the last discharge the material is said to have been projected almost horizontally towards the valley on the north. The fine dust and vapour rapidly ascended into the higher regions of the atmosphere, where at a height of some 18,000 feet the material spread out into the usual pine-tree shape, and was gradually carried by the wind in a south-easterly direction, spreading out on its way, and passing out to sea. The area of land over which this fine dust fell was 790 square miles. How far it was carried across the Pacific was not ascertained. So thick was the canopy of dust that immediately around the mountain the day became black as night; and the vapour condensed into a warm rain which fell with the hot ashes. While the darkness still lasted the whole summit and side of the mountain gave way, and an immense avalanche of earth and rock rushed down the slopes, burying the Nagase with its villages and people, and devastating an area of 27 square miles. In all seven villages and 461 inhabitants were destroyed.

According to the observations of the Japanese geologists who at once proceeded to the spot to make a detailed investigation of the circumstances of the eruption, the fine dust that accompanied the successive explosions of steam was not pumice such as results from the sudden expansion of the superheated vapour absorbed in a molten magma, but fine powder of pre-existing andesitic rocks, which had been more or less decomposed by fumarole action. These observers believed that the dust resulted from the explosive force of the steam acting upon the older solidified lavas, and from the mechanical trituration of the stones against each other in their ascent and descent in the air. Some of it, mingling with the steam, fell as a hot mud that clung to the leaves and branches of the trees. It was estimated that no less an amount than 1587 millions of cubic yards of the mountain had been blown away and reduced to fragments and dust. The uppermost 540 feet of Bandai-san disappeared, and instead of the forest-covered slope on one side of the mountain there was left a vast horseshoe-shaped chasm, at the back of which the inside of the old crater was laid bare in a great cliff 1658 feet high, wherein were revealed the successive sheets of lava and fragmentary materials whereof the cone had been built up. The loosened and dislocated side of the mountain is described as having been launched downwards as a huge landslip that rushed into the plain below with a velocity of about 48 miles an hour. Most of the material that so travelled is spoken of as having been comparatively dry, though no doubt mingled with the hot rain from the condensed steam, and sweeping up the waters of streams and lakes so as to become in some places a pasty mud. The torrent of debris swelled up into great waves 130 to 200 feet high in front of obstructions, and was strewn with enormous blocks of stone; even at a considerable distance from the crater such blocks measured 15 or 30 feet on the side.

[1] "The Eruption of Krakatoa and subsequent Phenomena." *Report of the Krakatoa Committee of the Royal Society*, London, 1888.

Its surface rose into conical mounds or hills formed of blocks of stone, the cause of which has not been very satisfactorily explained.

Among the most marked circumstances of the explosions were the prodigious blasts of wind by which they were accompanied. The sudden radial expansion of the liberated volumes of steam at quick intervals produced violent disturbances of the air. It was estimated from the effects produced that the velocity with which these tornadoes were propagated outwards from the crater could not have been less than 90 miles an hour. The forests that lay in the pathway of the wind were utterly destroyed, only a few stems being left standing, each as bare as a telegraph pole. The trees fell with their heads pointing away from the crater, showing that the blasts radiated in straight lines. Places in the lee of protecting eminences escaped with little damage.

Another feature of the eruption which has given rise to some discussion was the production of numerous conical basin-like holes varying up to 10 feet in diameter and to more than 3 feet in depth. They were found in thousands around the crater, as well as on slopes a mile or more away from it. Three explanations have been proposed for these singular depressions: (1) they may have been caused by the collapse of the walls of underground springs, whereby the water was forcibly ejected to the surface; or (2) by the uprooting and removal of trees, whereby cavities were left in the ground; or (3) by the projection of stones from the crater and their fall through the loose soil and ashes that covered the surface. It is possible that examples of all of these modes of origin may have occurred. Holes left by the uprooting of trees were undoubtedly noticed. But according to the careful observations of the Japanese investigators, the vast majority of the holes arose from the third cause. Some of the cavities were dug open and the stones that formed them were found lying at the bottom, sometimes with crushed and bruised but still fresh green leaves lying below them, which they had carried with them in their descent from the surface. On rocky places which the stones could not penetrate, they were found in fragments scattered all about. This Japanese example is interesting as a well-attested illustration of the nature and effects of a true volcanic explosion from a long-dormant or seemingly extinct crater. It shows the enormous disruptive force of imprisoned steam even when no lava or true ashes are discharged. Like Vesuvius, Monte Somma, and other vents, it indicates how volcanic energy, which may have been quiescent since beyond the times even of tradition, may suddenly awake with destructive violence, and then relapse into its previous condition of apparent extinction.[1]

Fissure-eruptions.—With regard to fissure-eruptions, so much has been learnt since 1880 that this phase of volcanic action is now recognized as one which, in modern as well as ancient times, has given rise to the most voluminous outpourings of molten material from the earth's interior. It is from Iceland that the most detailed information has been obtained regarding recent eruptions of this kind. Mr Thoroddsen, a geologist resident on the island, has explored and mapped its geology and, in anticipation of an ample detailed work on which he is now engaged, has published a number of interesting and important contributions to our knowledge of the subject. He protests against the common misconception that volcanoes of the type of Etna and Vesuvius may be assumed to represent the general character of modern volcanic action. On the contrary, in Iceland, where the most copious lava-floods of historic times have been discharged, the regular Vesuvian cone, built of successive sheets of lava and ashes, is comparatively infrequent and unimportant among the manifestations of subterranean energy. It appears that the Icelandic eruptions are essentially due to the opening of fissures in the ground and to the outflow of lava from these over the surrounding country. Mr Thoroddsen has traced two systems of such fissures, of which one, developed in the south of the island, trends from south-west to north-east, while the other, in the northern districts, runs from south to north. The famous volcano, Hekla, is situated on a fissure belonging to the first system. Though built up of lavas and tuffs, it does not form a cone, but an oblong ridge, which has been split by a fissure along its length and bears a row of craters along the rent. The production of these dislocations has been observed in connexion with recent volcanic disturbances. Thus in 1875 a violent eruption took place at Askja, where two lines of fissure crossed each other, while many large rents were opened at the surface, some of which could be followed in a north and south direction for nearly 50 miles. Intense volcanic activity was displayed along some of these fissures. But in other cases no discharge of either lava or ashes has taken place. When lava is emitted it may flow out from the whole length of a fissure across a plain, without the production of any cones or craters, the molten material welling forth tranquilly either towards one or both sides. An example of this nature has been observed at the great Eldgjá fissure, which runs for more than 18 English miles with a depth of from 420 to 650 feet. From three points on this chasm lava spread out quietly, so as to cover an area of 270 English square miles, but without forming any craters or cones of scoriæ or ashes, except towards the southern narrowed end, where a row of low slag-cones made its appearance. More usually, however, the line of the fissure is marked by ramparts of slags and lava-blocks heaped up on each side, or by a row of cones immediately over the dislocation. The great Laki fissure of 1783, so well described and mapped by Dr A. Helland, is marked by hundreds of little cones running along the chasm for about 20 miles. From each of these craters two or more streams of lava issued, now to the one side, now to the other, which, uniting and surrounding the cones, formed vast fields of naked and rugged stone. The western stream reached a distance of more than 40 miles, but a lava of prehistoric time from one of the fissures of the Odádahraun flowed for upwards of 60 miles. The lava desert of this locality is formed of lava that has been discharged from about 20 vents, mostly on parallel fissures, and covers an area computed to be about 1700 English square miles. Mr Thoroddsen has estimated that the mass of lava there displayed, if poured out over Denmark, would have covered that country to a depth of 16 feet.

In connexion with the modern volcanic phenomena of Iceland, reference may be made here to a feature which is well illustrated among them—the production of what have been called explosion craters, that is, cavities opened in the ground by volcanic explosions, but with little or no surrounding cone of ejected materials. An interesting example of one of these cavities was produced by a violent explosion at Askja on 29th March 1875. Though it measures no more than 280 feet in diameter, so energetic was the explosion which blew it open that the pumiceous stones ejected at the time fell over an area of 468 English square miles, and the finer dust which was propelled into higher layers of the atmosphere was borne by north-westerly air-currents as far as Norway and Sweden. Nine years after the eruption Mr Thoroddsen,

[1] S. Sekiya and Y. Kikuchi, "The Eruption of Bandai-san," *Journ. College of Science, Imperial University of Japan*, vol. iii. part ii., Tôkyô, Japan (1889).

on visiting the place, found the bottom of the crater covered with bluish-green boiling mud.

These recent fissure-eruptions of Iceland serve to explain the history of some prehistoric and still more ancient areas of volcanic action, wherein extensive sheets of lava have been poured out with no relation to any great central cone from which they could have issued. Such are the vast lava-fields of Western America. In Idaho, Utah, Nevada, southwards into Arizona and New Mexico, northwards into Montana and westwards into Oregon, lavas have been piled up into wide plateaux, stretching out as deserts of black verdureless stone. In some cases the molten material has accumulated sheet above sheet to a depth of many hundred feet. Through this thick mass of material rivers have cut their way, forming gorges 700 feet deep or more, along the walls of which the successive beds of lava may be followed for miles. From these comparatively fresh outpourings of lava, trenched by winding ravines, it is no great step to the much older development of the same features displayed by the basalt-plateaux of Antrim and the Inner Hebrides, which date from older Tertiary time. There the phenomena of fissure-eruption are revealed in innumerable ranges of picturesque sea-cliff, and denudation has advanced so far as to lay bare much of the inner arrangement of such plateaux, which can never be studied among modern and still undenuded lava-fields. Still more ancient is the Cretaceous volcanic plateau of the Ghauts in the Bombay Presidency, where the same general phenomena are visible—innumerable dykes representing former fissures, widespread sheets of basalt, and an absence of any central cone from which the eruptions might be supposed to have emanated.

Distribution of Volcanic Action in Time.—In no branch of geological inquiry has more progress been made in recent years than in the collection and investigation of proofs that volcanoes were formerly rife in many parts of the Earth where they have long been extinct, and that their relics can be traced back through successive ages of the geological record to the time of the oldest formations of the Earth's crust. Materials have thus been accumulating for a history of volcanic action during the past, and though these materials have not yet been gathered from a wide enough area to allow, perhaps, satisfactory generalization for the planet as a whole, they are sufficiently ample for a few regions to indicate some of the main conclusions which fuller evidence will probably confirm and extend.

By far the most complete chronicle anywhere as yet obtained of the volcanic manifestations during the geological past is that presented in the British Isles.[1] Various fortunate circumstances have united to ensure this completeness. Few countries of the same size as Great Britain contain so ample and varied a representation of the series of systems and formations from which geological history is compiled. This record has been sedulously explored by innumerable observers since the first rise of geology; hence there is hardly any region of which the detailed geological structure and history have been so well ascertained. Each formation has been so fully studied that the various episodes of past time can be accurately assigned to their relative position in the chronological series. Then the peculiar position of Great Britain, along the outer or critical border-line of a continent, while placing it advantageously for witnessing and chronicling the successive revolutions of former ages—upheaval, depression, denudation, and deposition—has in a special measure been favourable for volcanic evolution. It is a familiar fact that at the present day volcanoes tend to group themselves near the sea, either on the edge of a continent, or in lines and groups of oceanic islands. Doubtless the same distribution has also held good in the past. Certainly nowhere can so ample and continuous a series of volcanic chronicles be found as in the British Isles, extending from a time earlier than that of the oldest fossiliferous rocks down to so late a period as the older Tertiary formations. This wonderfully full record includes illustrations of all the great types of volcanic activity that have been observed among modern volcanoes. On the one hand we have evidence of colossal eruptions, whereby hundreds of square miles of territory were buried under several thousand feet of lava; and on the other, of isolated vents with an energy so feeble as to be capable of nothing more than the explosion of the steam that produced them. In some parts of the country relics remain of the Vesuvian type of volcanoes, in others the volcanic materials have been supplied from fissures as in Iceland, while in not a few places the vents have the character of the *puys* of Central France and the Eifel. The lavas and tuffs of the older volcanic periods have been preserved by being submerged and buried under sedimentary accumulations. And they have subsequently been once more exposed to the day, in consequence of those geological revolutions of uplift and denudation whereby so large a part of the terrestrial crust has been made accessible to observation.

Geological history of volcanic action in the British Isles.

The oldest rocks of the British Isles are probably those comprised under the general name of Archæan or Lewisian gneiss, which form the chain of the Outer Hebrides and occupy many detached areas in the west of the counties of Sutherland and Ross. They include masses which recall the deep-seated bosses of eruptive material connected with volcanic discharges. But so extensive has been the denudation which they have undergone, even long anterior to Cambrian time, that if they were ever associated with any superficial manifestations of volcanic action, all trace of these has long since disappeared. Yet in the overlying Torridonian sandstones, which are certainly pre-Cambrian, fragments of lava-like rocks occur, suggestive of superficial eruptions before these sandstones were laid down. Another group of pre-Cambrian rocks rises along the borders of Wales and Shropshire into a chain of heights of which the Wrekin and Caer Caradoc are the most prominent. These rocks include acid tuffs and lavas which point to true volcanic action, and mark the earliest known eruptions in the long volcanic history of England and Wales. Perhaps to the same primeval period should be referred certain relics of volcanic discharges found in the Malvern Hills, and still more remarkably in Charnwood Forest. One characteristic feature of all these rocks is the prominence of the breccias and tuffs. It would seem that the pre-Cambrian volcanoes of England and Wales were specially remarkable for the vigour and continuance of their explosions and discharges of fragmentary material, rather than for the amount or variety of the lavas that flowed from them.

The most ancient series of fossiliferous rocks, to which the name of Cambrian is assigned, contains the records that form the first of the long succession of chapters of fairly continuous geological history. In Great Britain they are chiefly developed in Wales and the border English counties; they occupy a narrow belt 100 miles long in the north-west of Scotland, and certain groups of rock in the south-east of Ireland have been classed with them, though destitute of any of the characteristic Cambrian fossils. The Scottish and Irish developments of these primeval strata have not disclosed any trace of contemporaneous

[1] This subject will be found fully discussed in the author's *Ancient Volcanoes of Britain*, 2 vols., London, 1897.

volcanic action. But both in South and North Wales a remarkably full chronicle has been preserved of a long series of volcanic eruptions. Around St Davids in Pembrokeshire a mass of volcanic material, at least 1800 feet thick, forms the lowest visible portion of the Cambrian system. It consists chiefly of tuffs which represent successive showers of volcanic ashes thrown from submarine vents over the floor of the sea in which the earliest fossiliferous sediments were deposited. These tuffs present most of the characteristic features of Palæozoic volcanoes. They include both acid and basic varieties, which are represented in such a way as to show that both siliceous and basic lavas existed in the vents and were successively blown out in dust and lapilli. The volcanic series also includes some sheets of basic lava which in turn display some of the familiar features of later Palæozoic eruptions. Their slaggy bottoms, cellular structure, and identity of character with many of the lapilli in the tuffs in which they are intercalated, show them to be true lavas which flowed over the sheets of still unconsolidated ashes lying on the sea-bottom. Various intrusive bosses, sills, and dykes traverse the volcanic series of St Davids. Though some of the tuffs pass into coarse agglomerates, no remnant of a true volcanic neck or orifice has yet been noticed in the district. In North Wales relics of at least two distinct Cambrian volcanic centres have been detected. One of these lies in the picturesque district around the lower end of the lake of Llanberis and stretches thence towards Bangor; the other extends along the ground to the west of the great range of Cader Idris. We there meet with evidence of abundant volcanic explosions, marked by intercalated tuffs, and including occasional sheets of acid and basic lavas, and we learn that these records of subterranean energy ascend up to the very top of the Cambrian system and beyond it into the overlying Silurian formations. Though less voluminous in their discharges than the Silurian eruptions, those of Cambrian time were perhaps more long-continued over the region of Wales. In the Malvern Hills and in the neighbourhood of Nuneaton traces of other Cambrian volcanic centres have been found.

Unfortunately the Cambrian rocks have been so widely and deeply overspread by later formations that they only appear here and there at the surface where they have been ridged up by subterranean movements and laid bare by prolonged denudation. The next overlying system, known as Silurian, is exposed over a far wider area, and as it also has preserved a long series of volcanic records, we obtain from it a clearer view of the development and characteristics of the older Palæozoic volcanoes. Of the two sections into which it is divided the Lower is pre-eminently replete with volcanic intercalations which are widely distributed over the area of the British Isles on certain definite stratigraphical platforms. The eruptions appear to have come from many separate vents often placed far apart over the sea-floor. Some of these vents, more particularly in North Wales, were already in activity during the Cambrian period. But in Silurian time a much more vigorous display of volcanic energy took place. Each of the three great divisions of the Lower Silurian period was marked by outbursts of lava and ashes. In each volcanic district during the long intervals of quiescence that separated the several periods of subterranean activity, the ordinary sedimentation of the time went on undisturbed, and enclosed and preserved the remains of the organisms that lived on the sea-bottoms. The stupendous piles of material erupted in those ages now form some of the most picturesque mountainous regions in the country. In North Wales they constitute in whole or in great part Snowdon, Moel Siabod, Moel Wyn, the Arans, and Arenig Fawr, and they are prolonged southwards in Cader Idris. Again they form the material out of which the hills and valleys of part of the Lake District have been carved. Even where they rise into no conspicuous eminences they may be detected in so many places all over the southern uplands of Scotland as to show that they underlie the Silurian formations of that region as a great volcanic floor which, though for the most part concealed, has been brought up to the surface again and again on the crests of anticlinal folds. They reappear in the south-east and south of Ireland, and though it is now ascertained that much of the material which in that region has been considered to be tuff proves to be crushed igneous rocks simulating a pyroclastic structure, and that much of the "felstone" mapped as intercalated lava really occurs as intrusive sills, evidence enough remains that active vents rose over the sea-floor during older Palæozoic time in that part of Ireland. Far to the west, in the same long section of geological history, a group of submarine volcanoes rose in what is now the hilly district between Lough Mask and Killary Harbour.

But while it is clear that volcanic action was widespread over the area of the British Isles in the older half of the Silurian period, there is no less certainty that the volcanic centres often stood far apart from each other, were quite independent in their activity, and were not all, even in a geological sense, contemporaneous. The three great subdivisions of the Lower Silurian rocks—Arenig, Llandeilo, and Bala—which must represent a vast succession of ages, have each their volcanic chronicles. We thus learn that the eruptive energy shifted from one part of the region to another; that there were long intervals of quiescence in each district, and that before the close of the period in which the Lower Silurian rocks were deposited the whole series of volcanic foci had become extinct. The volcanoes that were active during the oldest or Arenig eruptions have left their memorials in the ranges of Cader Idris, Aran Mowddwy, Arenig, and Moel Wyn. These thick ranges of rock comprise trachytic or andesitic lavas and tuffs, together with sills of dolerite, felsite, and microgranite. It has been noticed that the upper parts of the series are more acid in composition than the lower—a chemical and petrographical sequence that reappears again and again all through the geological record in Great Britain. The site of another Arenig volcano is indicated by the andesitic tuffs and lavas that rise to the surface in Shropshire between Church Stoke and Pontesbury. To the same geological period we must assign the oldest visible parts of the volcanic platform which has been above alluded to as underlying the Silurian formations of the south of Scotland. This platform appears to extend over an area of nearly 2000 square miles. Whether the volcanic sheet is continuous underneath over this wide tract or is separated into distinct districts marking local centres of eruption will probably never be ascertained. It is interesting to note that while in Scotland the volcanic activity of Arenig times was prolonged in successive eruptions through the Llandeilo and Bala periods, the great volcano of Merionethshire became entirely extinct, and a long interval elapsed in that region when, so far as we know, volcanic action continued quiescent. The Llandeilo rocks of Wales contain no remains of any great volcano, but they are not entirely destitute of contemporaneous volcanic records, for numerous small isolated patches of lava and tuff can be traced at wide intervals down the east side of the principality and across to the coast of Pembrokeshire. Of these the most important is that of Builth; others make their appearance near St Lawrence, around Fishguard and on Abereiddy Bay. But no trace of Llandeilo eruptions has been detected among the volcanic records of North Wales.

The long interval of rest that elapsed after the eruptions of Arenig, the Arans, and Cader Idris, during which Llandeilo volcanoes were active in the southern half of the principality, while no volcanic activity showed itself in the northern half, was at last brought to a close in the north by a renewed and vigorous outburst over the site of Carnarvonshire during the Bala period. To this revival of subterranean energy we owe the mass of Snowdon and the picturesque mountain-groups around it. For a distance of at least 30 miles from south to north the lavas and ashes of this centre of eruption may be traced. Yet there can be no doubt that only a portion of these is now exposed at the surface, and that much of their original mass has been removed by denudation or lies concealed beneath the younger rocks that now form the surface. The mass of ejected material is probably not less than from 6000 to 8000 feet thick; in Snowdon alone the higher part of it amounts to 3100 feet. The lavas and tuffs are thickest around the probable centres of discharge, and are intercalated among the ordinary sediment of the Silurian sea-bottom, in such a manner as to demonstrate that they were erupted during the time when the Bala group of rocks was deposited in the form of sand, mud, and calcareous silt. The lavas are chiefly varieties of felsite or rhyolite, with some andesites towards the top. The tuffs largely developed on Snowdon are sometimes fine-grained well-stratified rocks, more or less mingled with ordinary sediment. They contain the fossils of the Bala group, and indeed occasionally become calcareous and pass into the Bala limestone, which is so marked a palæontological horizon in the Lower Silurian series of North Wales. In other cases the fragmentary materials consist of very coarse agglomerates, including large blocks of felsite and andesite. Some of the vents from which these various lavas, tuffs, and agglomerates were erupted are probably represented by a series of bosses which rise at intervals from Penmaenmawr into the peninsula of Lleyn —a distance of about 50 miles. The latest manifestation of volcanic energy in the district appears to have been the intrusion of a large number of basic sills both into the sedimentary strata and into the overlying volcanic pile. In a geological sense contemporaneously with the eruptions of Carnarvonshire, one or more vents were active farther to the east, on the site of the present Berwyn Hills; others made their appearance where Anglesey now stands. The Lake District, during the same period of geological history, became a centre of remarkable volcanic energy. Over an area of not less than 550 square miles the lavas and tuffs can still be traced there, and they probably extended originally far beyond their present visible limits. They were piled over each other to a depth of perhaps as much as 8000 or 9000 feet, and remain as the chronicle of the most prolonged and most continuous display of volcanic energy among the Palæozoic rocks of Great Britain. The earliest eruptions began in the Arenig period, and they followed each other so uninterruptedly that no marked interval of quiescence separated any of them, at least such as would be indicated by a thick group of intercalated sediments. By one discharge after another, lavas and ashes were heaped upon the sea-bottom until the close of the Bala period.

In southern Scotland and in south-eastern Ireland active vents were scattered over the sea-floor and continued their eruptions until towards the close of the same period of geological history. But after that time a complete quiescence ensued, and continued for a long interval. It is a remarkable fact that over England, Wales, southern Scotland, and south-eastern Ireland, where volcanic action had been so vigorous and prolonged during the Lower Silurian period, no trace has been found of any eruption during Upper Silurian time, except certain igneous rocks at Tortworth in Gloucestershire which may now be regarded as dating from that later epoch. Another centre of volcanic eruption contemporaneous with the deposition of the Upper Silurian formations lies on the coast of the Dingle promontory in the extreme west of Ireland, where nodular felsites, tuffs, and volcanic breccias are intercalated among highly fossiliferous strata of Wenlock and Ludlow age.

The next great cycle of geological time—that of the Devonian and Old Red Sandstone rocks—was marked by a renewal of volcanic energy, more especially over the site of Scotland. The Silurian sea had there given place to land, that enclosed a number of large lakes or inland seas, and it was in these basins that the volcanoes particularly displayed their activity. The largest sheet of water, to which the name of Lake Caledonia has for the sake of distinction been given, seems to have stretched across the midland valley of Scotland between the highlands and the southern uplands, and to have extended at least as far as Lough Erne in the north of Ireland. In this long and wide trough two lines of volcanoes lay towards the northern margin, where the Ochil and Sidlaw Hills now rise. These vents poured out sheets of andesitic and felsitic lavas which, together with abundant showers of ashes and stones, accumulated upon and among the red sandstones and coarse conglomerates that formed the ordinary sediments of the lake. The thickness of volcanic material thus discharged amounts in the Ochil chain to more than 6500 feet, but as the bottom of the whole pile is concealed, the total depth may far exceed that amount. The direction of this line of vents coincided with the trend of the long axis of the lake, that is, from north-east to south-west. In the same general direction, at a distance of perhaps 20 miles to the south, another volcanic bank ran from the neighbourhood of Edinburgh south-westwards through the group of the Pentland and Biggar Hills, by the head of Nithsdale, into the south of Ayrshire. These two chains of eruptive vents are probably prolonged far to the south-west. Traces of the northern series may be observed in the Isle of Arran and at the south end of Kintyre. Beyond the limits of Scotland some of the breccias are well developed on the Irish coast at the Red Bay, Antrim, while still farther to the south-west, between Dungannon and Omagh, numerous sheets of andesitic lava are interstratified among the red sandstones. Nor were the volcanic eruptions confined to this largest of the Lower Old Red Sandstone basins. They occurred on a considerable scale in the tract of Lorne, in the west of Argyllshire. Small scattered vents were opened on the south side of the Moray Firth, in the Orkney Isles, and still more conspicuously among the Shetlands. Possibly while some of these northern volcanoes were active, another group made its appearance in the south of Devonshire, where its lavas and tuffs can be traced in a tolerably continuous belt from Torbay into Cornwall. Long before the time of the Upper Old Red Sandstone vigorous volcanic activity had ceased over Great Britain. There appears to have been another long interval of quiescence during the deposition of the uppermost subdivision of the Old Red Sandstone, only broken, so far as we know, by the appearance of a group of small volcanic cones not far to the south of Limerick, and of another in the island of Hoy among the Orkneys.

The Carboniferous period witnessed another revival of volcanic energy and a considerable modification of the forms in which this energy manifested itself. The volcanoes now belonged to two distinct types, that of *plateaux* and that of *puys*. In the former the lavas and tuffs were discharged over wide areas, generally from small vents or fissures, and were gradually built up into masses several hundred feet thick. This type was the older of the two. It made its appearance at, or perhaps even before, the close of the Upper Old Red Sandstone period; but ceased before the Carboniferous Limestone began to be laid down. The second type showed itself in the appearance of small vents from which sometimes only ashes, and, even in the most vigorous examples, comparatively limited streams of lava were emitted. The pipes or funnels of these volcanoes are now marked by plugs of tuff or basalt, and are generally the most conspicuous and sometimes the only visible record of the volcanic action that produced them. Both volcanic types are developed almost entirely in the south of Scotland. The plateaux extend from Stirling, through the Campsie, Dumbartonshire, and Renfrewshire hills, to the heart of Ayrshire and the borders of Lanarkshire. They form the Garleton hills in Haddingtonshire, and they stretch in an interrupted band from the Merse of Berwickshire across the hilly country of the Slitrig and Liddesdale to the southern coast of Kirkcudbrightshire and into the English border. The *puys* are the more usual and more widespread type of Carboniferous volcanoes. Their chief development is to be found in the Lothians and Fife, where they are so abundant, well-preserved, and clearly exposed that this district may be regarded as classic ground for their study. The *puy* type is seen among the toadstones of Derbyshire and far to the south in the few scattered vents of West Somerset. It is also exemplified in Ireland by the neck of Croghan Hill, King's County, and by the remarkably interesting volcanic district of Limerick. Carboniferous eruptions began earliest and lasted longest in Scotland. They were feebler than those of the Old Red Sandstone, as these in turn were less voluminous and widespread than those of older Palæozoic time. They displayed as large a range of petrographical composition among their materials as those of previous ages, for they included such highly basic rocks as picrite, together with basalts and dolerites, andesites, trachytes, and phonolites, and even more acid rocks containing free quartz. They became extinct in England and Ireland long before the end of the deposition of the Carboniferous Limestone; in Scotland they likewise ceased generally within the same period, but in Ayrshire they prolonged a diminished activity until the Coal Measures began to accumulate.

The continued enfeeblement of volcanic energy over the area of the British Isles is strikingly displayed by the next group of small scattered vents and occasional sheets of lavas and tuffs, which are probably referable to the Permian period. These remains are almost wholly confined to the south of Scotland. In Ayrshire, where they are best developed, a number of "necks" of tuff and agglomerate rise through the Coal Measures. From these, and no doubt other buried vents a thin series of basic lavas and tuffs has been ejected, which overlies the Coal Measures and passes under a group of massive brick-red sandstones which are believed to represent the Permian sandstones of the north of England. Again in Nithsdale small patches of similar volcanic rocks are found intercalated in the prolongation of the same red sandstones. But for the most part, only the necks of the little volcanoes have been preserved, all trace of any material which may have been thrown out from them having been removed by denudation. In the east of Fife, within an area of about 70 square miles, upwards of eighty distinct vents have been counted. In a space of only about one square mile, near St Andrews, some two dozen separate "necks" have been detected, each marking the site of a volcanic orifice. It cannot be affirmed with certainty that all these vents belong to the Permian period, but some of them which pierce the very uppermost subdivision of the Coal Measures must be later than that group of strata, and may thus be considered as not older than Permian time. If some of the series be so late, there seems a probability that others, perhaps the whole, having the same general characters and mode of occurrence in the district, may be of similar age. The only other volcanic series that may be referable to the same part of the geological record lies in Devonshire near Exeter and Crediton. Lavas of basic and intermediate character are there intercalated among the presumably Permian red sandstones and breccias.

In our review of the volcanic history of Great Britain we have now arrived at one of its most important stages. The decay of energy traceable among the later Palæozoic periods becomes strikingly manifest in the scattered little vents of southern Scotland and Devonshire just referred to, which were, so far as yet known, the last Palæozoic manifestations of the underground fires. Throughout the whole of the Mesozoic rocks not a single trace of any contemporaneous eruption has been met with. And yet these rocks are admirably exposed over hundreds of square miles of inland country and for many miles of coast-sections. Had they contained any record of volcanic eruptions we may conclude that it would ere now have been detected. But this remarkable quiescence of Mesozoic time was not confined to Great Britain; we find that throughout the continent of Europe, with some trifling exceptions, there is a similar absence of any relic of contemporaneous volcanic disturbance. The gradual enfeeblement of energy in the Palæozoic periods was followed by a vast interval, in the voluminous sedimentary records of which no trace of volcanic action has for the most part been found.

After this momentous pause, the pent-up internal energy once more broke out with renewed vigour and on a scale not inferior to any of its earlier displays. Over the north of England, the southern half and west coast of Scotland, and the north of Ireland—a total area of more than 40,000 square miles, and therefore larger than either Ireland or Scotland—the solid crust of the earth was rent by thousands of fissures, having a general parallelism of direction from south-east to north-west. Up these innumerable dislocations molten rock rose from below, and solidified there in a great system of dykes, for which the British Isles have long been celebrated. So far as the geological record enables us to pronounce an opinion, nothing of the kind on so colossal a scale had taken place in any period in the history of the country since the wonderful dyke-intrusions in the Lewisian gneiss. From the independence of geological structure which the dykes maintain, they are evidently of comparatively late date. They cross indifferently all the various formations up to the Chalk and the volcanic plateaux which, on the strength of imbedded vegetable remains, have been pronounced to be older Tertiary, that is, about the age of the London Clay and other associated deposits in the south of England. When we consider the wide area over which these dykes extend, and reflect that they indicate a connexion with one or more subterranean reservoirs of molten materials which at some unknown, but probably not very great, depth beneath the surface extended over a tract of the terrestrial crust about 40,000 square miles in extent, we may surmise that this upwelling lava would hardly everywhere stop short of the surface, but would not improbably break forth here and there, so as to give rise to the ordinary phenomena of volcanic eruptions. In actual fact we see that such outbreaks have taken place on a vast scale in the north of Antrim and along the west coast of Scotland. If any superficial discharges occurred in the south of Scotland or the north of England, all trace of them has been removed by denudation. Late though the eruptions were in geological history, the time which separates them from the present day is so vast as to have allowed a stupendous waste of the surface, so that only a series of fragments of this youngest chapter of the volcanic chronicle has come down to us.

The great basalt plateaux of Antrim, Mull, Morven, and Skye consist of successive sheets of basaltic lava with occasional layers of tuff and seams of sediment containing remains of an older Tertiary terrestrial flora. These volcanic piles must originally have attained a great thickness. Their surface has been enormously wasted and lowered, yet even now they are more than 3000 feet thick in Mull. They must have been poured forth like the lava-floods of Iceland and the Snake river, stretching out as a level plain of black basalt and scoriæ over areas of many hundred square miles. Vast numbers of sills were injected among the strata beneath the volcanic pile, and likewise between the successive sheets of the pile itself. Huge sills or bosses of gabbro that disrupted the level lavas of the plateaux are now visible in the picturesque mountain-groups of the Cuillin hills, the Isle of Rum, Ben Buy in Mull, and the promontory of Ardnamurchan. Subsequently still more extensive intrusions of granitoid material broke into the basalt and into the gabbro, further disturbing the regularity of the plateaux. And lastly renewed dislocation of the crust and fissuring of all the Tertiary volcanic series led to the uprise of a new series of basaltic dykes. These latest manifestations of subterranean energy formed the concluding phase of the Tertiary eruptions, and they close the long record of the volcanic history of Britain. Since their time denudation has been unceasingly at work; the Tertiary plateaux, with their various invasions of eruptive material, have been dissected in countless valleys and ravines and on long ranges of sea-cliffs, and their structure has thus been revealed with a fulness of detail such as none of the earlier records presents for the consideration of the geologist. It may be remarked, in passing, that the lessons in the history of denudation derivable from the study of these Tertiary volcanic rocks are not less interesting nor less important than those which relate to vulcanism. Thus, there can be no doubt that the present topography of Scotland has been mainly carved out by subaërial action since the Tertiary eruptions. It can be demonstrated, for example, that wide and deep glens, such as that in which Loch Lomond lies, and long and deep sea-lochs and straits like the fjords of Skye and the Sound of Mull, have all been gradually excavated since that time.

Conclusions as to the history of vulcanism.

From the study of so remarkably varied and complete a chronicle as is found in Great Britain some conclusions of interest may be drawn regarding the history of vulcanism during the geological past. It is evident from the distribution of the British volcanic rocks that they have been erupted along the continental border, mostly over the sea-bottom and in a general north and south direction. One of the most impressive features of these rocks is their reappearance on different platforms during successive geological periods, and the persistence of volcanic energy which they thus prove to have been maintained in the British area during so vast a section of geological time. An attentive consideration of the distribution of these rocks furnishes ample proof that, in a number of instances, the same district became, at widely-separated intervals, the theatre of eruptions, while other tracts remained entirely and persistently free from any such manifestations of subterranean activity. The plateau-eruptions were connected with abundant fissures, represented now by multitudes of dykes. On the other hand, the ordinary volcanic vents, from the earliest times to the latest, do not furnish any evidence of having had their sites determined by important lines of fault or other dominant geological structure. But they do show a frequent preference for lines of hollow rather than hills and ridges. They made their appearance in areas that were subsiding, and the majority of them were submarine. Alike in the nature and composition of the erupted materials, and in the form in which the volcanic activity showed itself, the volcanoes of the geological past have their counterparts in those of recent time. There has been, indeed, a singularly persistent uniformity in the main characters of vulcanism throughout geological history. The Vesuvian and Icelandic types of volcano can be recognized even among those of the Palæozoic ages.

Another important fact in the history of vulcanism is clearly deducible from the geological records of Britain. There has been no gradual and progressive diminution in the intensity of the volcanic forces during past time, such as some physicists have asserted to have occurred as a necessary consequence of the slow cooling of the planet and its resultant loss of energy. If we take a broad view of the volcanic chronicle of Palæozoic time, we find evidence of many successive periods of eruptive activity, differing from one another in vigour and duration, and each showing a time of maximum energy, followed by a time of diminution, and then by a time of absolute quiescence. It is true that the later eruptions of the Palæozoic ages showed a marked diminution in number and area, as well as in the variety and amount of the igneous material ejected. It is likewise true that this obvious dying out of the subterranean forces was followed by the long and profound calm of Mesozoic time. Nevertheless it is no less certain that when these forces reawakened in the older Tertiary ages, they showed themselves on at least as vast a scale as ever, ranged over a wider region, and poured out more voluminous floods of lava.

Denudation has so extensively laid open the igneous rocks of former ages that innumerable points in the detailed structure of volcanic vents, fissures, and plateaux can be studied to which no access is possible in modern volcanoes. The whole history of a volcano or volcanic epoch, from its beginning to its end, is disclosed. We see that many vents were opened by gaseous explosions, without the aid of any concomitant or pre-existing fissure. We can trace the actual walls of a vent, and mark how the materials have been piled up within them. We can follow the effects of the volcanic heat upon the surrounding rocks, and of the uprise of heated vapours through the materials that choked up the orifice. And we discover how important a part in the subterranean operations of volcanoes is taken by the intrusion of sheets of molten material among the surrounding rocks.

One of the most interesting results of a study of the volcanic rocks of Great Britain is the proof thereby obtained of the gradual change in the condition of the molten magma during the course of a continuous volcanic episode. The evidence shows that the reservoirs which supplied the lavas usually began with the emission of material basic or intermediate in composition, which became finally more acid, and even gave forth such rocks as granite and felsite. Moreover, this sequence from basic to acid was repeated in successive geological periods sometimes even in the same region. It thus appears that the magma beneath a volcanic centre, after it has become acid, and after the volcanic activity has ceased, eventually, during the prolonged interval of quiescence, acquires once more a basic character, and goes through a similar gradual change of composition in the next volcanic cycle.

While the British records of ancient volcanic activity are more complete, and have been more fully explored than those of other countries, the progress of investigation has brought to light many new facts of interest and importance in regard to ancient eruptions in regions which have long been unvisited by any such outbreaks. Thus in the north-west of France a remarkable succession of four principal periods of eruption has been discovered by Prof. Barrois, who records the existence there of volcanoes in Cambrian and Lower Silurian time, of others in the ages of the Middle and Upper Silurian rocks, of a third series in the Upper Devonian, and of a fourth in the Carboniferous period. The Harz supplies volcanic rocks of Silurian, Devonian, Carboniferous, and Permian age. The volcanoes of this last-named period broke out also in Thuringia and Bohemia, and even as far as the shores of the Mediterranean to the west of Cannes. In Tirol active vents existed in Triassic time. The period of volcanic calm which is so marked in the geological record of the British Isles during Mesozoic times appears to have extended over the site of continental Europe, though some rocks in Portugal may possibly mark Cretaceous eruptions, while others in the Crimea have been cited as of Jurassic age. But it was in Tertiary time that volcanic energy recovered its ancient vigour over all the European area. The British examples already referred to were accompanied and followed by copious eruptions. During a long succession of geological periods on the Continent, in central France, Rhineland, Saxony, Bohemia, Hungary, Würtemberg, Italy, and other parts of Europe, innumerable vents were active from an early part of Tertiary time, and some may not have become extinct until shortly before the dawn of history.

Earthquakes (see also separate article).—Much information has been gathered in recent years regarding the movements of the earth's crust. Those of the sudden and paroxysmal kind embraced under the general term earthquakes have been studied by means of self-recording instruments in countries which, like Japan, are specially subject to them; while in other regions, where no such instruments are established, the phenomena have been subjected to a more exhaustive examination than was formerly attempted. We now know that what we call the "solid earth" is liable to continual vibrations and tremors which, though for the most part inappreciable by the ordinary senses, can be detected by delicate instruments, and are sufficiently pronounced to have frustrated observations to determine the lunar disturbance of gravity. Slight movements of this nature arise from changes of atmospheric pressure and temperature, and from movements in the soil caused by heavy rain and by frost. There are likewise slow and periodic changes of level within small limits. Some of these depend on daily, others on seasonal, conditions, such as temperature, moisture, and evaporation. It thus appears that the surface of the land is in a perpetual state of strain from the influence of forces acting from without.

Though it cannot yet be said that the origin of earthquakes is quite understood, some appreciable advance has been made towards the comprehension of this geological problem. There can be no doubt that any movement upon or within the earth, sufficiently violent to give a stroke or blow, and thereby generate an elastic wave or series of waves, will produce an earthquake. A sudden rock-fall or landslip from the side of a mountain, if of sufficient magnitude, may give rise to a widespread concussion of the ground. But the phenomena of true earthquakes arise from changes within the earth. In volcanic districts these precede or accompany the violent explosions by which steam, gases, ashes, and lava are projected from the earth's interior into the atmosphere. In non-volcanic regions they may arise from the sudden collapse of underground cavities, such, for instance, as has been caused by the solvent action of percolating water. But in none of these instances do earthquakes reach their greatest intensity and widest range of disturbance. It has now been established that earthquakes are most frequent and most violent in regions where there are no active volcanoes. Hence it is reasonably inferred that, although volcanic explosions undoubtedly give rise to severe concussion of the ground, this effect is comparatively local, while the more potent earthquakes extend over vast areas of the globe. It has further been noted that earthquakes are specially prevalent in mountain regions, also in tracts that lie along one or more lines of fault, or on the critical line between the continental plateaux and the ocean basins. In all these tracts the crust of the earth is probably in a state of strain and of unstable equilibrium. It has there been bent by tangential pressure and rupture, and has consequently become weakened and ready to give way again under an accumulation of the same cause. For years or centuries no change may take place along one of these lines of weakness, but eventually the strain becomes irresistible, and the crust gives way in a sudden snap. In the case of the more powerful earthquakes, the bending and fracturing, instead of being confined to a mere point, like the focus of a volcano, may stretch for many leagues along the axis of a mountain chain, or along the submarine front of a continent. And thus the cause of the concussion of the ground may be propagated through the crust for hundreds of miles beyond the centre at which the beginning of the snap took place.

The phenomena of earthquakes are discussed in the article on this subject. We are concerned only with their immediate geological relations. Though the progress of observation has not materially increased our information regarding the nature of the geological changes brought about by earthquakes, many new and striking illustrations of these changes have been noted. Of the numerous additional examples which have been chronicled of the effects produced upon the soil and general surface of a country, some of the most remarkable have been observed in Japan. Reference may be specially made to the severe earthquake which convulsed that country on 28th October 1891. By that visitation in 30 seconds 10,000 people were killed and twice that number were wounded; 128,750 houses were levelled with the ground, besides numerous temples, factories, and other buildings; railway bridges and viaducts were twisted and ruined, and hundreds of square miles of central Japan were laid waste. Green forest-covered mountains were denuded of their trees and turned into ridges of naked stone. Everywhere landslips were produced, and the valleys were blocked up with the rubbish, so that lakes were formed by the interrupted drainage. But, besides these superficial and more or less transient effects, others were noted of a more deep-seated and more lasting kind. The surface of the ground underwent a horizontal compression, whereby valleys and river-beds had their sides brought nearer to each other, so that in the reconstruction of the ruined bridges the engineers had to allow for a diminution of from 1 to 3 per cent. in the length required. A rupture of the ground could be traced for 60 miles, showing in many places as a long low cliff. On one side of this dislocation the ground had sunk some 20 feet, and other evidence was obtained of an alteration of the relative levels of the country. These remarkable results confirm observations made in other earthquake countries. They show the paramount influence of the rupturing of the terrestrial crust, and they serve to indicate that though no stupendous geological change may be made, even by the most violent earthquake, the repeated recurrence of such events may eventually entirely change the surface of a country.

Further light on the geological results of earthquakes has been obtained from a study of the effects of the great catastrophe which on 12th June 1897 devastated about 150,000 square miles in Assam and the adjacent parts of India, and of which the shock was felt over about 1,750,000 square miles of the earth's surface. A voluminous report on this event, prepared by Mr R. D. Oldham for the Geological Survey of India, has more especially added to our knowledge of the fissures in the ground which have so frequently been observed in great terrestrial disturbances. From the detailed narrative in this report, it appears that two distinct types of fissures could be recognized, one of a superficial, the other of a deep-seated origin. The ruptures of the first class probably start at the surface of the ground and descend to variable but, no doubt, shallow depths. They are probably produced by the wave-motion which is propagated outwards from the centre of shock, and are more especially developed in the alluvial plains, where their direction is often determined by that of a river-course, line of embankment, or roadway. The fissures of the second type arise from displacements within the terrestrial crust. They much less frequently appear at the surface, where they not merely affect the alluvial deposits, but even split through hills of crystalline rock, and where they are accompanied by evidence of great violence of shock. They are regarded by Mr. Oldham not as a result of the wave-motion, but as themselves a cause of that motion and as surface manifestations of the deeper-seated fracture of the crust to which the origination of the earthquake wave is to be ascribed. The tract of country within which this type of fissure was displayed extended in an east and west direction through the hills and plains of Assam for a maximum distance of perhaps 200 miles, with a maximum breadth of 50 miles. Along this belt, at a depth of not improbably less than five miles below the surface, a sudden rupture or overthrust of the terrestrial crust is believed to have taken place, accompanied by secondary thrust-planes and faults, some of which actually extended up to the surface of the ground.

Apart from great destruction of life and property, extensive prostration of forests, and other relatively evanescent though lamentable effects, this Indian earthquake of 1897 left many more lasting traces of its passage. The surface of the alluvial plains was thrown into undulations, and after the catastrophe did not return to its previous condition. Some portions remained permanently depressed, and now became receptacles for the interrupted drainage, which thus gathered in pools and lakes over the sunk land. Moreover, there was a horizontal displacement or torsion amounting sometimes to as much as 10 or 15 feet. River banks were pushed nearer to each other, and the beds of the narrowed streams were ridged up until sometimes they were on a level with the banks on either side. Vast numbers of landslips took place along the sides of the hills and river-courses, whereby the drainage was seriously affected. One of the most interesting observations contained in Mr Oldham's report has reference to the production of lakes along a river valley. One of the great lines of fault was traced for some 12 miles along the course of the Chedrang river. In some places its throw or vertical displacement amounted to as much as 35 feet, but elsewhere it diminished and disappeared. There was thus a differential movement whereby some portions of the river-bed were pushed up into the air, while other tracts of the valley were depressed below the level of the stream. The line of fault, which has an upthrow to the east, repeatedly crosses the river, which is consequently ponded back in a pool when the elevated side faces up stream, and tumbles over a waterfall when that side looks down stream. Wherever the line of fault could be traced in solid rock it was found to be a vertical fissure. A chain of pools and lakes has been formed along the valley. One of these sheets of water is fully half a mile long, between 300 and 400 yards broad, and 18 feet deep. Another of still larger dimensions occurs farther down the stream. Where the fault leaves the hills and runs out into the plain, much more extensive alterations of the drainage have taken place, wide tracts of ground have been submerged, and the sites of fields and villages are now covered by lakes 12 feet or more in depth. Similar effects have been produced over wide tracts of alluvial country which have not been directly affected by the deep-seated fractures, but have been thrown into undulations and traversed by superficial fissures. Some of the lakes formed by the depression of the ground are upwards of 20 feet in depth.

Secular Upheaval and Depression.—It is now recognized that the surface of the sea preserves no uniformity in its distance from the centre of the earth, but is liable to wide divergences therefrom. The term "sea-level" is thus apt to be somewhat misleading. The surface of the ocean in the equatorial regions must be more than thirteen miles farther from the centre than it is at the poles, so that any diminution in the rate of rotation would cause the ocean to sink at the equator and rise at the poles. The preponderance of water in the southern hemisphere appears to be due to an excess of heavy materials in the lithosphere under the Pacific Ocean, so that if any transference of such materials to the northern hemisphere were conceivably possible it would shift the level of the ocean. But these causes of difference in the distance of the surface of the sea from the earth's centre may be regarded as permanent. There are others, however, of a less fixed kind which affect sea-level, and any modification of which may at any time give rise to changes in that level. The attraction of large masses of high land raises the surface of the neighbouring ocean. Thus the influence of the chain of the Himalaya causes that surface to be 300 feet farther from the planet's centre at the mouth of the Indus than it is 1200 miles away in Ceylon. Hence any movement of the crust whereby the bed of the sea is raised into land, and especially into lofty land, will draw the ocean water towards the elevated region. The accumulation of masses of snow and ice, thousands of feet thick, at the pole will attract the oceanic water and lower the sea-level in other parts of the globe. The mere removal of so much snow and ice from the general body of water on the earth's surface must tend to lower the sea-level, so that fluctuations in the bulk of the polar ice-cap will be accompanied by corresponding variations in the general surface of the ocean. Any cause which may give rise to an excessive heaping up of ice at one pole, while the opposite pole is relieved of the ice-cap, will tend to shift the centre of gravity of the planet and to raise the level of the ocean where the frozen material accumulates. Again, in inland seas considerable variations of the water may arise from meteorological conditions, especially from excessive rain or drought, as has been registered in the Baltic and Gulf of Bothnia.

That some of these causes of alteration in the relative levels of sea and land are not without influence at present, and have come into play in the past history of the earth, may be freely conceded. We may grant that in various ways the sea may rise and fall even to the extent of hundreds of feet without any change in the position of the surface of the lithosphere. Obviously, it may often be hardly possible to distinguish the effects of such transferences of the oceanic water from those that have been produced by movements of the lithosphere itself. No fact is more abundantly demonstrable in geology than that the sea-floor has again and again been ridged up, convoluted, fractured, and elevated not only into land, but into chains of lofty mountains. But besides the more violent disturbances directly connected with mountain-making, others of a gentler kind appear to take place, not perhaps in any essential point differing from these, save in intensity and duration. These slower and more tranquil alterations of the relative levels of sea and land are sometimes in an upward, sometimes in a downward, direction. They must be caused either by a rise or fall of the sea-level or by an upheaval or depression of the surface of the lithosphere. The opinion of geologists is divided as to which of these two causes should be invoked. During most of the 19th century the general belief was that on the whole it is the land rather than the sea that rises and falls. In recent years, however, this view has been combated by Prof. Suess of Vienna, who holds that the limits of the dry land depend upon certain large indeterminate oscillations of the statical figure of the oceanic envelope; that not only are "raised beaches" to be thus explained, but that there are absolutely no vertical movements of the crust save such as may form part of the plication arising from secular contraction, and that the doctrine of secular fluctuations in the level of the continents is merely a remnant of the old Elevation-crater theory, destined to speedy extinction.[1]

Of the fact that within recent times large tracts of land have emerged from the sea, while other tracts have been submerged, there cannot be any question. If these changes arise solely from some alteration of the figure of the ocean, they can hardly be of merely local occurrence, nor can we suppose that they vary in amount within short distances, or change from an upward to a downward direction. Where any such local peculiarities make themselves manifest we are constrained to regard them as arising from unequal movements of the land and not from an advance or retreat of the sea.

One of the classic regions for the study of this question is the Scandinavian peninsula, together with the basin of the Baltic and the coast-line of Finland. The earlier observations were hardly precise enough and continued over a sufficiently long time to warrant perhaps the definite conclusions drawn from them. But since 1875 the investigation has been pursued with great care, and the result has been to afford good ground for the conclusion that, after every allowance has been made for seasonal variations of the sea-level in the Baltic and Gulf of Bothnia, there is trustworthy evidence of a gradual elevation of the Scandinavian peninsula. The axis of movement appears to coincide broadly with that of the peninsula, and to increase towards the interior of the land. In some places, both on the Kattegat and on the shores of the Gulf of Bothnia, the rate of rise is estimated at 25 centimetres or nearly 10 inches in a century; but at Quarken, where the gulf narrows, the rise on the west side has been computed at 1 metre or 3 feet 3 inches during the last hundred years. On the coast of Finland the upward movement gradually diminishes and disappears in the Baltic provinces, and at St Petersburg no change of level has been detected.[2]

Important observations have in recent years been made in the region of the Great Lakes of North America, which indicate that a slow elevation of the land is in progress towards the north-east, so that the water of the lakes is being driven towards the south-west. In the latter direction the shores are undergoing submergence, while towards the opposite quarter they are gaining ground. The rate of movement is estimated to be four-tenths of a foot in a hundred miles during a century.[3]

Much interesting information on this subject has recently been gathered in Japan, where volcanoes, earthquakes, and slower movements of the ground are developed on so striking a scale. Though volcanic action is abundant and vigorous in that country, observation shows that the most powerful earthquakes are not connected with volcanic eruptions. They originate partly in tracts of old crystalline rocks, but mainly under the sea beyond the eastern coast-line of the islands. We have seen that they sometimes give rise to important changes of level in the land. But besides such sudden alterations others have been watched which, while they are in progress, are in themselves inappreciable, and can only be detected after the lapse of more or less time. They are partly of an elevatory and partly of a subsiding nature. In order to obtain more ample and more definite information in regard to these changes, Prof. D. Kikuchi, of the Imperial University of Japan, in the year 1891 issued a circular to officials at the principal towns and villages round the coast, requesting them to furnish any evidence they could collect of advance or retreat of the sea.[4] Out of several thousand replies received, very few intimated that there had been no change. During fifty years, and even in some places within ten years, harbours had become shallow at rates varying from 1 foot in three to 1 foot in ten years. Some of this change must no doubt be attributed to the abundant deposit of sediment brought down by rivers from the land. But no amount of silting up will explain the concomitant uprise of cliffs carrying with them their faces pierced by boring shells, their seaworn caves, and the sea-beaches deposited at their feet. Prof. Milne, who has personally examined the evidence, concludes that some portions of the east coast of Japan are, at the lowest estimate, emerging from the sea at the rate of about an inch per annum. Elsewhere the change has been of an opposite kind. Grass and rice fields have disappeared, and have been replaced by beaches of sand or shingle; rocks have sunk, the height of the tide has increased and the depth of the sea has augmented at rates varying from 1 foot in sixteen years to 1 foot in five years; buildings and roads are now threatened, and the sea advances so rapidly that the inhabitants contemplate removing inland. Maps constructed a century ago show that the sites of former dwelling-places are now beneath the sea. Some of these changes may be accounted for by ordinary marine erosion without any change of level either in the sea or on the land. But their general concurrence, taken together with the submarine prolongation of land-valleys, seems to show that certain portions of the Japanese coast are actually undergoing submergence.

It is impossible to suppose that within the compass of a limited district the level of the sea can be at the same time both falling and rising. Any simultaneous change of sea-level within such a district must be nearly uniform and in the same direction. The actual observed divergences in direction and in rate of change are only explicable on the supposition that it is the land which is undergoing distortion, whereby some portions of it are pushed upwards, while others subside. Thus the evidence of recent changes of level in Japan confirms the general belief which has been recently impugned.

A study of the raised beaches of Great Britain affords further support to the view that it is the land rather than the sea that has shifted its level. These evidences of old sea-margins are traceable along the south coast of England at various levels. But it is in Scotland that the former "strand-lines" are most abundantly and most clearly developed. These lines sometimes consist of terraces of deposit, like the sand, gravel, and silt of the present shores, and are then properly described as "beaches." But in other places they are platforms of erosion, which have been cut along the edge of the land when the sea-margin stood at higher levels than it does now. They appear on both sides of the island, but are more especially marked on the west side from the Firth of Clyde to the coast of Ross-shire, and on the east side in the estuaries of the Forth and Tay and along the shores of the group of northern firths between Inverness and Helmsdale. Where most fully developed, as near Tain, they are at least five in number, and follow each other in successive platforms at heights of about 15, 25, 50, 75, and 100 feet. It is much to be desired that a careful topographical survey with accurate levellings were made of these terraces on both sides of the country, with the view of determining their variations in level. So far as present information goes, they do not preserve strict uniformity, and their local

[1] *Antlitz der Erde*, Vienna, Band ii. (1888), chaps. viii. ix. and x.

[2] De Geer, *Geol. För. Stockholm. Förhandl.*, 1888, p. 195; R. Sieger, *Zeitsch. Gesellsch. Erdkunde*, Berlin, xxviii. (1893); E. Brückner, *Verhand. Neunten Geographentages*, Vienna (1891); W. Ramsay, *Fennia*, xvi. (1898).

[3] G. K. Gibert, *18th Annual Report of the U.S. Geological Survey* (1898), part ii. p. 601.

[4] Professor J. Milne, *Seismology*, p. 2, London, 1898.

differences appear to be too great for any variation of sea-level, and to require irregularities in the uprise of the land. One of the most remarkable peculiarities in their distribution is the fact that, although so well developed, up almost to the extreme north of the mainland of Scotland, they cease beyond that point. On the Orkney and Shetland Islands they have not been detected, although numerous sheltered inlets would have preserved them there had they ever been formed. The "submerged forests" of western Europe, quoted to prove sinking of land, have probably been mostly caused by mere local slipping of peat attacked and overspread by the sea.

Evidence of coral reefs.

One of the proofs formerly relied on in favour of widespread sinking of the lithosphere was the structure and distribution of coral islands. Darwin's striking hypothesis to account for these oceanic points of land captivated the imagination, while at the same time his explanation of the successive stages by which fringing reefs became barrier reefs, and barrier reefs became atolls, appeared so clear and convincing that the conclusion he drew was not only universally accepted, but was regarded as one of the most signal achievements in science ever accomplished by any geographical expedition. It was received as an established truth in geology that the rings of coral, so widely distributed over the Pacific and Indian Oceans, proved a vast subsidence of the floor of these sea-basins and the gradual submergence of wide tracts of land which once rose on their site. But the progress of investigation has shown that though Darwin's explanation may still hold good in some cases, it cannot be regarded as of universal application, and that more especially it can no longer be held to prove that widespread subsidence which was claimed for it. As far back as the year 1868 C. Semper met with some reefs among the Pelew Islands which he could not explain by Darwin's hypothesis of general subsidence, for only 60 miles away from them he found upraised coral reefs and an island entirely without reefs. He therefore concluded that these atolls had grown up upon an area of sea-floor that was rising rather than sinking.[1] A few years later J. J. Rein brought forward the coral reefs of Bermuda as examples that could be explained by the accumulation of calcareous organisms upon the bottom, without necessarily requiring subsidence.[2] Subsequently the subject was more fully investigated by Mr (afterwards Sir John) Murray, one of the naturalists attached to the *Challenger* expedition. From all that he had seen of coral reefs he was led to infer that they may arise without any assistance from a sinking of the sea-bottom. It appeared to him that they might grow outwards from the land upon the top of a steep slope of their own debris, broken off by the waves. He thought that this growth might continue seawards until the steep face of calcareous material had advanced into deep water, and thus that while the whole of it might be supposed to be actually coral that had grown upwards from the bottom, only the uppermost 20 fathoms or thereabouts might be coral rock still *in situ*, all below that upper layer being calcareous debris on which the living corals had built. He pointed out the obvious connexion between the distribution of coral reefs and that of volcanoes in the Pacific basin, and showed that the atolls appeared always to have been planted on the tops of submerged volcanic peaks. To the obvious objection that it was difficult to conceive the possibility of so vast a number of volcanic cones coming just up to the level at which coral-building polyps could begin their operations he replied that those which lay too deep might be brought up to the proper level by the gradual deposit of the remains of the organisms that abound in these waters, while those which rose too high might be cut down by the waves to the depth at which the reef-builders could commence.[3] These views have been further developed by Professor Alexander Agassiz, who has applied them in elucidation of the history of the Florida reefs and those of the West Indian Islands, Hawaii, Fiji, and Australia.[4] He has brought forward abundant evidence, additional to that originally furnished by Semper, that fringing reefs, barrier reefs, and atolls co-exist in the same region, and that no general subsidence can possibly explain their association. He has shown that the whole group of the Fiji Islands has been upraised to a height of more than 1000 feet, and he claims that the east coast of Australia, so famous for its great barrier reef, has risen as much as 2500 feet. Dr Guppy has supplied important evidence from the Solomon Islands, where he has found that fringing reefs, barrier reefs, and atolls have been formed in a region that is undergoing upheaval, and that the elevation has amounted to 900 feet or more.

With the view of obtaining accurate information as to the thickness of a living coral reef and the nature of its foundations, a committee of the Royal Society was appointed in 1896 to investigate the structure of the atoll of Funafuti, one of the group of the Ellice Islands. Professor Sollas, on whose initiative the research was started, was appointed to take charge of it, and he spent some time on the island. Though he made many interesting observations and brought away much valuable material to be worked out in regard to the composition and history of coral reefs, the boring came to a stop before any decisive results had been obtained. Subsequently the investigation was resumed by Professor Edgeworth David, of Sydney, New South Wales, under the auspices of the same committee. The boring was begun again, and continued to a depth of more than 1000 feet without meeting with any other than calcareous and dolomitic material. For a discussion of the results see under ANTHOZOA; but sufficient evidence has now been accumulated to show that coral atolls do not necessarily prove subsidence, and that they can no longer be brought forward as in themselves a demonstration of widespread submergence over the basins of the oceans.

4. Structural Geology.

In this division of the science, treating of the arrangement of the rocks in the crust of the earth, the chief progress made has been in the department that deals with the curvatures and dislocations which rocks have undergone since their formation. Though such changes of position may almost everywhere be detected, it is in mountain chains that they are most impressively developed and can be most profitably studied. Accordingly the Alps have long been classic ground for the investigation of these problems of geology. Even to the uninstructed traveller the proofs of gigantic movements are so manifest that he cannot miss them. No one, for instance, can sail up the Lake of the Four Cantons without marvelling at the way in which sheets of solid gray limestone, hundreds of feet in thickness, have been tossed and folded, as if they had been mere piles of carpet, showing their crumpled layers from the level of the water up to the crests of the mountains on either side. But when the geologist begins to explore this corrugated structure, he finds it infinitely more complicated than could ever have been anticipated. The oldest rocks have been placed above the youngest, and now cap the summits, while the later formations have been often plunged deep under the valleys. Fortunately the order of succession of the different members of the Alpine stratigraphical series can be satisfactorily deter-

[1] C. Semper, *Zeitsch. Wissen. Zool.* xiii. p. 558; *Verhandl. Phys. Med. Gesellsch.*, Würzburg, February 1868; *Die Phillippen und ihre Bewohner*, 1869, p. 100.

[2] *Senckenb. Naturforsch. Gesellsch.*, Würzburg, 1869–70, p. 157.

[3] J. Murray, *Proc. Roy. Soc. Edin.* x. p. 505, xvii. p. 79; *Narrative of the Cruise of the "Challenger,"* vols. i. ii.

[4] *Amer. Acad.* xi. p. 107; *Bull. Mus. Comp. Zool.* Harvard, xvii. No. 3, xxvi. Nos. 1 and 2, xxxiii. (1899, giving his researches in Fiji); *Three Cruises of the "Blake,"* Boston, 1888.

mined, from experience in other lands which have escaped such intense disturbance. Partly by the evidence of fossils, and partly by that of lithological characters, the actual position of the several rocks and groups of rock can be fixed with considerable accuracy. It was indeed only after this knowledge had been laboriously acquired that geologists began to realize how vastly more complex the structure of the Alps is than could otherwise have been suspected.

At the beginning of the 19th century Leopold von Buch and Conrad Escher von der Linth attempted to grapple with the difficulties of Alpine structure. After them Bernhard Studer, Arnold Escher von der Linth, Murchison, and Sedgwick attacked the same problems and threw much light upon them. Studer's life-long devotion to Swiss geology did much to advance our knowledge of mountain-architecture. Arnold Escher carried on with brilliance and success the labours bequeathed to him by his father, and he imbued with his own enthusiasm his pupils Heim, Baltzer, and Mösch. These younger enthusiasts have thrown themselves with ardour into the study of the questions left to them by their predecessors. Heim has especially gained distinction by his minute and laborious investigations of the Glärnisch, Tödi, Windgällen, and other mountain groups, by his unrivalled drawings of the complicated intricacies of structure in these groups, and by the ample discussion of that structure in his beautifully illustrated volumes published in 1878, *Mechanismus der Gebirgsbildung*. This was by far the most important treatise that had yet appeared on the subject, and marks a great advance in the treatment of the problems of mountain-building. Fastening on the evidence of intense plication, Heim followed it up not only into the architecture of great mountain-masses, but downwards step by step in unbroken sequence, till he traced it into such minute details as can be appreciated in hand-specimens. He brought forward abundant proofs that the rocks of the Alps had undergone enormous pressure, in virtue of which they had been folded, compressed, and crushed, and had been reduced to a kind of plastic condition. He believed that the Mesozoic strata of the Alps had been thrown over in folds extending with gentle inclinations for many miles across the mountains, the so-called "double fold" of the Glarner Alps being the most conspicuous example. But he found no prominent place in his sections for dislocations, as important parts of the structure of the ground. It was not difficult to admit that in the deeper portions of the disturbed area of the terrestrial crust, under the vast pressure there existing, movements of the rocks might conceivably take place without faults, by an internal disruption or plasticity. But in the higher parts, where the pressure was greatly diminished, it might be expected that displacement by faulting of some kind would come into play.

That within some indeterminate limits the causes invoked by Heim were adequate to produce the effects ascribed by him to them, could not be doubted. But it was difficult to follow him when he applied his explanation to account for the disappearance of thick formations by mere plasticity. Thus, in the mountain-group culminating in the Hausstock, between the valley of the Linth and that of the Vorder Rhein, the Jurassic formations are represented by him as thrown into the immense "double fold" just alluded to, the two loops of which are supposed nearly to meet somewhere above the crest of the Hausstock. In the upper limb of the western fold these formations are some hundreds of feet in thickness, as shown on the eastern slopes of the Glärnisch. But only a short way below, on the side of the Linth, they are reduced to a few inches. It was not easy to see on what evidence such vast overfolding had been postulated, nor how, within a few hundred yards, a group of massive limestones could be rolled out to nearly the vanishing-point. Thus, while fully admitting the lasting value of Professor Heim's contribution to the unravelling of the architectural details of the mountains, geologists who had specially studied the subject could not but hesitate to accept all his deductions, and felt that there might still be some important feature in the structure that had been missed.

In particular the absence of dislocations in Professor Heim's sections of a region so prodigiously disturbed could not but attract attention. He was well aware that powerful lines of dislocation had been described by different geologists as existing in the Alps. Studer, for instance, had long before pointed out that along the line of the Lake of Thun there must be a dislocation across the strike, with a horizontal displacement of nearly two miles. Suess had remarked a series of north and south horizontal dislocations in the Alps, by which the eastern side was sometimes driven towards the north. Schafhäutl had noticed similar structures among the Bavarian Alps. But though Heim treated skilfully some of the relations between folding and faulting, showing in particular how the rupture of a closely pressed fold might give rise to a reversed fault, it was chiefly on the minute scale that he dealt with these phenomena, as they are developed in the "ausweichungs-clivage" of schistose rocks. Of greater ruptures in the Alpine region he remarks: "I may observe in passing that in contrast with the plications, large overthrust faults are not to be assumed without good reason to exist here and there in the Alps. What we directly see in the Alps are numberless plications which pass into cracks and faults, but true faults affecting the structure of a great mountain chain are but seldom to be seen; they appear to occur with extreme rarity in the Alps." [1]

The true reading of the complex structure of the Alps, however, seemed to require that dislocation as well as plication should be recognized as having contributed to the present arrangement of the rocks. The extreme plasticity required by Heim appeared to be hardly possible among hard sedimentary strata, lying under no greater pressure than that of the comparatively small depth of younger strata that covered them. It was conceivable that deep down beneath the Alps, where solid rocks had undergone enormous stresses under a great overlying thickness of the terrestrial crust, they would be crushed, and their component particles might be made to move over each other, possibly with an infinity of minute ruptures, but without any great dislocation. Yet in this mountain chain, where Tertiary strata had been involved in the plication, it could not be supposed that these strata could ever have been buried under more than, at the most, a few hundred or even thousand feet of younger sediments. It was therefore to be expected that at least the uppermost formations, while being driven together, would be not only plicated but disrupted, and that some portions of them would be found to have been pushed horizontally over other portions.

It had, however, become a settled belief among geologists that in the northern Alps dislocations were either entirely non-existent, or at least possessed no tectonic importance. They were ignored on the published geological maps of that region; and in Heim's beautifully artistic sections and drawings, while full justice is done to the wonderful plications of the region he discusses, faults are conspicuously absent. The first definite and systematic step in the inquiry how far dislocation as well as folding entered into the structure of the Swiss Alps was taken by

[1] *Mechanismus*, Band ii. p. 14.

Dr A. Rothpletz, who, after studying the structure of the Oberland and other parts of Switzerland, announced in 1881 to the Helvetian Society of Natural Science that he had been led to conclude that faults take a much more important place in the geological structure of that region than had up till then been supposed. He instanced three large dislocations which he said he had himself traced in the Oberland, and which, with many others observed by him elsewhere, had convinced him that the striking proofs of great plication had misled observers into the belief that dislocations were either entirely absent in the northern Alps, or at least were of no consequence in the general structure.[1] With great energy and perseverance he devoted himself to the further prosecution of an inquiry into the existence and effects of faults in mountain-structure, and traversed a large part of Switzerland in the research. Among the districts specially examined by him was that between the Reuss and Rhine, including the tract where the "double-fold" of the Glarner Alps was stated to occur. In the year 1883 he communicated to the German Geological Society a remarkable paper on the framework of the Swiss mountains lying on each side of the Rhine.[2] He therein proposed a totally different view of the structure which the "double-fold" was proposed to explain. He believed that this fold had no existence, but that the rocks had been brought into their positions by a gigantic horizontal displacement that had pushed up the older masses over the newer. He traced what he regarded as three main lines of these dislocations or overthrust faults, and indicated their trend upon a map. One of them was represented by him as running from the middle of the Lake of Lucerne by the head of the Lake of Zürich across to the Rhine above the Lake of Constance, and thence far to the east by Bolgenach. A second he traced from the head of the Lake of Lucerne, in a great curve through the mountains by the Glärnisch to Glarus, and thence in a very sinuous line across the Sernf valley and the Foo Pass to Sargans and beyond. A third was shown to follow the line of the Rhine valley as far down as Chur. He further pointed out that these gently inclined displacements were cut through and shifted by transverse faults, as in the valleys of the Reuss, Linth, and Rhine. As a first broad sketch of an altogether new version of mountain-structure, this paper marks a turning-point in the history of this branch of geology. It covered so much ground that it could hardly be free from imperfections which more detailed observation would correct, but it laid a foundation on which later students could satisfactorily advance.

Dr Rothpletz in successive publications has brought forward much additional detail in support of his views.[3] The writer of this article, who has had the great advantage of being conducted by the Bavarian geologist over some of his evidence in the Linththal, and of carefully examining the sections on which he relies, has no hesitation in declaring his belief that the horizontal displacements asserted to be there by Dr Rothpletz undoubtedly exist, and produce the effects claimed for them. One of the most notable localities in this district is that at the foot of the Sernf Thal, where the so-called Lochseite limestone occurs. According to the theory of the "double-fold," this limestone represents there the whole Jurassic formation of the region, squeezed out to a thickness of at most two or three feet. It lies between the Verrucano above and the Flysch below. But in reality it is not here at least a true limestone, but a band of crushed material permeated by calcite derived from the Flysch. This crushed calcareous band has resulted from a horizontal or gently inclined dislocation, the plane of which can actually be seen passing through the band. The older reddish brecciated conglomerate (Verrucano) which here lies uppermost has been thrust forward over the disturbed Eocene strata, and has had its component materials drawn out and its pebbles rearranged parallel with the plane of movement below.[4]

While Dr Rothpletz was pursuing his researches in Switzerland, another series of investigations was in progress in the north-west of Scotland, which eventually shed more fresh light on the problems of mountain-making. Working independently of each other, Professor Lapworth and the officers of the Geological Survey discovered that the geological structure of that region was much more complicated than had been supposed, and that it included a series of dislocations of so novel a kind that, although conspicuously visible when once recognized, their existence had never been even suspected by the geologists who first examined the ground. This complex structure was worked out in great detail by the officers of the Geological Survey between the years 1883 and 1888. They found that the rocks of that region had been ruptured by dislocations which had thrust them horizontally for great distances. The very lowest and oldest rocks had been torn up from below and launched forward in a westerly direction, sometimes for a distance of ten miles. Above one of these planes of movement the rocks were found to have been sometimes pushed over each other by small reversed faults, as cards may be slid one upon another. These minor dislocations were then seen to give way to another more nearly horizontal plane of intenser movement, whereby another slice of older rock was thrust forward. In this way a succession of thick slices of the more ancient formations may be observed to lie on clean-cut surfaces of much younger rocks. Such flat, gently inclined, or undulating surfaces of displacement have been termed by the Survey officers "thrust-planes." They exactly resemble the "Haupt-Längsverwerfungsspalten" which Dr Rothpletz has traced through the Swiss Alps. The rupturing has not taken place as a consequence of excessive plication. The rocks appear to have been dislocated as the immediate effect of intense tangential pressure, probably at no very great depth beneath the surface. But curvature has undoubtedly taken place in them during the displacement, particularly in front of a mass of piled-up strata which was being driven forward on a thrust-plane, and the front of which is apt to be dragged in under the advancing pile. Everywhere, however, the dominant feature is rupture, traceable from the largest dislocations in the thrust-planes down to the minute puckering and cleavage seen in "ausweichungsclivage" and to the crushing of the materials of the rocks and the production of "mylonite." Gradations can thus be traced through successive reversed faults, so small as to be visible in hand-specimens or only with a lens, up to those which extend from top to bottom of

[1] *Archives Sciences Phys. et Natur.*, Geneva, tome vi. (3me Période 1881), p. 292.

[2] A. Rothpletz, "Zum Gebirgsbau der Alpen beiderseits des Rheines," *Zeitsch. Deutsch. Geol. Gesell.* Band xxxv., 1883, p. 134.

[3] *Ein Geologischer Querschnitt durch die Ost-Alpen*, Stuttgart, 1894; *Geotektonische Probleme*, Stuttgart, 1894; *Das geotektonische Problem der Glarner Alpen*, Jena, 1898; *Geologische Alpenforschungen*, part i., Munich, 1900.

[4] The existence of a thrust-plane at this locality is now admitted by Professor Heim, though he adheres to his view of the "double-fold." Compare his sections in the *Mechanismus*, Plate vii. section xiii. and Plate xvi. Fig. 7, with Plate vii. Figs. 2 and 3, in the *Livret Guide* of the International Geological Congress, 1894, and p. 104 of the text of that book; also *Beiträge zur Geol. Karte Schweiz*, 25th Lieferung (1891), p. 204. A special literature has grown up in reference to this so-called "Lochseiten Kalk." For the two opposite views regarding its stratigraphical relations, see Heim, *Mechanismus*, i. pp. 138–223, where the band is boldly affirmed to have been formed by the rolling out especially of the Jurassic limestone between the Verrucano and Flysch; and Rothpletz, *Zeitsch. Deutsch. Geol. Gesell.* xxxv. p. 165; *Ein Geologischer Querschnitt*, p. 243; *Das geotektonische Problem*, &c., Plate vii. Fig. 16.

a cliff and onwards to the maximum thrusts which can be followed for scores of miles across mountain and glen.

Each thrust-plane has a sole or floor over which the rock above has been driven. Under favourable conditions this sole is sharply defined from the immediately overlying material, which often displays evidence of intense crushing even though now in a hard compact condition. Its substance has been ground into powder, and has been made to move along the sole, so that in some cases it has acquired a "flow-structure" and might at first be taken for a felsite or rhyolite. Where a conglomerate has been the material driven over the thrust-plane, its pebbles may be observed to have been drawn out in the line of movement. Pegmatite-veins have been broken up and crushed into fine felspathic dust, so that every step may be traced from the obvious vein into a streaky felsite-like substance.

The major dislocations are usually inclined at a gentle angle in an easterly direction. Hence they behave like nearly horizontal strata, and can be traced winding up the sides of valleys for miles. Not only so, but they have been trenched by denudation in such a way that outliers of them have been left on the tops of hills, affording the singular appearance of a capping of the oldest rock of the district resting apparently quite regularly and conformably upon the newest. The thrust-planes can be followed along the strike for great distances. The most important of these extends for more than 100 miles from the north coast of Sutherland to Sleat in Skye. They have been shifted by ordinary transverse faults belonging to a much later period of movement.[1]

Similar structures have subsequently been found to play an important part in the geological structure of Scandinavia. Törnebohm, Holmquist, and other geologists have traced lines of thrust whereby, as in Scotland, enormous slices of the older rocks have been pushed horizontally over the top of much younger formations. As the most recent example which has been described, reference may be made here to the country lying to the south-east of the mountain Sulitelma on the confines of Sweden and Norway, where Mr P. T. Holmquist has mapped an important thrust-plane over an area of nearly 40 Swedish miles.[2] It is so gently inclined that its outcrop winds up the valleys, and portions of the thrust rocks have been left by denudation as outliers. The effect of the dislocation is to place a series of mica-schists and granulitic quartzites (so-called "Algonkian") above some of the oldest Cambrian strata which lie immediately on the Archæan gneiss and granite. Thus the same structure which deceived geologists in Scotland is repeated in Arctic Sweden, but the key to it has now been found, and though at first sight it might seem that the Scandinavian *Hyolithus* series passes upwards into mica-schists and quartzites, the horizontal thrust-plane has been recognized that accounts for the superposition of the older upon the younger rock. There can be little doubt that the same structure pervades a large part of the Scandinavian peninsula. As in Scotland, it chiefly affects there the older formations of the Earth's crust. But in the Alps it has been powerfully developed among the older Tertiary strata. It thus appears to have played an important part in the structure of mountains, and in the general movements of the Earth's crust from early geological time onwards. Nor is it confined to the more prominent elevations of the Earth's surface. In the south of England, for example, it may be seen in a feeble development in the Chalk of the coast between Weymouth and Studland Bay. There is reason, indeed, to believe that ruptures of the nature of overthrusts have been much more extensively developed throughout the terrestrial crust than has hitherto been supposed.

Various experiments have been made to reproduce artificially and on a small scale the structures displayed in the crust of the Earth. Curvature of strata was studied in this way by Hall, the founder of experimental geology, in the early years of the 19th century.[3] Since his day A. Favre,[4] Daubree,[5] F. Schardt,[6] and others have varied the methods of investigation, and have imitated with more or less success the phenomena exhibited among the rocks. Since the existence and nature of thrust-planes were realized, experimental research in this subject has been resumed by Mr H. M. Cadell[7] in Scotland and Mr Bailey Willis in Washington.[8] Mr Cadell, realizing that the structures which had been worked out by his Survey colleagues and himself in the north-west Highlands of Scotland pointed to the rupture of solid rocks under great stresses, and probably at no great depth beneath the surface, imitated them by placing in a box alternate thin layers of plaster-of-Paris between thicker layers of damp sand or loam. No weight was placed above the layers. The plaster, absorbing moisture from the materials above and below, set into hard brittle laminæ. Pressure was then applied to one end of the box, and a series of experiments was carried on with the view of observing the mechanical effects of the pushing of strata over an immovable surface, and of ascertaining the probable origin of thrust-planes. Some of his more interesting results may be here summarized. Horizontal pressure applied at one side is not propagated far forward into a mass of strata which have no great overlying cover of rock. The compressed mass, in such conditions, tends to find relief along a series of small gently-inclined thrust-planes which dip towards the side from which pressure is exerted. After a certain amount of heaping-up along a series of such minor thrust-planes which thus grow steeper, the heaped mass tends to rise and ride forward bodily along the sole of one or more major thrust-planes. Experiment showed that thrust-planes and reversed faults do not necessarily arise from the rupture of overfolds, but often spring up immediately from the application of horizontal pressure. What takes the form of a thrust-plane below may pass into an anticline above, and may never reach the surface, while a major thrust-plane above may and probably always does originate in a fold below. A thrust-plane may branch into smaller thrust-planes, or may pass into an overfold along the strike. The front portion of a mass of rock that is pushed forward along a thrust-plane tends to bow forward and roll under the back part. The peculiar arrangement in mountains known as fan-structure may be produced by the continued compression of a simple anticline, and thrust-planes strongly tend to arise at the sides of the fan. The compression that produces the fan imparts a schistose structure to its core.

5 and 6. Palæontological and Stratigraphical Geology.

It is in this department of the science that the largest amount of new material has been collected since 1875. In every one of the various systems of sedimentary forma-

[1] C. Lapworth, *Proc. Geol. Assoc.* vol. viii. p. 438; *Geol. Mag.*, 1885, p. 97; A. Geikie, B. N. Peach, and J. Horne, *Nature*, vol. xxxi. (1884), p. 39; B. N. Peach, J. Horne, W. Gunn, C. T. Clough, L. Hinxman, and H. M. Cadell, *Quart. Journ. Geol. Soc.*, 1888, p. 378.

[2] *Geol. För. Stockholm. Förhandl.* Band xxii. (1900), p. 72.

[3] *Trans. Roy. Soc. Edin.* vol. vii. (1812), p. 85.

[4] *Archives Sci. Phys. Nat.*, Geneva, 1878, No. 246; *Nature*, vol. xix. p. 103.

[5] *Géologie Experimentale*, Paris, 1879, pp. 288 *et seq.*

[6] *Bull. Soc. Vaudoise Sci. Nat.* vol. xx. (1884), p. 143.

[7] *Trans. Roy. Soc. Edin.* vol. xxxv. (1890), p. 337.

[8] "The Mechanics of Appalachian Structure," *13th Annual Report of United States Geol. Survey*, Washington, 1894.

tions into which the accessible part of the Earth's crust has been divided vast additions have been made to our knowledge of their fossil contents, geographical distribution, tectonic arrangement, and geological history. But while this mass of infinite detail has been accumulated, the broad outlines traced in the article on Geology in the ninth edition of this work remain, on the whole, not seriously affected. Two sections, however, of this department of the science have more especially advanced. One of these deals with the nature, arrangement, and probable history of the oldest known portions of the terrestrial crust; the other discusses the principles and methods according to which the investigation of the fossiliferous formations should be conducted.

Pre-Cambrian Geological History.—No part of the geological record has in recent years been more diligently studied than those earlier chapters which deal with the ages that preceded the deposition of the earliest fossiliferous formations. More especially has this research been prosecuted in Great Britain and in North America. Though many known problems in the subject remain unsolved, and doubtless many new problems will arise as the investigation is pursued, we are now in possession of a large body of information regarding the primeval parts of geological history, and can carry our eyes backwards into earlier stages of the Earth's progress than were formerly realized.

So far as research has yet gone all over the world, the distinctly fossiliferous formations terminate downwards in the Cambrian system. At the base of that system, strata specially characterized by the presence of the genus of trilobites known as *Olenellus* are taken as the starting-point of the Palæozoic series. But the variety of the fauna found in these and the overlying strata may be regarded as demonstrative proof that this fauna does not represent the first beginning of life on the globe. Some biologists, indeed, following Darwin, maintain that the time required for the evolution of *Olenellus* and its contemporaries may have been as long at least as all the ages that have passed since these organisms lived and died. But of earlier types of life than these only scanty traces have yet been found. By degrees, however, groups of sedimentary rocks are coming to be recognized in many different parts of the world below the *Olenellus* zone, which are not unlikely eventually to yield up some more definite relics of primeval life. In Europe the most complete and most unmistakable series of pre-Cambrian formations is developed in the north-west of Scotland and in Scandinavia. In North America pre-Cambrian rocks have been largely studied in recent years, and are now known to have a wide extent, vast thickness, and great variety. It will suffice to give here some account of the Scottish and the American groups.

In the west of the counties of Sutherland and Ross certain thick dolomites and limestones containing Upper Cambrian and possibly Lower Silurian fossils pass downwards into dolomitic shales and sandstones, with bands of rusty dolomite. These shales, besides being crowded with worm-castings, contain *Olenellus*, and thus mark the generally accepted base of the Cambrian system. They lie conformably, however, upon, and are closely linked with, white and pink quartzites, from 400 to 600 feet thick, which in some of their bands are crowded with worm-burrows and casts. This arenaceous series, terminating downwards in a conglomeratic base and lying unconformably on the rocks below, must clearly be regarded as part of the Cambrian system, though it lies below the lowest horizon in which *Olenellus* has yet been detected. Doubtless the quartz-sand, which is now represented by quartzite, did not afford a suitable habitat for trilobite life. If a band of shale or dolomite were met with in the quartzite, it might be expected to yield specimens of the distinctive crustacean.

Below the bottom of the quartzites of the north-west of Scotland lies a series of far more ancient rocks. They are separated from the Cambrian series by an important unconformability which must represent a vast interval of time. They thus constitute a true pre-Cambrian series, and bring before us the very beginnings of geological history in the west of Europe. They include two distinct assemblages of rock. Of these the lower and older consists of gneiss and other crystalline masses, while the upper and younger is composed of a thick mass of red sandstones, shales, and conglomerates. Between these two formations there is again a violent unconformability which must mark the passing of an enormous interval of time. The older rocks had already acquired their present crystalline structures and arrangement before the younger sediments were derived from their waste and were laid down upon them. Thus while the deposition of these sediments is shown to belong to a period vastly more remote than the Cambrian, the formation of the underlying crystalline rocks is pushed back into an inconceivably more distant past. Two widely separated periods of pre-Cambrian time can consequently be recognized in the north-west of Scotland. The oldest of these is known as Lewisian, the second as Torridonian.

Lewisian.—The rocks which contain the records of this earliest stage in the geological evolution of western Europe are well developed in the island of Lewis; hence the name that has been locally applied to them. What are no doubt the same formations cover wide areas in Scandinavia, where they are known as *urberget*, or primeval rocks. Similar masses reappear in various parts of Europe, repeating the same lithological types, though it cannot always be safely affirmed that they are the true stratigraphical equivalents of the crystalline rocks of the north-west. Again, in Canada and the United States vast tracts of country are occupied by rocks having the same general characters. As a comprehensive designation to embrace all these most ancient rocks the term Archæan is commonly used. But we have at present no means of deciding how far the rocks so designated in one country really belong to the same interval of geological time as those so designated elsewhere. It has been discovered, indeed, that what had been called Archæan formations in some countries are really of Palæozoic age. Hence there is a certain convenience in the use meanwhile of local names for the types of rock met with in widely separated regions. Such names remain appropriate and useful, even if we have to shift their stratigraphical position backwards or forwards.

The Lewisian rocks of north-west Scotland comprise a series of crystalline gneisses, the great majority of which are undoubtedly of igneous origin, but in one or two districts include what are probably highly metamorphosed sediments. Here and there among the crystalline gneisses there occur tracts which have more or less completely escaped deformation and wherein the materials are seen to consist of such perfectly recognizable rocks as in younger portions of the terrestrial crust are admitted to be deep-seated intrusions of igneous material. These comparatively uncrushed rocks are often highly basic, for they include gabbros, peridotites, picrites, pyroxene-granulites, and diorites. They occur as lenticular zones or belts, running for several hundred yards more or less parallel with the foliation of the gneiss, into which they graduate, and also as irregular patches about a quarter of a square mile in area. They are intersected by veins of gray pegmatite consisting mainly of quartz and felspar. These tracts may represent the original condition of the gneisses of the surrounding region. Judging from analogy, we may suppose them to be remnants of eruptive masses which were injected into the primeval crust of the earth and solidified there at some depth below the surface. They have in many respects their counterparts among the deeper-seated intrusions that have invaded the various stratified formations up even to those of Tertiary age. They obviously consist of at least two groups of intrusive material—an older and more abundant series of basic masses which seem to have risen in extensive bosses, and a later set of acid injections. Whether any of these eruptive materials were connected with superficial discharges remains unknown. They are not essentially different from the masses that are found about the roots of ancient volcanoes. But no trace of any lavas or tuffs in association with them has yet been discovered. For a long time nothing had been detected to show the nature of that part of the terrestrial crust into which these primeval injections had made their way. Obviously they were not themselves masses that had congealed above ground, so that all speculations about their representing a former terrestrial surface were wholly inadmissible. Eventually, however, the officers of the Geological Survey found a group of rocks which may be a portion of the overlying crust in and beneath which the eruptive masses consolidated. These rocks, seen at Loch Maree, Loch Carron, and Glenelg, comprise mica-schists, graphitic schists, and limestones, probably the remnants of a series of sedimentary formations, and if so, perhaps the oldest yet met with in Europe. The relations of the gneisses and other crystalline rocks to this presumably sedimentary series are somewhat obscure. We may believe, however, that the eruptive masses have been injected into the schists and limestones, and have been the cause of the development of new minerals in the calcareous bands, and of other changes suggestive of contact-metamorphism.

At some time subsequent to the intrusion of the acid pegmatite veins, the rocks were subjected to powerful tangential pressures, whereby they were crushed and sheared so as to acquire a foliated structure. The basic masses became rudely foliated gneisses, in which plagioclase felspar, augite, diallage, hornblende, quartz, and magnetite are the predominant minerals, while the acid pegmatites became gray acid gneisses composed mainly of opalescent quartz and felspar. The dip of the foliation-planes of these rocks is usually at gentle angles. The gradation of the non-foliated igneous rocks into the coarse gneisses can often be traced, and it can be seen that in some cases the foliation passes across the junction lines between the two varieties of original rock. How far there may have been bands of segregation in the eruptive bosses, like those, for instance, in the Tertiary gabbros of Skye, has not at present been determined. But it is quite possible that some at least of the bands of different mineral constitution, such as those of hornblende or pyroxene and felspar, may belong to the original igneous magma, and not to the time of the foliation. This much may at least be confidently affirmed—what has been called "the fundamental complex" of the Lewisian rocks has been formed out of eruptive basic materials and the pegmatites introduced into them prior to the first foliation.

But the igneous history does not end here. After the movements that converted so much of the eruptive masses into coarse gneisses, and possibly after an enormous interval of unrecorded time, another series of igneous injections took place. A remarkable succession of dykes, of different petrographical characters, invaded the older masses. The most striking of these are the dykes of dolerite and basalt which follow each other in great numbers, having a general north-westerly trend, and running for long distances, sometimes for ten or twelve miles, from the coast-line inland, until they pass under the Torridonian sandstones. These intrusions present many of the familiar features of the dykes of much later periods. They obviously rose in fissures that had been opened in rocks already cold, for they present the characteristic close-grained or "chilled" margins. After their uprise, a second group of dykes was injected along fissures which ran in a nearly east and west direction. The material of these intrusions consists of peridotites and palæo-picrites, and as they cut the dolerites they are obviously of later date. What length of interval separated these successive up-wellings of molten material in the terrestrial crust must be matter merely for speculation. Some considerable lapse of time may possibly have followed the appearance of the ultra-basic dykes before a third and decidedly acid group was erupted. Numerous instances have now, however, been observed of a close connexion between granite cores and highly basic peripheral parts of large intrusive bosses. The magma from which such bosses were fed included both acid and basic parts, rising together, but the latter tending to gather towards the outside, while the more voluminous acid body occupied the centre. There may therefore have been a closer genetic relation than might at first be supposed between the palæo-picrites and peridotites of the second series of dykes and the granites and pegmatites of the third series. This third system of dykes has a general trend towards west-north-west. Its members attain far larger proportions than their predecessors in the other two series, for they sometimes come together so as to form bands more than 500 yards wide. An interesting parallel presents itself between these various igneous protrusions and those of later geological ages, especially the Tertiary volcanic series of the Inner Hebrides and Antrim. In both cases there are large protrusions of basic material. In the younger example, among the Inner Hebrides, this material has been arranged in bands of different composition according to the original disposition of a heterogeneous magma; in the older a somewhat similar structure may be partly attributable to the same cause, though subsequent foliation has in some measure obscured its history. The system of basic and acid dykes ranging towards west and north-west is strikingly alike in the operations of two geological periods so infinitely remote from each other. Again, the order of appearance of the igneous materials has followed the same sequence in each case; the basic intrusions came first, and the acid last.

After these various groups of eruptive rock had been successively injected, the crust of the earth in the north-west of Scotland, under another series of powerful stresses, was ruptured by thrust-planes and also by more vertical lines of crushing or shearing. Of these dislocations, the officers of the Geological Survey have distinguished three series; one which runs more or less nearly parallel with the basalt and dolerite dykes, one trending nearly east and west, and one which stretches north-east and south-west, or north and south. The first two series are much the most important, and have effected some remarkable transformations both on the dykes and on the gneiss. Where the north-western lines of movement are more or less parallel with the trend of the basic dykes, the dolerites are changed into diorites, without the development of foliation, but where one of these lines runs along the margin of a dyke, or where several of them traverse it along its length, the basic rock passes into true hornblende-schist. Lenticles or eyes of uncrushed diorite may be traced, round which the more crushed parts have moved and have assumed the schistose condition. The more basic materials (peridotites, &c.) in the same circumstances have been crushed into soft talcose schists, while the granite of the dykes has been converted into granitoid gneiss. The vertical east and west lines of movement have had the effect of wrenching the rocks out of their normal course, sometimes for nearly a mile. Dykes fifty or sixty yards broad are crushed and drawn out in these lines, till they are reduced to a width of no more than four feet, while sometimes they are still further attenuated into detached lenticles enclosed in crushed and reconstructed gneiss. Not less decided have been the effects of these lines of movement upon the gneiss. As this rock approaches one of them, its usually gentle inclination becomes steep and the foliation planes are thrown into sharp folds. The folia are drawn out, and sometimes their component minerals are rearranged parallel to those in the hornblende-schist of the adjacent dykes, so that a secondary foliation has been superinduced. There has likewise been a mineralogical reconstitution of the materials of the gneiss; the original blue opalescent quartz has been drawn out and in large part changed into the ordinary clear vitreous variety, black mica has been formed out of the hornblende, and white mica out of the felspar, while the hornblende has in part been re-crystallized in needles of actinolite, and new or secondary felspar has been plentifully developed. Lastly, the gneiss has been ruptured by crush-lines and shear-planes, some of which have given rise in one place to coarse breccia, in another to thin schistose bands.

The newer foliation superinduced by these later movements has affected considerable areas of the gneiss. It sometimes entirely obliterates the earlier structure of the rock, but where not so well developed it may be seen crossing the bands of that structure, so that the gneiss then presents the curious result of a double foliation. The gentle arches and troughs of the first foliation, striking north-east and south-west, have been replaced by sharp folds which, according to the trend of the later movements, vary from west to north-west. In this way the original massive or igneous structure has been so profoundly modified, and over such extensive tracts, that it has survived only here and there in comparatively limited parts of the region. All the geological changes now described—the initial uprise of the first basic bosses, the long sequence of igneous invasions, and the successive movements of the crust that produced the first and subsequent foliation—took place long before the Torridonian rocks began to be formed. It is obvious that not only the intrusion of the igneous masses, but their subsequent conversion into gneisses and schists, could not have been effected save under the pressure of a considerable depth of overlying rock. We have no means of telling what was the nature or the thickness of that superjacent cover. It had been completely removed by denudation before the earliest of the surviving Torridonian sediments began to be laid down. From the pebbles in these sediments we may form vague conjectures as to the character of the rocks that have disappeared, but there is no proof that these pebbles actually came from the rocks under which the Lewisian gneiss received its complex structure. They may belong to some much younger era. They include pieces of gneiss, jasper, chert, quartzite, quartz-schist, mica-schist, and felsite. The quartzites are altered gray, buff, red, or liver-coloured sandstones. The cherts are usually black or yellow, which resemble those met with among sedimentary deposits; they have been searched for *Radiolaria*, but hitherto without success. The felsites are dark purplish compact rocks with a spherulitic, micro-pegmatitic, micro-poikilitic, or micro-crystalline ground-mass, in which are scattered porphyritic crystals of felspar, often oligoclase. The spherulitic varieties show occasional traces of perlitic structure.[1]

Torridonian.—It is impossible to form any conjecture as to the chronological value of the interval between the close of the Lewisian and the opening of the Torridonian periods in the geological history of the north-west of Scotland. All we can say regarding it is that, even when compared with other geological intervals, it must have been of enormous duration. A great thickness of rock was removed by denudation, and the Lewisian gneiss was exposed to the air. Some fragments of the land-surface thus carved out have been preserved under the Torridonian sediments, and have a singular interest as relics of the earliest known land in Europe. They show the surface of that land to have been in some parts as uneven as that of the Highlands of the present day. There were mountains at least 3000 feet high, separated by wide valleys from other ridges. The ground was worn down into rounded crags and rocky domes on which the gneiss and its dykes stood up bare to the sun and wind. This ancient topography may be traced among the wild group of mountains between Loch Marce and Loch Broom. It appears behind the hill of Queenaig in Assynt, and it comes out impressively along the south side of Loch Torridon. That it has been preserved is due to the deep mass of sediment under which it sank and was buried. This sedimentary accumulation is known as Torridonian from its large development in the district around Loch Torridon, on the west coast of Ross-shire. It has been subdivided by the Geological Survey into the following groups of strata in descending order :—

4. Cailleach Head group (1000 to 1500 feet thick) of sandstones, flags, dark and black shales, and calcareous bands.
3. Aultbea group (2000 to 3000 feet) of chocolate-coloured and red sandstones and flags, and gray micaceous flags, with partings of gray, green, and dark shale.
2. Applecross group (4000 to 5000 feet) of coarse arkose, with pebbles of gneiss, quartzite, quartz-schist, felsite, jasper, &c.
1. Diabeg group (500 feet and upwards, much thicker in Skye). Hard red sandstones and grits, gray graywackes, red mudstones, dark gray and black shales, limestones and calcareous bands, with, at the base, green epidotic grits, and in some places a band of conglomerate resting on the gneiss.

Where most fully developed the series of sediments exceeds 10,000 feet in thickness. It forms some of the most conspicuous and most peculiarly shaped mountains in Sutherland and Ross-shire, rising into pyramids and cones, the sides of which have been scarped into precipices and scooped out into cauldron-shaped corries. The nearly level stratification gives a singularly architectural aspect to these huge masses of reddish-brown bare rock, and affords to the eye a ready means of appreciating how potently the forces of denudation have been concerned in developing the present scenery of the region. Several features of interest are presented by this thick mass of sedimentary deposits. The well-rounded pebbles, the regular layers of alternating detritus, the intercalation of coarse and fine materials, the lamination of the shales, the intercalation of calcareous bands and limestones, towards both the top and the bottom of the series, indicate conditions of sedimentation in no respect different from those of Palæozoic and later times. There are no traces of the violent action which, as some physicists have maintained, should have been characteristic of the earliest geological ages. On the contrary, not only do the layers of sediment succeed each other as they do in any series of similar materials in other and later portions of the geological record, but down even to minute details we see examples of the gentle sifting operations of tidal, fluviatile, or lacustrine waters. Thin dark laminæ may be noticed intercalated among the paler grits and sandstones, and these on examination prove to consist mainly of magnetic iron ore and other heavy minerals which, as above remarked, have been sorted out by the currents from the lighter quartzose or felspathic sand, precisely as

[1] *Annual Report of Geological Survey* for 1895, p. 21.

grains of similar ore are gathered together by the tides and strewn as a thin layer above the quartz-sand of the beaches of to-day.

No break or unconformability has been detected in any part of this thick mass of stratified deposits. But owing to the remarkably uneven surface of gneiss on which the sediments were laid down, they are continually overlapping each other, so that different members of the series come to lie directly on the older rock. They were probably accumulated in a lake or inland sea, the floor of which was gradually sinking. As the hills and valleys were successively submerged, they were buried under a pile of sediment. The actual shore-line during this time of subsidence can be followed up the side of a mountain, and the geologist may stand with one foot on the gneiss which formed the dry land and the other on the consolidated gravel which was accumulated by the water. Some of this material is excessively coarse, passing indeed into boulder-beds that remind one of the boulder-clay of the Ice Age, or the moraines of the present day. Indeed, some of the rounded contours of gneiss as they pass under the Torridon sandstone, taken together with these overlying masses of boulders, are suggestive of ice action, though it is difficult to suppose that in these remote ages terrestrial climates had become so far differentiated as to include frost, snow, and ice even down to the 57th parallel of north latitude. So regular is the sedimentation of the Torridonian rocks, and so precisely similar to that of Palæozoic formations, that there seems no reason why fossils should not be looked for and found in these ancient strata. The most likely parts of the series, particularly the shales and the calcareous bands, have been carefully searched by the Geological Survey, but hitherto with only scant success. Various markings have been found which are not impossibly those made by annelids. Certain curious spicular bodies, partly filled with calcite and partly existing as empty casts in the shale, have likewise been obtained, but though they bear some resemblance to magnified sponge spicules, it is by no means certain that they are of organic origin. Quite recently renewed search has been rewarded by the discovery of a number of flattened nodules of dark compact material in the shales, which prove to be phosphatic. It may be suspected that the phosphate of lime in these aggregations was probably derived from organisms. The shells of *Lingula* and the tests of trilobites and other organisms have supplied materials for phosphatic nodules and layers among the older Palæozoic rocks, and possibly some such organisms have been concerned in the formation of the nodules in the Torridonian shales. A thin slice of one of the nodules placed under a microscope reveals numbers of thread-like fibres, not improbably of vegetable origin, together with aggregates of what appear to be cells, as if some kind of plant had been macerated and broken up into shreds. But this subject is still under investigation, and more definite information may before long be obtained in regard to it.[1]

Pre-Cambrian Rocks of North America.—In Canada and the United States, from below the lowest Cambrian strata, a vast mass of rocks emerges presenting a close parallel to those of Scotland, but with an ampler development and over a far wider region. It consists of two contrasted groups, the Archæan below and the Proterozoic or Algonkian above. It is most copiously represented in the Lake Superior region, where some of its members were studied long ago by Logan, the pioneer in this branch of geology. The Archæan division of that region consists of massive and gneissoid granites, massive and foliated syenites, gabbros and peridotites, and finely laminated or banded gneiss and schists. None of these rocks have been proved to be of sedimentary origin. The great majority, and probably the whole, are igneous masses of deep-seated origin which have had a more or less distinctly foliated structure imparted to them by great mechanical movements within the crust of the earth. But there are proofs that they belong to different periods of intrusion. Thus the massive granites, which show little or no trace of orogenic movements, are of comparatively late date. In short, the geological history of the "basement complex" of Canada and the neighbouring United States appears to have been broadly similar to that of the Lewisian equivalent in Scotland. Between the Archæan gneiss and the base of the Cambrian system, however, a far more copious stratigraphical series exists in the Lake Superior region than in Scotland. No fewer than three distinct divisions have been determined, each of ample dimensions and great variety, and separated from one another by unconformabilities that probably mark protracted intervals of time. These strata form a vast succession of sedimentary deposits with igneous intercalations. They have been grouped together under the general name of Proterozoic or Algonkian. In ascending order they consist of (1) Lower Huronian, (2) Upper Huronian, (3) Keweenawan.

1. The Lower Huronian (Keewatin) series, about 5000 feet thick, varies considerably in general character as it passes from district to district. It everywhere rests with a strong unconformability upon the gneiss, which must have undergone great denudation before the lowest Huronian sediments began to be laid down upon it. These lowest sediments are conglomerates or quartzites covered by dolomites, sometimes 1000 feet thick. The dolomites pass under slates and quartzites among which an important group of acid and basic volcanic rocks is intercalated. The uppermost subdivision consists of iron ores (siderite, hæmatitic slates), cherts, and jaspers, and in the Lower Marquette district ranges from 1000 to 1500 feet in thickness. The iron-carbonates suggest an organic origin, and possibly the cherts and jaspers may have been aggregated by marine organisms, like the cherts of the Cambrian, Lower Silurian, and Carboniferous formations, and the flints of the Chalk. After the Lower Huronian rocks were accumulated, they suffered from earth-movements by which they were folded, and even, in many places, violently plicated. Raised above sea-level, they underwent prolonged exposure and denudation before the next member of the series was deposited. So vast was this interval that it appears to have sufficed for the local removal of the whole depth of the Lower Huronian rocks and the erosion of part of the platform of gneiss below.

2. The Upper Huronian series rests with complete unconformability on everything older than itself. Where typically developed, in the Penokee district, it consists of three subdivisions. At the base comes a quartz-slate group, about 500 feet thick, with a conglomerate at the bottom and a persistent band of quartzite at the top. The central formation, about 800 feet thick, consists of cherty iron-carbonate, ferruginous slates and cherts, and actinolitic and magnetitic slates. The upper subdivision is stated to attain the enormous thickness of 12,000 feet. It consists of sedimentary material, ranging from clay-slate through graywacke and graywacke-slate to mica-slate. Possibly part of the great apparent thickness of the Upper Huronian series in this district is due to the masses of diabase that have been injected into it. The deposition of this subdivision was followed by another period of disturbance, during which the rocks were tilted, plicated, and raised above the sea. So great were the effects of the movements

[1] See J. J. H. Teall in *Summary of Progress of the Geological Survey* for 1899.

that the rocks here and there acquired foliated structures, and were transformed into schists and gneisses. Prolonged and gigantic denudation followed the upheaval. In some places the whole of the vast thickness of the series was eroded down to the underlying rocks before the next series began to be deposited.

3. The Keweenawan series is in large measure of volcanic origin. It attains far vaster dimensions than either of the other divisions of the Algonkian rocks; indeed, it is stated to attain in some places the hardly credible thickness of 50,000 feet. As most of the series consists of igneous rock, it might have been accumulated in a comparatively short time. The local character of its extravasation seems to be indicated by the fact that it rapidly dies out in particular directions. It is divisible into three members—(*a*) a lower mass of gabbros; (*b*) a vast succession of great sheets of basic and acid lavas comparable to the extensive basalt-fields of the Far West. With these rocks are intercalated sandstones and conglomerates, chiefly derived from the waste of the lavas on which they lie; (*c*) a group of sandstones and conglomerates, mainly made up of the detritus of the igneous rocks below. Again, the accumulation of a division of the Algonkian rocks was followed by terrestrial disturbance, by the elevation of the Keweenawan lavas and sediments, and by extensive denudation. Another prolonged interval ensued, during which what may have been lofty mountains were worn down to mere stumps. It was after this interval that the Cambrian system of North America commenced to be formed.[1]

In other portions of North America various different types of pre-Cambrian rocks have been discovered, but they generally consist of a sedimentary series resting upon gneiss. In some places they have yielded a few fossils. Thus in south-eastern Nova Scotia, from a mass of slates, schists, and conglomerates, the obscure form called *Eophyton* has been obtained. In Newfoundland, below the *Olenellus* zone at the base of the Cambrian system, lies unconformably a series of quartzites, sandstones, conglomerates, and slates more than 11,000 feet thick, in which two fossils, *Aspidella terranovica* and *Arenicolites spiralis*, have been found. Far to the west, in the Grand Cañon of the Colorado, two great groups of sedimentary strata, having a united thickness of nearly 12,000 feet, are covered unconformably by Middle Cambrian rocks. They have yielded a larger fauna, including a minute discinoid or patellinoid shell, a small lingula-like shell, a fragment of what appears to be a trilobite, and a *Stromatopora*-like form, probably organic. It is much to be desired that some more fossiliferous bands may be discovered among pre-Cambrian rocks. The definite progress that has been made in the investigation of this subject during the last few years encourages the hope that further and greater success will before long reward persistent search.

Zonal Stratigraphy.—The most prominent feature in the general progress of combined stratigraphical and palæontological research during the last quarter of the 19th century has been the wide extension of the principle of palæontological zones in the subdivision of the geological formations, and in their correlation in different countries. This principle was only a further development of William Smith's famous idea, "Strata identified by Organized Fossils." Several years ago it was carried out in much detail by various palæontologists in reference to the Jurassic formations, notably by Quenstedt and Oppel in Germany and D'Orbigny in France. The publication of Oppel's classic work *Die Juraformation Englands, Frankreichs und des südwestlichen Deutschlands* (1856–58) marked an epoch in the development of stratigraphical geology. Combining what had been done by various observers with his own laborious researches in France, England, Würtemberg, and Bavaria, he drew up a classification of the Jurassic system, grouping its several formations into zones, each characterized by some distinctly predominant fossil after which it was named. Thus the Lower Lias was subdivided by him into zones which received the following names: (1) Planorbis-bed, zone of *Ammonites planorbis;* (2) Angulatus-bed, zone of *Amm. angulatus;* (3) Bucklandi-bed, zone of *Amm. Bucklandi;* (4) Tuberculatus-bed, zone of *Pentacrinus tuberculatus;* (5) Obtusus-bed, zone of *Amm. obtusus;* (6) Oxynotus-bed, zone of *Amm. oxynotus;* (7) Raricostatus-bed, zone of *Amm. raricostatus.* Oppel had spent several years among the Swabian Jurassic rocks during his student days at Tübingen and Stuttgart. He had passed seven months in France, partly among the collections in Paris, partly making himself familiar with the localities in the field. In the same way he had devoted four summer months to the classic grounds of the Lias and Oolites of England. He had thus convinced himself that, all over the western half of Europe, the several zones which he had distinguished held their place. His results were speedily confirmed and his classification was adopted by geologists and palæontologists both on the Continent and in England. The method followed by him was eventually applied with success to other portions of the Mesozoic formations. Notably was this the case with regard to the Cretaceous system, which in France, through the labours of D'Orbigny, Hébert, and others, was partitioned not only into more or less definitely marked formations, but also into zones characterized by one or more distinctive species of organism. Thus the whole of the Mesozoic division of the geological record has been subdivided into fossil zones from the Trias up to the top of the Chalk.

Within undefined and no doubt variable geographical limits, these zones have been found to be remarkably persistent. They follow each other in the same general order, but not always with equal definiteness. The type fossil sometimes appears on a higher or a lower platform than it does elsewhere. Only to a limited degree is there any coincidence between lithological variations in the strata and the sequence of the fossil zones. In the Jurassic formations, indeed, where frequent alternations of different sedimentary materials are to be met with, it is in some cases possible to trace a definite upward or downward limit for a zone by some abrupt change in the sedimentation, such as from limestone to shale. But such a precise demarcation is impossible where no distinct bands of different sediment are to be seen. The fossil zones can then only be vaguely determined by finding their characteristic fossils, and noting where these begin to appear in the strata and where they cease. It would seem, therefore, that the sequence of fossil-zones or life-horizons has not depended merely upon changes in the nature of the conditions under which the organisms lived. We should naturally expect that these changes must have had a marked influence; that, for instance, a difference should be perceptible between the character of the fossils in a limestone and that of those in a shale or a sandstone. The environment when a limestone was in course of deposition would generally be one of clear water favourable for a more vigorous and more varied fauna than one where a shale series was accumulating, for then the water must have been discoloured, and only such animals would continue living in it or on the bottom as could maintain themselves in the midst of mud. But no such lithological reason, betokening geographical changes that would affect living creatures, can be adduced as a universally applicable explanation of the occurrence and

[1] For a useful summary of the state of our knowledge regarding the pre-Cambrian rocks of North America, see a memoir by Mr Charles R. van Hise in the *16th Annual Report U.S. Geol. Survey*, Part I., 1896.

limitation of palæontological zones. One of these zones may be only a few inches or feet or yards in vertical extent, and no obvious cause can be seen why its specially characteristic fossils should not be found just as frequently in the similar strata above and below. There is often little or no evidence of any serious change in the conditions of sedimentation, still less of any widespread physical disturbance, such as the catastrophes by which the older geologists explained the extinction of successive types of life. It has been suggested that, where the life-zones are well defined, sedimentation has been extremely slow, and that though these zones follow each other with no break in the sedimentation, they were really separated by prolonged intervals of time during which organic evolution could come effectively into play. But it is difficult to see how, for example in the Lower Lias, there could have been a succession of prodigious intervals when practically no sediment was laid down, and yet that the strata should show no sign of contemporaneous disturbance, but succeed each other as if they had been accumulated by one continuous process of deposit. It must be admitted that the problem of life-zones in stratigraphical geology has not yet been solved.

The principle of zonal classification has been extended into the investigation of the Palæozoic formations, though on the whole it has been less fully applied there than among the Mesozoic systems. Possibly when it is extended in the same detailed and patient way to the older rocks, it may be found not less useful in their elucidation. The Carboniferous Limestone of Great Britain, for instance, would be an excellent field for the application of the method of zonal classification. It is a thick mass of calcareous material almost entirely composed of organisms. We know that certain species range throughout its whole extent from bottom to top, but we have still to learn whether it can be subdivided into platforms, each characterized by the presence of some distinctive forms of life that are absent or much less frequent on platforms above or below. The most successful use of this method among the Palæozoic rocks has been made by Professor Lapworth among the Silurian formations. He has found that the species of graptolite have each a comparatively narrow vertical range, and that they may consequently be used for stratigraphical purposes. Applying the method, in the first instance, to the highly plicated Silurian rocks of the south of Scotland, he found that by means of graptolites he was able to work out the structure of the ground. Each great group of strata was seen to possess its own graptolitic zones, and by their means could be identified not only in the original complex Scottish area, but in England and Wales and in Ireland. It was eventually ascertained that the succession of zones determined to exist in Great Britain could be recognized on the Continent, in North America, and even in Australia. The brachiopods and trilobites have likewise been made use of for zonal purposes among the oldest sedimentary formations. The most ancient of the Palæozoic systems has as its fitting base the *Olenellus* zone. It is doubtless in the further application of zonal stratigraphy that the next important advances will be made in the detailed investigation of fossiliferous formations, and of the history of organic life upon the Earth. (A. GE.)

Geometrical Continuity.—In a report of the Institute prefixed to Poncelet's *Traité des propriétés projectives des figures* (Paris, 1822), it is said that he employed "ce qu'il appelle le *principe de continuité*." The law or principle thus named by him had, he tells us, been tacitly assumed as axiomatic by "les plus savans géomètres." It had been enunciated under another name by Kepler in cap. iv. 4 of his *Ad Vitellionem Paralipomena quibus Astronomiæ Pars Optica traditur* (Francofurti, 1604). Of sections of the cone, he says, there are five species from the "recta linea" or line-pair to the circle. From the line-pair we pass through an infinity of hyperbolas to the parabola, and thence through an infinity of ellipses to the circle. Related to the sections are certain remarkable points which have no name. Kepler calls them foci. The circle has one focus at the centre, an ellipse or hyperbola two foci equidistant from the centre. The parabola has one focus within it, and another, the "cæcus focus," which may be imagined to be *at infinity* on the axis *within or without the curve.* The line from it to any point of the section is parallel to the axis. To carry out the analogy we must speak paradoxically, and say that the line-pair likewise has foci, which in this case coalesce as in the circle and fall upon the lines themselves; for our geometrical terms should be subject to analogy. Kepler dearly loves analogies, his most trusty teachers, and intimate with all the secrets of nature, "*omnium naturæ arcanorum conscios.*" And they are to be especially regarded in geometry as, by the use of "however absurd expressions," classing extreme limiting forms with an infinity of intermediate cases, and placing the whole essence of a thing clearly before the eyes.

Here, then, we find formulated by Kepler the doctrine of the concurrence of parallels at a single point at infinity and the principle of continuity (under the name analogy) in relation to the infinitely great. Such conceptions so strikingly propounded in a famous work could not escape the notice of contemporary mathematicians. Henry Briggs, in a letter to Kepler from Merton College, Oxford, dated "10 Cal. Martiis 1625," suggests improvements in the *Ad Vitellionem Paralipomena*, and gives the following construction:—Draw a line CBADC, and let an ellipse, a parabola, and a hyperbola have B and A for focus and vertex. Let CC be the other foci of the ellipse and the hyperbola. Make AD equal to AB, and with centres CC and radius in each case equal to CD describe circles. Then any point of the ellipse is equidistant from the focus B and one circle, and any point of the hyperbola from the focus B and the other circle. Any point P of the parabola, in which the second focus is missing or infinitely distant, is equidistant from the focus B and the line through D, which we call the directrix, this taking the place of either circle when its centre C is at infinity, and every line CP being then parallel to the axis. Thus Briggs, and we know not how many "savans géomètres" who have left no record, had already taken up the new doctrine in geometry in its author's lifetime. Six years after Kepler's death in 1630 Girard Desargues, "the Monge of his age," brought out the first of his remarkable works founded on the same principles, a short tract entitled *Méthode Universelle de mettre en perspective les objets donnés réellement ou en devis* (Paris, 1636). Kepler as a modern geometer is best known by his *New Stereometry of Wine Casks* (Lincii, 1615), in which he replaces the circuitous Archimedean method of exhaustion by a direct "royal road" of infinitesimals, treating a vanishing arc as a straight line and regarding a curve as made up of a succession of short chords. Some 2000 years previously one Antipho, probably the well-known opponent of Socrates, had regarded a circle in like manner as the limiting form of a many-sided inscribed rectilinear figure. Antipho's notion was rejected by the men of his day as unsound, and when reproduced by Kepler it was again stoutly opposed as incapable of any sort of geometrical demonstration—not altogether without reason, for it rested on an assumed law of continuity rather than on palpable proof.

To complete the theory of continuity, the one thing needful was the idea of imaginary points implied in the algebraical geometry of Descartes, in which equations between variables representing co-ordinates were found often to have imaginary roots. Newton, in his two sections on "Inventio Orbium" (*Principia*, i. 4, 5), shows in his brief way that he is familiar with the principles of modern geometry. In two propositions he uses an auxiliary line which is supposed to cut the conic in X and Y, but, as he remarks at the end of the second (prop. 24), it may not cut it at all. For the sake of brevity he passes on at once with the observation that the required constructions are evident from the case in which the line cuts the trajectory. In the scholium appended to prop. 27, after saying that an asymptote is a tangent at infinity, he gives an unexplained general construction for the axes of a conic, which seems to imply that it has asymptotes. In all such cases, having equations to his loci in the background, he may have thought of elements of the figure as passing into the imaginary state in such manner as not to vitiate conclusions arrived at on the hypothesis of their reality.

Boscovich (1711–87), a careful student of Newton's works, has a full and thorough discussion of geometrical continuity at the end of his *Sectionum Conicarum Elementa*, his first principle being that all varieties of a defined locus have the same properties, so that what is demonstrable of one should be demonstrable in like manner of all, although some artifice may be required to bring out the underlying analogy between them. The opposite extremities of an infinite straight line, he says, are to be regarded as joined, as if the line were a circle having its centre at the infinity on either side of it. This leads up to the idea of a *veluti plus quam infinita extensio*, a line-circle containing, as we say, the line infinity. Change from the real to the imaginary state is contingent upon the passage of some element of a figure through zero or infinity, and never takes place *per saltum*. Lines being some positive and some negative, there must be negative rectangles and negative squares, such as those of the exterior diameters of a hyperbola. Boscovich's first principle was that of Kepler, by whose *quantumvis absurdis locutionibus* the boldest applications of it are covered, as when we say with Poncelet that all concentric circles in a plane touch one another in two imaginary fixed points at infinity. In G. K. Ch. von Staudt's *Geometrie der Lage* and *Beiträge zur G. der L.* (Nürnberg, 1847, 1856–60) the geometry of position, including the extension of the field of pure geometry to the infinite and the imaginary, is presented as an independent science, "welche des Messens nicht bedarf." (See GEOMETRY, PROJECTIVE, *Ency. Brit.*, 9th ed., vol. x.)

Ocular illusions due to distance, such as Roger Bacon notices in the *Opus Majus* (i. 126, ii. 108, 497; Oxford, 1897), lead up to or illustrate the mathematical uses of the infinite and its reciprocal the infinitesimal. Specious objections can, of course, be made to the anomalies of the law of continuity, but they are inherent in the higher geometry, which has taught us so much of the "secrets of nature." Kepler's excursus on the "analogy" between the conic sections hereinbefore referred to is given at length in an article on "The Geometry of Kepler and Newton" in vol. xviii. of the *Transactions of the Cambridge Philosophical Society* (1900). It had been generally overlooked, until attention was called to it by the present writer in a note read in 1880 (*Proc. C. P. S.* iv. 14–17), and shortly afterwards in *The Ancient and Modern Geometry of Conics, with Historical Notes and Prolegomena* (Cambridge, 1881). (C. T*.)

Geometry, Line, is the name applied to those geometrical investigations in which the straight line replaces the point as element. Just as ordinary geometry deals primarily with points and systems of points, this theory deals in the first instance with straight lines and systems of straight lines. In two dimensions there is no necessity for a special line geometry, inasmuch as the straight line and the point are interchangeable by the principle of duality; but in three dimensions the straight line is its own reciprocal, and for the better discussion of systems of lines we require some new apparatus, *e.g.*, a system of co-ordinates applicable to straight lines rather than to points. The essential features of the subject are most easily elucidated by analytical methods: we shall therefore begin with the notion of line co-ordinates, and in order to emphasize the merits of the system of co-ordinates ultimately adopted, we first notice a system without these advantages, but often useful in special investigations.

In ordinary Cartesian co-ordinates the two equations of a straight line may be reduced to the form $y=rx+s$, $z=tx+u$, and r, s, t, u may be regarded as the four co-ordinates of the line. These co-ordinates lack symmetry: moreover, in changing from one base of reference to another the transformation is not linear, so that the degree of an equation is deprived of real significance. For purposes of the general theory we employ homogeneous co-ordinates; if $x_1y_1z_1w_1$ and $x_2y_2z_2w_2$ are two points on the line, it is easily verified that the six determinants of the array

$$\begin{vmatrix} x_1y_1z_1w_1 \\ x_2y_2z_2w_2 \end{vmatrix}$$

are in the same ratios for all point-pairs on the line, and further, that when the point co-ordinates undergo a linear transformation so also do these six determinants. We therefore adopt these six determinants for the co-ordinates of the line, and express them by the symbols $l, \lambda, m, \mu, n, \nu$ where $l=x_1w_2-x_2w_1, \lambda=y_1z_2-y_2z_1$, &c. There is the further advantage that if $a_1b_1c_1d_1$ and $a_2b_2c_2d_2$ be two planes through the line, the six determinants

$$\begin{vmatrix} a_1b_1c_1d_1 \\ a_2b_2c_2d_2 \end{vmatrix}$$

are in the same ratios as the foregoing, so that except as regards a factor of proportionality we have $\lambda=b_1c_2-b_2c_1$, $l=c_1d_2-c_2d_1$, &c. The identical relation $l\lambda+m\mu+n\nu=0$ reduces the number of independent constants in the six co-ordinates to four, for we are only concerned with their mutual ratios; and the quadratic character of this relation marks an essential difference between point geometry and line geometry. For elementary analytical investigations cf. Cayley, "The Six Co-ordinates of a Line," *Camb. Phil. Trans.*, 1868, or *Collected Papers*, vol. v.; for example, the condition of intersection of two lines is

$$l\lambda'+l'\lambda+m\mu'+m'\mu+n\nu'+n'\nu=0$$

where the accented letters refer to the second line.

Since a line depends on four constants, there are three distinct types of configurations arising in line geometry—those containing a triply-infinite, a doubly-infinite, and a singly-infinite number of lines; they are called Complexes, Congruences, and Ruled Surfaces or Skews respectively (see SURFACES, THEORY OF). A *Complex* is thus a system of lines satisfying one condition—that is, the co-ordinates are connected by a single relation; and the degree of the complex is the degree of this equation supposing it to be algebraic. The lines of a complex of the nth degree which pass through any point lie on a cone of the nth degree, and those which lie in any plane envelop a curve of the nth class: there are n lines of the complex in any plane pencil, and this statement combines the former two, for it shows that the cone is of the nth degree and the curve is of the nth class. To find the lines common to four complexes of degrees n_1, n_2, n_3, n_4, we have to solve five equations, viz., the four complex equations together with the quadratic equation connecting the line co-ordinates, therefore the number of common lines is $2n_1n_2n_3n_4$. As an example of complexes we have the lines meeting a twisted curve of the nth degree, which form a complex of the nth degree.

A *Congruence* is the set of lines satisfying two conditions: thus a finite number m of the lines pass through any point, and a finite number n lie in any plane; these numbers are called the degree and class respectively, and the congruence is symbolically written (m, n). The simplest example of a congruence is the system of lines constituted by all those that pass through m points and those that lie in n planes; through any other point there pass m of these lines, and in any other plane there lie n, therefore the congruence is of degree m and class n. It has been shown by Halphen that the number of lines common to two congruences is $mm' + nn'$, which may be verified by taking one of them to be of this simple type. The lines meeting two fixed lines form the general (1, 1) congruence; and the chords of a twisted cubic form the general type of a (1, 3) congruence; Halphen's result shows that two twisted cubics have in general ten common chords. As regards the analytical treatment, the difficulty is of the same nature as that arising in the theory of curves in space, for a congruence is not in general the complete intersection of two complexes.

A *Ruled Surface*, *Regulus*, or *Skew* is a configuration of lines which satisfy three conditions, and therefore depend on only one parameter. Such lines all lie on a surface, for we cannot draw one through an arbitrary point; only one line passes through a point of the surface; the simplest example, that of a quadric surface, is really two skews on the same surface. The degree of a ruled surface *quâ* line geometry is the number of its generating lines contained in a linear complex. Now the number which meets a given line is the degree of the surface *quâ* point geometry, and as the lines meeting a given line form a particular case of linear complex, it follows that the degree is the same from whichever point of view we regard it. The lines common to three complexes of degrees, $n_1n_2n_3$, form a ruled surface of degree $2n_1n_2n_3$; but not every ruled surface is the complete intersection of three complexes.

Linear complex.

In the case of a complex of the first degree (or linear complex) the lines through a fixed point lie in a plane called the polar plane or nul-plane of that point, and those lying in a fixed plane pass through a point called the nul-point or pole of the plane. If the nul-plane of A pass through B, then the nul-plane of B will pass through A; the nul-planes of all points on one line l_1 pass through another line l_2. The relation between l_1 and l_2 is reciprocal; any line of the complex that meets one will also meet the other, and every line meeting both belongs to the complex. They are called conjugate or polar lines with respect to the complex. On these principles can be founded a theory of reciprocation with respect to a linear complex. This may be aptly illustrated by an elegant example due to Voss. Since a twisted cubic can be made to satisfy twelve conditions, it might be supposed that a finite number could be drawn to touch four given lines, but this is not the case. For, suppose one such can be drawn, then its reciprocal with respect to any linear complex containing the four lines is a curve of the third class, *i.e.*, another twisted cubic, touching the same four lines, which are unaltered in the process of reciprocation; as there is an infinite number of complexes containing the four lines, there is an infinite number of cubics touching the four lines, and the problem is porismatic.

The following are some geometrical constructions relating to the unique linear complex that can be drawn to contain five arbitrary lines. To construct the nul-plane of any point O, we observe that the two lines which meet any four of the given five are conjugate lines of the complex, and the line drawn through O to meet them is therefore a ray of the complex; similarly, by choosing another four we can find another ray through O: these rays lie in the nul-plane, and there is clearly a result involved that the five lines so obtained all lie in one plane. A reciprocal construction will enable us to find the nul-point of any plane. Proceeding now to the metrical properties and the statical and dynamical applications, we remark that there is just one line such that the nul-plane of any point on it is perpendicular to it. This is called the central axis; if d be the shortest distance, θ the angle between it and a ray of the complex, then $d \tan \theta = p$, where p is a constant called the pitch or parameter. Any system of forces can be reduced to a force R along a certain line, and a couple G perpendicular to that line; the lines of nul-moment for the system form a linear complex of which the given line is the central axis and the quotient G/R is the pitch. Any motion of a rigid body can be reduced to a screw motion about a certain line, *i.e.*, to an angular velocity ω about that line combined with a linear velocity u along the line. The plane drawn through any point perpendicular to the direction of its motion is its nul-plane with respect to a linear complex having this line for central axis, and the quotient u/ω for pitch (cf. Sir R. S. Ball, *Theory of Screws*).

The following are some properties of a configuration of two linear complexes. The lines common to the two complexes also belong to an infinite number of linear complexes, of which two reduce to single straight lines. These two lines are conjugate lines with respect to each of the complexes, but they may coincide, and then some simple modifications are required. The locus of the central axis of this system of complexes is a surface of the third degree called the cylindroid, which plays a leading part in the theory of screws as developed synthetically by Ball. Since a linear complex has an invariant of the second degree in its co-efficients, it follows that two linear complexes have a lineo-linear invariant. This invariant is fundamental: if the complexes be both straight lines, its vanishing is the condition of their intersection as given above; if only one of them be a straight line, its vanishing is the condition that this line should belong to the other complex. When it vanishes for any two complexes they are said to be in *involution*; the nul-points P, Q of any plane then divide harmonically the points in which the plane meets the common conjugate lines, and each complex is its own reciprocal with respect to the other. As regards a configuration of these linear complexes, the common lines from one system of generators of a quadric, and the doubly infinite system of complexes containing the common lines, include an infinite number of straight lines which form the other system of generators of the same quadric.

General line co-ordinates.

If the equation of a linear complex is $Al + Bm + Cn + D\lambda + E\mu + F\nu = 0$, then for a line not belonging to the complex we may regard the expression on the left-hand side as a multiple of the moment of the line with respect to the complex, the word moment being used in the statical sense; and we infer that when the co-ordinates are replaced by linear functions of themselves the new co-ordinates are multiples of the moments of the line with respect to six fixed complexes. The essential features of this co-ordinate system are the same as those of the original one, viz., there are six co-ordinates connected by a quadratic equation, but this relation has in general a different form. By suitable choice of the six fundamental complexes, as they may be called, this connecting relation may be brought into other simple forms of which we mention two: (i.) When the six are mutually in involution it can be reduced to $x_1^2+x_2^2+x_3^2+x_4^2+x_5^2+x_6^2=0$; (ii.) When the first four are in involution and the other two are the lines common to the first four it is $x_1^2+x_2^2+x_3^2+x_4^2-2x_5x_6=0$. These generalized co-ordinates might be explained without reference to actual magnitude, just as homogeneous point co-ordinates can be; the essential remark is that the equation of any co-ordinate to zero represents a linear complex, a point of view which includes our original system, for the equation of a co-ordinate to zero represents all the lines meeting an edge of the fundamental tetrahedron.

The system of co-ordinates referred to six complexes mutually in involution was introduced by Klein, and in many cases is more useful than that derived directly from point co-ordinates; *e.g.*, in the discussion of quadratic complexes: by means of it Klein has developed an analogy between line geometry and the geometry of spheres as treated by Darboux and others. In fact, in that geometry a point is represented by *five* co-ordinates, connected by a relation of the same type as the one just mentioned when the five fundamental spheres are mutually at right angles and the equation of a sphere is of the first degree. Extending this to four dimensions of space, we obtain an exact analogue of line geometry, in which (i.) a point corresponds to a line; (ii.) a linear complex to a hypersphere; (iii.) two linear complexes in involution to two orthogonal hyperspheres; (iv.) a linear complex and two conjugate lines to a hypersphere and two inverse points. Many results may be obtained by this principle, and more still are suggested by trying to extend the properties of circles to spheres in three and four dimensions. Thus the elementary theorem, that, given four lines, the circles circumscribed to the four triangles formed by them are concurrent, may be extended to six hyperplanes in four dimensions; and then we can derive a result in line geometry by translating the inverse of this theorem. Again, just as there is an infinite number of spheres touching a surface at a given point, two of them having contact of a closer nature, so there is an infinite number of linear complexes touching a non-linear complex at a given line, and *three* of these have contact of a closer nature (cf. Klein, *Math. Ann.* v.).

Lie has pointed out a different analogy with sphere geometry. Suppose, in fact, that the equation of a sphere of radius r is

$$x^2+y^2+z^2+2ax+2by+2cz+d=0,$$

so that $r^2=a^2+b^2+c^2-d$; then introducing the quantity e to make this equation homogeneous, we may regard the sphere as given by the six co-ordinates a, b, c, d, e, r connected by the equation $a^2+b^2+c^2-r^2-de=0$, and it is easy to see that two spheres touch if the polar form $2aa_1+2bb_1+2cc_1-2rr_1-de_1-d_1e$ vanishes. Comparing this with the equation $x_1^2+x_2^2+x_3^2+x_4^2-2x_5x_6=0$ given above, it appears that this sphere geometry and line geometry are identical, for we may write $a=x_1$, $b=x_2$, $c=x_3$, $r=x_4\sqrt{-1}$, $d=x_5$, $e=\frac{1}{2}x_6$; but it is to be noticed that a sphere is really replaced by two lines whose co-ordinates only differ in the sign of x_4, so that they are polar lines with respect to the complex $x_4=0$. Two spheres which touch correspond to two lines which intersect, or more accurately to two pairs of lines (p, p') and (q, q'), of which the pairs (p, q) and (p', q') both intersect. By this means the problem of describing a sphere to touch four given spheres is reduced to that of drawing a pair of lines (t, t') (of which t intersects one line of the four pairs (pp'), (qq'), (rr'), (ss'), and t' intersects the remaining four). We may, however, ignore the accented letters in translating theorems, for a configuration of lines and its polar with respect to a linear complex have the same projective properties. In Lie's transformation a linear complex corresponds to the totality of spheres cutting a given sphere at a given angle. A most remarkable result is that lines of curvature in the sphere geometry become asymptotic lines in the line geometry.

Some of the principles of line geometry may be brought into clearer light by admitting the ideas of space of four and five dimensions. Thus, regarding the co-ordinates of a line as homogeneous co-ordinates in five dimensions, we may say that line geometry is equivalent to geometry on a quadric surface in five dimensions. A linear complex is represented by a hyperplane section; and if two such complexes are in involution, the corresponding hyperplanes are conjugate with respect to the fundamental quadric. By projecting this quadric stereographically into space of four dimensions we obtain Klein's analogy. In the same way geometry in a linear complex is equivalent to geometry on a quadric in four dimensions; when two lines intersect the representative points are on the same generator of this quadric. Stereographic projection, therefore, converts a curve in a linear complex, *i.e.*, one whose tangents all belong to the complex, into one whose tangents intersect a fixed conic: when this conic is the imaginary circle at infinity the curve is what Lie calls a minimal curve. Curves in a linear complex have been extensively studied. The osculating plane at any point of such a curve is the nul-plane of the point with respect to the complex, and points of superosculation always coincide in pairs at the points of contact of stationary tangents. A rational curve of degree n in a linear complex has $2n-6$ stationary tangents; but conversely, when this is the case, the curve may not belong to a linear complex. Examples are afforded by the twisted cubic and the twisted quartic with two stationary tangents.

Non-linear complexes.

In giving an account of non-linear complexes we restrict the discussion mainly to the quadratic variety; comparatively little is known of those of higher degrees, and the known theorems do not differ essentially from those referring to the quadratic complex. The lines through a given point that belong to a complex of the nth degree lie on a cone of the nth degree: if this cone has a double line the point is said to be a singular point. Similarly, a plane is said to be singular when the envelope of the lines in it has a double tangent. It is very remarkable that the same surface is the locus of the singular points and the envelope of the singular planes: this surface is called the singular surface, and both its degree and class are in general $2n(n-1)^2$, which is equal to four for the quadratic complex. Following Plücker, we give an account of the lines of a quadratic complex that meet a given line. The cones whose vertices are on the given line all pass through eight fixed points and envelop a surface of the fourth degree; the conics whose planes contain the given line all lie on a surface of the fourth class and touch eight fixed planes. It is easy to see by elementary geometry that these two surfaces are identical. Further, the given line contains four singular points A_1, A_2, A_3, A_4, and the planes into which their cones degenerate are the eight common tangent planes mentioned above; similarly, there are four singular planes, a_1, a_2, a_3, a_4, through the line, and the eight points into which their conics degenerate are the eight common points above. The locus of the pole of the line with respect to all the conics in planes through it is a straight line called the *polar line* of the given one; and through this line passes the polar plane of the given line with respect to each of the cones. The name polar is applied in the ordinary analytical sense; any line has an infinite number of polar complexes with respect to the given complex, for the equation of the latter can be written in an infinite number of ways; one of these polars is a straight line, and is the polar line already introduced. The surface on which lie all the conics through a line l is called the Plücker surface of that line: from the known properties of (2, 2) correspondences it can be shown that the Plücker surface of l cuts l_1 in a range of the same cross ratio as that of the range in which the Plücker surface of l_1 cuts l. Applying this to the case in which l_1 is the polar of l, we find that the cross ratios of (A_1, A_2, A_3, A_4) and (a_1, a_2, a_3, a_4) are equal. The identity of the locus of the A's with the envelope of the a's follows at once; moreover, a line meets the singular surface in four points having the same cross ratio as that of the four tangent planes drawn through the line to touch the surface. The Plücker surface has eight nodes, eight singular tangent planes, and a double line, which have further properties. The relation between a line and its polar line is not a reciprocal one with respect to the complex; but Stahl has pointed out that the relation *is* reciprocal as far as the singular surface is concerned.

The singular lines of a complex $F=0$ are the lines common to F and the complex

$$\frac{\delta F}{\delta l}\frac{\delta F}{\delta \lambda}+\frac{\delta F}{\delta m}\frac{\delta F}{\delta \mu}+\frac{\delta F}{\delta n}\frac{\delta F}{\delta \nu}=0.$$

Singular lines. As already mentioned, at each line l of a complex there is an infinite number of tangent linear complexes, and they all contain the lines adjacent to l. If now l be a singular line, these complexes all reduce to straight lines which form a plane pencil containing the line l. Suppose the vertex of the pencil is A and its plane a, then it follows that the cone of any point on l touches a along l, and the curve of any plane through l touches l at A. Hence l is a double line for the cone of A and for the curve of a, so that A is a singular point and a is a singular plane. Conversely, a double line of a cone or curve is a singular line, and a singular line clearly touches the curves of all planes through it in the same point. This is the usual definition. Further, of the singular lines through A two coincide in l, and of those in a two coincide in l; and it follows almost at once that the locus of the A's coincides with the envelope of the a's, and forms part of the focal surface of the congruence of singular lines (see "Congruences," *infra*). Hence when a line touches a complex it touches the singular surface, for it belongs to a plane pencil like (Aa), and thus in Klein's analogy the analogue of a focus of a hypersurface being a bitangent line of the complex is also a bitangent line of the singular surface. The theory of cosingular complexes is thus brought into line with that of confocal surfaces in four dimensions, and guided by these principles the existence of cosingular quadratic complexes can easily be established, the analysis required being almost the same as that invented for confocal cyclides by Darboux and others. Of cosingular complexes of higher degree nothing is known.

To facilitate the discussion of the general quadratic complex we introduce Klein's canonical form. We have, in fact, to deal with two quadratic equations in six variables; and by suitable linear transformations these can be reduced to the form

$$a_1x_1^2+a_2x_2^2+a_3x_3^2+a_4x_4^2+a_5x_5^2+a_6x_6^2=0$$
$$x_1^2+x_2^2+x_3^2+x_4^2+x_5^2+x_6^2=0$$

subject to certain exceptions, which will be mentioned later.

Taking the first equation to be that of the complex, we remark that both equations are unaltered by changing the sign of any co-ordinate; the geometrical meaning of this is, that the quadratic complex is its own reciprocal with respect to each of the six fundamental complexes, for changing the sign of a co-ordinate is equivalent to taking the polar of a line with respect to the corresponding fundamental complex. It is easy to establish the existence of six systems of bitangent linear complexes, for the complex $l_1x_1+l_2x_2+l_3x_3+l_4x_4+l_5x_5+l_6x_6=0$ is a bitangent when

$$l_1=0, \text{ and } \frac{l_2^2}{a_2-a_1}+\frac{l_3^2}{a_3-a_1}+\frac{l_4^2}{a_4-a_1}+\frac{l_5^2}{a_5-a_1}+\frac{l_6^2}{a_6-a_1}=0,$$

and its lines of contact are conjugate lines with respect to the first fundamental complex. We therefore infer the existence of six systems of bitangent lines of the complex, of which the first is given by

$$x_1=0, \frac{x_2^2}{a_2-a_1}+\frac{x_3^2}{a_3-a_1}+\frac{x_4^2}{a_4-a_1}+\frac{x_5^2}{a_5-a_1}+\frac{x_6^2}{a_6-a_1}=0.$$

Each of these lines is a bitangent of the singular surface, which is therefore completely determined as being the focal surface of the (2, 2) congruence above. It is thence easy to verify that the two complexes $\Sigma ax^2=0$ and $\Sigma bx^2=0$ are cosingular if $b_r=\frac{a_r\lambda+\mu}{a_r\nu+\rho}$.

The singular surface of the general quadratic complex is the famous quartic, with sixteen nodes and sixteen singular tangent planes, first discovered by Kümmer. We cannot give a full account of its properties here, but we deduce at once from the above that its bitangents break up into six (2, 2) congruences, and the six linear complexes containing these are mutually in involution. The nodes of the singular surface are points whose complex cones are coincident planes, and the complex conic in a singular tangent plane consists of two coincident points. This configuration of sixteen points and planes has many interesting properties; thus each plane contains six points which lie on a conic, while through each point there pass six planes which touch a quadric cone. In many respects the Kümmer quartic plays a part in three dimensions analogous to the general quartic curve in two; it further gives a natural representation of certain relations between hyperelliptic functions.

Classification of quadratic complexes. As might be expected from the magnitude of a form in six variables, the number of projectively distinct varieties of quadratic complexes is very great; and in fact Weiler, by whom the question was first systematically studied on lines indicated by Klein, enumerated no fewer than forty-nine different types. But the principle of the classification is so important, and withal so simple, that we give a brief sketch which indicates its essential features. We have practically to study the intersection of two quadrics F and F′ in six variables, and to classify the different cases arising we make use of the results of Weierstrass on the equivalence conditions of two pairs of quadratics. As far as at present required, they are as follows:—Suppose that the factorized form of the determinantal equation Disct $(F+\lambda F')=0$ is

$$(\lambda-a)^{s_1+s_2+s_3\ldots}(\lambda-\beta)^{t_1+t_2+t_3+\ldots}\ldots$$

where the root a occurs $s_1+s_2+s_3\ldots$ times in the determinant, $s_2+s_3\ldots$ times in every first minor, $s_3+\ldots$ times in every second minor, and so on; the meaning of each exponent is then perfectly definite. Every factor of the type $(\lambda-a)^s$ is called an *elementartheil* (elementary divisor) of the determinant, and the condition of equivalence of two pairs of quadratics is simply that their determinants have the same elementary divisors. We write the pair of forms symbolically thus $[(s_1s_2\ldots), (t_1t_2\ldots), \ldots]$, letters in the inner brackets referring to the same factor. Returning now to the two quadratics representing the complex, the sum of the exponents will be six, and two complexes are put in the same class if they have the same symbolical expression; *i.e.*, the actual values of the roots of the determinantal equation need not be the same for both, but their manner of occurrence, as far as here indicated, must be identical in the two. The enumeration of all possible cases is thus reduced to a simple question in combinatorial analysis, and the actual study of any particular case is much facilitated by a useful rule of Klein's for writing down in a simple form two quadratics belonging to a given class—one of which, of course, represents the equation connecting line co-ordinates, and the other the equation of the complex. The general complex is naturally [111111]; the complex of tangents to a quadric is [(111), (111)] and that of lines meeting a conic is [(222)]. Full information will be found in Weiler's memoir, *Math. Ann.* vol. vii.

The detailed study of each variety of complex opens up a vast subject; we only mention two special cases, the harmonic complex and the tetrahedral complex. The harmonic complex, first studied by Battaglini, is generated in an infinite number of ways by the lines cutting two quadrics harmonically. Taking the most general case, and referring the quadrics to their common self-conjugate tetrahedron, we can find its equation in a simple form, and verify that this complex really depends only on seventeen constants, so that it is not the most general quadratic complex. It belongs to the general type in so far as it is discussed above, but the roots of the determinant are in involution. The singular surface is the "tetrahedroid" discussed by Cayley. As a particular case, from a metrical point of view, we have Painvin's complex generated by the lines of intersection of perpendicular tangent planes of a quadric, the singular surface now being Fresnel's wave surface. The tetrahedral or Reye complex is the simplest and best known of proper quadratic complexes. It is generated by the lines which cut the faces of a tetrahedron in a constant cross ratio, and therefore by those subtending the same cross ratio at the four vertices. The singular surface is made up of the faces or the vertices of the fundamental tetrahedron, and each edge of this tetrahedron is a double line of the complex. The complex was first discussed by Reye as the assemblage of lines joining corresponding points in a homographic transformation of space, and this point of view leads to many important and elegant properties. A (metrically) particular case of great interest is the complex generated by the normals to a family of confocal quadrics, and for many investigations it is convenient to deal with this complex referred to the principal axes. For example, Lie has developed the theory of curves in a Reye complex (*i.e.*, curves whose tangents belong to the complex) as solutions of a differential equation of the form $(b-c)xdydz+(c-a)ydzdx+(a-b)zdxdy=0$, and we can simplify this equation by a logarithmic transformation. Many theorems connecting complexes with differential equations have been given by Lie and his school. A line complex, in fact, corresponds to a Mongian equation having ∞^3 line integrals.

Congruences. As the co-ordinates of a line belonging to a congruence are functions of two independent parameters, the theory of congruences is analogous to that of surfaces, and we may regard it as a fundamental inquiry to find the simplest form of surface into which a given congruence can be transformed. Most of those whose properties have been extensively discussed can be represented on a plane by a birational transformation. But in addition to the difficulties of the theory of algebraic surfaces, a subject still in its infancy, the theory of congruences has other difficulties in that a congruence is seldom completely represented, even by two equations. A fundamental theorem is that the lines of a congruence are in general bitangents of a surface; in fact, since the condition of intersection of two consecutive straight lines is $ld\lambda+dmd\mu+dnd\nu=0$, a line l of the congruence meets two adjacent lines, say l_1 and l_2. Suppose l, l_1 lie in the plane pencil (A_1a_1) and l, l_2 in the plane pencil (A_2a_2), then the locus of the A's is the same as the envelope of the a's, but a_2 is the tangent plane at A_1 and a_1 at A_2. This surface is called the focal surface of the congruence, and to it all the lines l are bitangent. The distinctive property of the points A is that two of the congruence lines through them coincide, and in like manner the planes a each contain two coincident lines. The focal surface consists of two sheets, but one or both may degenerate into curves; thus, for example, the normals to a surface are bitangents of the surface of centres, and in the case of Dupin's cyclide this surface degenerates into two conics.

In the discussion of congruences it soon becomes necessary to introduce another number r, called the rank, which expresses the number of plane pencils each of which contains an arbitrary line and two lines of the congruence. The order of the focal surface is $2m(n-1)-2r$, and its class is $m(m-1)-2r$. Our knowledge of congruences is almost exclusively confined to those in which either m or n does not exceed two. We give a brief account of those of the second order without singular lines, those of order unity not being especially interesting. A congruence generally has singular points through which an infinite number of lines pass; a singular point is said to be of order r when the lines through it lie on a cone of the rth degree. By means of formulæ connecting the number of singular points and their orders with the class m of quadratic congruence Kümmer proved that the class cannot exceed seven. The focal surface is of degree four and class $2m$; this kind of quartic surface has been extensively studied by Kümmer, Cayley, Rohn, and others. The varieties (2, 2), (2, 3), (2, 4), (2, 5) all belong to at least one Reye complex; and so also does the most important class of (2, 6) congruences which includes all the above as special cases. The congruence (2, 2) belongs to a linear complex and forty different Reye complexes; as above remarked, the singular surface is Kümmer's sixteen-nodal quartic, and the same surface is focal for six different congruences of this variety. The theory of (2, 2) congruences is completely analogous to that of the surfaces called cyclides in three dimensions. Further particulars regarding quadratic congruences will be found in Kümmer's memoir of 1866, and the second volume of Sturm's treatise. The properties of quadratic congruences having singular lines, *i.e.*, degenerate focal surfaces, are not so interesting as those of the above class; they have been discussed by Kümmer, Sturm, and others.

Ruled surfaces. Since a ruled surface contains only ∞^1 elements, this theory is practically the same as that of curves. We pass over the point and plane theory of such surfaces with the remark that the degree and class are obviously equal, and deal exclusively with line geometry. Premising that if a linear complex contains more than n generators of a ruled surface of the nth degree it contains all the generators, we remark that for $n=2$ there are three linearly independent complexes, containing all the generators, and this is a well-known property of quadric surfaces. In ruled cubics the generators all meet two lines which may or may not coincide; these two cases correspond to the two main classes of cubics discussed by Cayley and Cremona. As regards ruled quartics, the generators must lie in one and may lie in two linear complexes. The first class is equivalent to a quartic in four dimensions and is always rational, but the latter class has to be subdivided into the elliptic and the rational, just like twisted quartic curves. A quintic skew may not lie in a linear complex, and then it is unicursal, while of sextics we have two classes not in a linear complex, viz., the elliptic variety, having thirty-six places where a linear complex contains six consecutive generators, and the rational, having six such places.

The general theory of skews in two linear complexes is identical with that of curves on a quadric in three dimensions, and is known. But for skews lying in only one linear complex there are difficulties; the curve now lies in four dimensions, and we represent it in three by stereographic projection as a curve meeting a given plane in n points on a conic. To find the maximum deficiency for a given degree would probably be difficult, but as far as degree eight the space-curve theory of Halphen and Nöther can be translated into line geometry at once. When the skew does not lie in a linear complex at all the theory is more difficult still; and we conclude by remarking that the deficiency of a skew surface, *quâ* line geometry of course, is equal to that of its line of striction when we deal with Euclidean space.

The earliest works of a general nature are PLÜCKER, *Neue Geometrie des Raumes*, Leipzig, 1868; and KÜMMER, "Ueber die algebraischen Strahlensysteme," *Berlin Academy*, 1866. Systematic development on purely synthetic lines will be found in the three volumes of STURM, *Liniengeometrie*, Leipzig, 1892, 1893, 1896; vol. i. deals with the linear and Reye complexes, vols. ii. and iii. with quadratic congruences and complexes respectively. For a highly suggestive review by Gino Loria see *Bulletin des sciences mathématiques*, 1893, 1897. A shorter treatise, giving a very interesting account of Klein's co-ordinates, is the work of KOENIGS, *La géometrie reglée et ses applications*, Paris, 1898. Many references to memoirs on line geometry will be found in HAGEN, *Synopsis der höheren Mathematik*, ii., Berlin, 1894; LORIA, *Il passato ed il presente delle principali teorie geometriche*, Milan, 1897; a clear résumé of the principal results is contained in the very elegant volume of PASCAL, *Repertorio di mathematiche superiori*, ii., Milan, 1900. Another treatise dealing extensively with line geometry is LIE, *Geometrie der Berührungstransformationen*, Leipzig, 1896. Many memoirs on the subject have appeared in the *Mathematische Annalen*; a full list of these will be found in the index to the first fifty volumes, p. 115. Perhaps the two memoirs which have left most impress on the subsequent development of the subject are KLEIN, "Zur Theorie der Liniencomplexe des ersten und zweiten Grades," *Math. Ann.* ii.; and LIE, "Ueber Complexe, insbesondere Linien- und Kugelcomplexe," *Math. Ann.* v. (J. H. GR.)

Geometry, Non-Euclidean.—Non-Euclidean Geometry, in the narrower sense, may be defined as the study of the consequences which follow from denying one or more of the (explicit or tacit) assumptions upon which the Euclidean system is founded. In a broader sense, for which the name Pangeometry is more appropriate, the word is used to describe systems which merely dispense with one or more of Euclid's assumptions, without making any decision as to the truth or falsity of these assumptions. The motives and scope of non-Euclidean Geometry can hardly be grasped without some knowledge of its growth and development. The present article, therefore, will begin with a historical sketch; it will then attempt to dispel some common confusions as to the meaning or the assumptions of non-Euclidean systems; and finally, it will briefly indicate the bearing of these systems upon Epistemology and the philosophy of space.

Definition.

"In pulcherrimo Geometriæ corpore," wrote Sir Henry Savile, in 1621, "duo sunt nævi, duæ labes nec quod sciam plures, in quibus eluendis et emaculendis cum veterum tum recentiorum . . . vigilavit industria." These two blemishes are the theory of parallels and the theory of proportion. The "industry of the moderns," in both respects, has given rise to important branches of mathematics, while at the same time showing that Euclid is more free from blemish than had been previously credible. It was from endeavours to improve the theory of parallels that non-Euclidean Geometry arose; and though it has now acquired a far wider scope, its historical origin remains instructive and interesting. To Euclid's successors, the axiom, or more properly the postulate, of parallels had signally failed to appear self-evident, and had failed equally to appear indemonstrable. Without the use of the postulate its converse is proved in Euclid's 28th proposition, and it was hoped that by further efforts the postulate itself could be also proved. The first step consisted in the discovery of equivalent axioms. Clavius in 1574 deduced the axiom from the assumption that a line whose points are all equidistant from a straight line is itself straight. Wallis in 1663 showed that the postulate follows from the possibility of similar triangles on different scales. Saccheri (1733) showed that it is sufficient to have a single triangle, the sum of whose angles is two right angles. Other equivalent forms may be obtained, but none shows any essential superiority to Euclid's. Indeed plausibility, which is chiefly aimed at, becomes a positive demerit where it conceals a real assumption.

Theory of parallels before Gauss.

A new method, which, though it failed to lead to the desired goal, proved in the end immensely fruitful, was invented by Saccheri, in a work entitled *Euclides ab omni nævo vindicatus* (Milan, 1733). If the postulate of parallels is involved in Euclid's other assumptions, contradictions must emerge when it is denied while the others are maintained. This led Saccheri to attempt a *reductio ad absurdum*, in which he mistakenly believed himself to have succeeded. What is interesting, however, is not his fallacious conclusion, but the non-Euclidean results which he obtains in the process. Saccheri distinguishes three hypotheses (corresponding to what are now known as Euclidean or parabolic, elliptic, and hyperbolic Geometry), and proves that some one of the three must be universally true. His three hypotheses are thus obtained: equal perpendiculars AC, BD are drawn to a straight line AB, and CD are joined. It is shown that the angles ACD, BDC are equal. The first hypothesis is that these are both right angles; the second, that they are both obtuse; and the third, that they are both acute. Many of the results afterwards obtained by Lobatchewsky and Bolyai are here developed. Saccheri fails to be the founder of non-Euclidean Geometry only because he does not perceive the possible truth of his non-Euclidean hypotheses. Some advance is made by Lambert (the demonstrator of the irrationality of π) in his *Theorie der Parallellinien* (written 1766; posthumously published, 1786). Though he still believed in the necessary truth of Euclidean Geometry, he confessed that, in all his attempted proofs, something remained undemonstrated. He deals with the same three hypotheses as Saccheri, showing that the second holds on a sphere, while the third would hold on a sphere of purely imaginary radius. The second hypothesis he succeeds in condemning, since, like all who preceded Riemann, he is unable to conceive of the straight line as finite and closed. But the third hypothesis, which is the same as Lobatchewsky's, is not even professedly refuted.[1]

Non-Euclidean Geometry proper begins with Gauss. The advance which he made was rather philosophical than mathematical: it was he (probably) who first recognized that the postulate of parallels is possibly false, and should be empirically tested by measuring the angles of large triangles. The history of non-Euclidean Geometry has been aptly divided by Klein into three very distinct periods. The first—which contains only Gauss, Lobat-

Three periods of non-Euclidean Geometry.

[1] On the theory of parallels before Lobatchewsky, see Stäckel und Engel, *Theorie der Parallellinien von Euklid bis auf Gauss*, Leipzig, 1895. The foregoing remarks are based upon the materials collected in this work.

chewsky and Bolyai—is characterized by its synthetic method and by its close relation to Euclid. The attempt at indirect proof of the disputed postulate would seem to have been the source of these three men's discoveries; but when the postulate had been denied, they found that the results, so far from showing contradictions, were just as self-consistent as Euclid. They inferred that the postulate, if true at all, can only be proved by observations and measurements. Only one kind of non-Euclidean space is known to them, namely, that which is now called hyperbolic. The second period is analytical, and is characterized by a close relation to the theory of surfaces. It begins with Riemann's inaugural dissertation, which regards space as a particular case of a *manifold*. The conception of measure of curvature is extended from surfaces to spaces, and a new kind of space, finite but unbounded (corresponding to the second hypothesis of Saccheri and Lambert), is shown to be possible. As opposed to the second period, which is purely metrical, the third period is essentially projective in its method. It begins with Cayley, who showed that metrical properties are projective properties relative to a certain fundamental quadric, and that different geometries arise according as this quadric is real, imaginary, or degenerate. Klein, to whom the development of Cayley's work is due, showed further that there are two forms of Riemann's space, called by him the elliptic and the spherical. Finally, it has been shown by Lie, that if figures are to be freely movable throughout all space in ∞^6 ways, no other three-dimensional spaces than the above four are possible.

Gauss. Gauss published nothing on the theory of parallels, and it was not generally known until after his death that he had interested himself in that theory from a very early date. In 1799, he announces that Euclidean Geometry would follow from the assumption that a triangle can be drawn greater than any given triangle. Though unwilling to assume this, we find him in 1804 still hoping to prove the postulate of parallels. In 1830 he announces his conviction that Geometry is not an *à priori* science; in the following year he explains that non-Euclidean Geometry is free from contradictions, and that, in this system, the angles of a triangle diminish without limit when all the sides are increased. He also gives for the circumference of a circle of radius r the formula $\pi k(e^{r/k} - e^{-r/k})$, where k is a constant depending upon the nature of the space. In 1832, in reply to the receipt of Bolyai's *Appendix*, he gives an elegant proof that the amount by which the sum of the angles of a triangle falls short of two right angles is proportional to the area of the triangle. From these and a few other remarks it appears that Gauss possessed the foundations of hyperbolic Geometry, which he was probably the first to regard as perhaps true. It is not known with certainty whether he influenced Lobatchewsky and Bolyai, but the evidence we possess is against such a view.[1]

Lobatchewsky. The first to publish a non-Euclidean Geometry was a Russian, Lobatchewsky, Professor of Mathematics in the new university of Kazañ.[2] In the place of the disputed postulate he puts the following: "All straight lines which, in a plane, radiate from a given point, can, with respect to any other straight line in the same plane, be divided into two classes, the *intersecting* and the *non-intersecting*. The *boundary line* of the one and the other class is called *parallel to the given line*." It follows that there are two parallels to the given line through any point, each meeting the line at infinity, like a Euclidean parallel. (Hence a line has two distinct points at infinity, and not one only as in ordinary Geometry.) The two parallels to a line through a point make equal acute angles with the perpendicular to the line through the point. If p be the length of the perpendicular, either of these angles is denoted by $\Pi(p)$. The determination of $\Pi(p)$ is the chief problem; it appears finally that, with a suitable choice of the unit of length,

$$\tan \tfrac{1}{2}\,\Pi(p) = e^{-p}.$$

Before obtaining this result it is shown that spherical trigonometry is unchanged, and that the normals to a circle or a sphere still pass through its centre. When the radius of the circle or sphere becomes infinite all these normals become parallel, but the circle or sphere does not become a straight line or plane. It becomes what Lobatchewsky calls a limit-line or limit-surface. The geometry on such a surface is shown to be Euclidean, limit-lines replacing Euclidean straight lines. (It is, in fact, a surface of zero measure of curvature.) By the help of these propositions Lobatchewsky obtains the above value of $\Pi(p)$, and thence the solution of triangles. He points out that his formulæ result from those of spherical trigonometry by substituting ia, ib, ic, for the sides a, b, c.

Bolyai. John Bolyai, a Hungarian, obtained results closely corresponding to those of Lobatchewsky. These he published in an appendix to a work by his father, entitled *Appendix Scientiam spatii absolute veram exhibens: a veritate aut falsitate Axiomatis XI. Euclidei (à priori haud unquam decidenda) independentem: adjecta ad casum falsitatis, quadratura circuli geometrica.*[3] This work was published in 1831, but its conception dates from 1823. It reveals a profounder appreciation of the importance of the new ideas, but otherwise differs little from Lobatchewsky's. Both men point out that Euclidean Geometry is a limiting case of their own more general system, that the geometry of very small spaces is always approximately Euclidean, that no *à priori* grounds exist for a decision, and that observation can only give an approximate answer. Bolyai gives also, as his title indicates, a geometrical construction, in hyperbolic space, for the quadrature of the circle, and shows that the area of the greatest possible triangle, which has all its sides parallel and all its angles zero, is πi^2, where i is what we should now call the space-constant.

Riemann. The works of Lobatchewsky and Bolyai, though known and valued by Gauss, remained obscure and ineffective until, in 1866, they were translated into French by J. Hoüel. But at this time Riemann's dissertation, *Ueber die Hypothesen welche der Geometrie zu Grunde liegen*,[4] was already about to be published. In this work Riemann, without any knowledge of his predecessors in the same field, inaugurated a far more profound discussion, based on a far more general standpoint; and by its publication in 1867, the attention of mathematicians and philosophers was at last secured. (The dissertation dates from 1854, but owing to changes which Riemann wished to make in it, it remained unpublished until after his death.)

Riemann's work contains two fundamental conceptions,

---

[1] See Stäckel und Engel, *op. cit.*, and "Gauss, die beiden Bolyai, und die nicht-Euklidische Geometrie," *Math. Annalen*, Bd. xlix.; also Engel's translation of Lobatchewsky (Leipzig, 1898), pp. 378 *ff.*

[2] Lobatchewsky's works on the subject are the following:—"On the Foundations of Geometry," *Kazañ Messenger*, 1829–30; "New Foundations of Geometry, with a complete Theory of Parallels," *Proceedings of the University of Kazañ*, 1835 (both in Russian, but translated into German by Engel, Leipzig, 1898); "Géométrie Imaginaire," *Crelle's Journal*, 1837; *Theorie der Parallellinien*, Berlin, 1840, 2nd ed. 1887, translated by Halsted, Austin, Texas, 1891. His results appear to have been set forth in a paper (now lost) which he read at Kazañ in 1826.

[3] Translated by Halsted, Austin, Texas, 4th ed., 1896.

[4] *Abhandlungen d. Königl. Ges. d. Wiss. zu Göttingen*, Bd. xiii. *Ges. Math. Werke*, pp. 254–269; translated by Clifford, *Collected Mathematical Papers*.

that of a *manifold*, and that of the *measure of curvature* of a continuous manifold possessed of what he calls flatness in the smallest parts. By means of these conceptions space is made to appear at the end of a gradual series of more and more specialized conceptions.

Definition of a manifold.

Conceptions of magnitude, he explains, are only possible where we have a general conception capable of determination in various ways. The manifold consists of all these various determinations, each of which is an element of the manifold. The passage from one element to another may be discrete or continuous; the manifold is called discrete or continuous accordingly. Where it is discrete two portions of it can be compared, as to magnitude, by counting; where continuous, by measurement. But measurement demands superposition, and consequently some magnitude independent of its place in the manifold. In passing, in a continuous manifold, from one element to another in a determinate way, we pass through a series of intermediate terms, which form a one-dimensional manifold. If this whole manifold be similarly caused to pass over into another, each of its elements passes through a one-dimensional manifold, and thus on the whole a two-dimensional manifold is generated. In this way we can proceed to n dimensions. Conversely, a manifold of n dimensions can be analysed into one of one dimension and one of $(n-1)$ dimensions. By repetitions of this process the position of an element may be at last determined by n magnitudes. Riemann proceeds to specialize the manifold by considerations as to measurement.

Measure of curvature.

If measurement is to be possible, some magnitude, we saw, must be independent of position; let us consider manifolds in which lengths of lines are such magnitudes, so that every line is measurable by every other. The co-ordinates of a point being $x_1, x_2, \ldots\ldots x_n$, let us confine ourselves to lines along which the ratios $dx_1 : dx_2 : \ldots\ldots : dx_n$ alter continuously. Let us also assume that the element of length, ds, is unchanged (to the first order) when all its points undergo the same infinitesimal motion. Then if all the increments dx be altered in the same ratio, ds is also altered in this ratio. Hence ds is a homogeneous function of the first degree of the increments dx. Moreover, ds must be unchanged when all the dx change sign. The simplest possible case is, therefore, that in which ds is the square root of a quadratic function of the dx. This case includes space, and is alone considered in what follows. It is called the case of flatness in the smallest parts. Its further discussion depends upon the measure of curvature, the second of Riemann's fundamental conceptions. This conception, derived from the theory of surfaces, is applied as follows. Any one of the shortest lines which issue from a given point (say the origin), is completely determined by the initial ratios of the dx. Two such lines, defined by dx and δx say, determine a pencil, or one-dimensional series, of shortest lines, any one of which is defined by $\lambda dx + \mu \delta x$, where the parameter $\lambda : \mu$ may have any value. This pencil generates a two-dimensional series of points, which may be regarded as a surface, and for which we may apply Gauss's formula for the measure of curvature at any point. Thus at every point of our manifold there is a measure of curvature corresponding to every such pencil; but all these can be found when $n.\overline{n-1}/2$ of them are known. If figures are to be freely movable, it is necessary and sufficient that the measure of curvature should be the same for all points and all directions at each point. Where this is the case, if a be the measure of curvature, the linear element can be put into the form

$$ds = \sqrt{\Sigma dx^2} / (1 + \tfrac{a}{4}\Sigma x^2).$$

If a be positive, space is finite, though still unbounded, and every straight line is closed—a possibility first recognized by Riemann. It is pointed out that, since the possible values of a form a continuous series, observations cannot prove that our space is strictly Euclidean. It is also regarded as possible that, in the infinitesimal, the measure of curvature of our space should be variable.

Criticism of Riemann.

There is one point, at least, upon which this profound work seems open to criticism, namely, as regards the introduction of co-ordinates. If we are to be able, without a vicious circle, to presuppose co-ordinates in discussing distance, it is evident that our co-ordinates must not presuppose distance. It then remains a question how they are to be defined—a question satisfactorily answered (as we shall see) by the projective method, but unanswerable from Riemann's metrical standpoint. Moreover, if our co-ordinates are to represent any kind of spatial magnitudes, we must assume the possibility of equal quantities in different places, and hence, it will be found, we shall be compelled to regard the measure of curvature as constant. Let us examine the consequences of supposing it variable. In the first place, the method of superposition would have become impossible, so that measurements could no longer be effected. As regards areas and volumes this is obvious, since congruent areas or volumes could not, generally speaking, exist in two different assigned regions. As regards lengths, it seems equally true that superposition would be impossible. For straight lines corresponding to different values of the measure of curvature differ, as we shall see later, not only in quantity, but also in quality. Hence two such lines cannot be fitted together, and are, strictly, neither equal nor unequal. Hence it would be impossible, in general, to divide a given length into equal portions, or to compare it numerically with other lengths. Thus a metrical co-ordinate system would become impossible. Moreover, Geometry would become akin to Geography; it would not consist of general theorems, but of descriptions of various localities. The variation of the space-constant would be not quantitative merely, but qualitative, and quantities in different places would be of different kinds. Thus the constancy of the measure of curvature is a precondition of any metrical co-ordinate system, and cannot be held doubtful while such a system is retained.[1] Another respect in which Riemann's language, though not fallacious, has proved unfortunate, is the use of the word curvature. This has led philosophers, and even mathematicians (*e.g.*, Newcomb), to suppose non-Euclidean spaces curved, and therefore necessarily contained in Euclidean spaces of more dimensions. So far is this from being the case that there is perfect reciprocity. Parabolic spaces can be contained both in elliptic and in hyperbolic spaces of one more dimension.[2] It has, consequently, become customary to speak of the reciprocal of the square root of Riemann's measure of curvature as the *space-constant*, in order to avoid all appearance of implying a curvature of non-Euclidean spaces.

Helmholtz.

The publication of Riemann's dissertation was closely followed by two works of Helmholtz,[3] again undertaken in ignorance of the work of predecessors. In these a proof is attempted that ds must be a rational integral quadratic function of the increments of the co-ordinates. This proof has since been shown by Lie to stand in need of correction (*v. infra*). Helmholtz's remaining works on the subject[4] are of

---

[1] See B. Russell, *Foundations of Geometry*, Cambridge, 1897.

[2] See Whitehead, "Geodesic Geometry of Surfaces in non-Euclidean Space," *Proc. Lond. Math. Soc.* vol. xxix.

[3] *Wiss. Abh.* vol. ii. pp. 610, 618 (1866, 1868).

[4] *Mind*, O.S., vols. i. and iii.; *Vorträge und Reden*, vol. ii. pp. 1 256.

almost exclusively philosophical interest. We shall return to them later.

Beltrami. The only other writer of importance in the second period is Beltrami, by whom Riemann's work was brought into connexion with that of Lobatchewsky and Bolyai. As he gave, by an elegant method, a convenient Euclidean interpretation of hyperbolic plane Geometry, his results will be stated at some length.[1] The *Saggio* shows that Lobatchewsky's plane Geometry holds on surfaces of constant negative curvature, straight lines being replaced by geodesics. Such surfaces are capable of a conformal representation on a plane, by which geodesics are represented by straight lines. Hence if we take, as co-ordinates on the surface, the Cartesian co-ordinates of corresponding points on the plane, the geodesics must have linear equations.

Hence it follows that

$$ds^2=\frac{R^2}{w^4}\{(a^2-v^2)du^2+2uvdudv+(a^2-u^2)dv^2\}$$

where $w^2=a^2-u^2-v^2$, and $-1/R^2$ is the measure of curvature of our surface. The angle between two geodesics u=const., v=const. is θ, where

$$\cos\theta=uv/\sqrt{(a^2-u^2)(a^2-v^2)},\ \sin\theta=aw/\sqrt{(a^2-u^2)(a^2-v^2)}.$$

Thus $u=0$ is orthogonal to all geodesics v=const., and *vice versâ.* In order that $\sin\theta$ may be real, w^2 must be positive; thus geodesics have no real intersection when the corresponding straight lines intersect outside the circle

$$u^2+v^2=a^2.$$

When they intersect on this circle, $\theta=0$. Thus Lobatchewsky's parallels are represented by straight lines intersecting on the circle. Again, transforming to polar co-ordinates $u=r\cos\mu$, $v=r\sin\mu$, and calling ρ the geodesic distance of u, v from the origin, we have, for a geodesic through the origin,

$$d\rho=Radr/(a^2-r^2),\ \rho=\frac{R}{2}\log\frac{a+r}{a-r},\ r=a\tanh\frac{\rho}{R}.$$

Thus points on the surface corresponding to points in the plane on the limiting circle $r=a$, are all at an infinite distance from the origin. Again, considering r constant, the arc of a geodesic circle subtending an angle μ at the origin is

$$\sigma=Rr\mu/\sqrt{a^2-r^2}=\mu R\sinh\frac{\rho}{R},$$

whence the circumference of a circle of radius ρ is $2\pi R\sinh\rho/R$. Again, if α be the angle between any two geodesics

$$V-v=m(U-u),\ V-v=n(U-u),$$

then $\tan\alpha=a(n-m)w/\{(1+mn)a^2-(v-mu)(v-nu)\}$.

Thus α is imaginary when u, v is outside the limiting circle, and is zero when, and only when, u, v is on the limiting circle. All these results agree with those of Lobatchewsky and Bolyai. The maximum triangle, whose angles are all zero, is represented in the auxiliary plane by a triangle inscribed in the limiting circle. The angle of parallelism is also easily obtained. The perpendicular to $v=0$ at a distance δ from the origin is $u=a\tanh\frac{\delta}{R}$, and the parallel to this through the origin is $u=v\sinh\frac{\delta}{R}$. Hence $\Pi(\delta)$, the angle which this parallel makes with $v=0$, is given by

$$\tan\Pi(\delta).\sinh\frac{\delta}{R}=1,\ \text{or}\ \tan\tfrac{1}{2}\Pi(\delta)=e^{-\delta/R}$$

which is Lobatchewsky's formula. We also obtain easily for the area of a triangle the formula $R^2(\pi-A-B-C)$.

Beltrami's treatment connects two curves which, in the earlier treatment, had no connexion. These are limit lines and curves of constant distance from a straight line. Both may be regarded as circles, the first having an infinite, the second an imaginary radius. The equation to a circle of radius ρ and centre u_0v_0 is

$$(a^2-uu_0-vv_0)^2=\cosh^2\frac{\rho}{R}w_0^2w^2=C^2w^2 \quad \text{(say).}$$

This equation remains real when ρ is a pure imaginary, and remains finite when $w_0=0$, provided ρ becomes infinite in such a way that $w_0\cosh\frac{\rho}{R}$ remains finite. In the latter case the equation represents a limit line. In the former case, by giving different values to C, we obtain concentric circles with the imaginary centre u_0v_0. One of these, obtained by putting $C=0$, is the straight line $a^2-uu_0-vv_0=0$. Hence the others are each throughout at a constant distance from this line. (It may be shown that all motions in a hyperbolic plane consist, in a general sense, of rotations; but three types must be distinguished according as the centre is real, imaginary, or at infinity. All points describe, accordingly, one of the three types of circles.)

The above Euclidean interpretation fails for three or more dimensions. In the *Teoria fondamentale*, accordingly, where n dimensions are considered, Beltrami treats hyperbolic space in a purely analytical spirit. The paper shows that Lobatchewsky's space of any number of dimensions has, in Riemann's sense, a constant negative measure of curvature. Beltrami starts with the formula (analogous to that of the *Saggio*)

$$ds^2=\frac{R^2}{x^2}(dx^2+dx_1^2+dx_2^2+\ldots+dx_n^2)$$

where $\qquad x^2+x_1^2+x_2^2+\ldots+x_n^2=a^2.$

He shows that geodesics are represented by linear equations between $x_1, x_2, \ldots, x_n$, and that the geodesic distance ρ between two points x and x' is given by

$$\cosh\frac{\rho}{R}=\frac{a^2-x_1x'_1-x_2x_2'-\ldots-x_nx'_n}{\{(a^2-x_1^2-x_2^2-\ldots-x_n^2)(a^2-x_1'^2-x_2'^2-\ldots-x_n'^2)\}^{1/2}}$$

(a formula practically identical with Cayley's, though obtained by a very different method). In order to show that the measure of curvature is constant, we make the substitutions

$$x_1=r\lambda_1,\ x_2=r\lambda_2\ldots x_n=r\lambda_n,\ \text{where}\ \Sigma\lambda^2=1.$$

Hence $\qquad ds^2=(Radr/\overline{a^2-r^2})^2+R^2r^2d\Lambda^2/(a^2-r^2).$

where $\qquad d\Lambda^2=\Sigma d\lambda^2.$

Also calling ρ the geodesic distance from the origin, we have

$$\cosh\frac{\rho}{R}=\frac{a}{\sqrt{a^2-r^2}},\ \sinh\frac{\rho}{R}=\frac{r}{\sqrt{a^2-r^2}}.$$

Hence $\qquad ds^2=d\rho^2+\left(R\sinh\frac{\rho}{R}\right)^2d\Lambda^2.$

Putting $\qquad z_1=\rho\lambda_1,\ z_2=\rho\lambda_2,\ \ldots z_n=\rho\lambda_n,$
we obtain

$$ds^2=\Sigma dz^2+\frac{1}{\rho^2}\left\{\left(\frac{R}{\rho}\sinh\frac{\rho}{R}\right)^2-1\right\}\Sigma(z_idz_k-z_kdz_i)^2.$$

Hence when ρ is small, we have approximately

$$ds^2=\Sigma dz^2+\frac{1}{3R^2}\Sigma(z_idz_k-z_kdz_i)^2 \quad . \quad . \quad (1).$$

Considering a surface element through the origin, we may choose our axes so that, for this element,

$$z_3=z_4=\ldots=z_n=0.$$

Thus $\qquad ds^2=dz_1^2+dz_2^2+\frac{1}{3R^2}(z_1dz_2-z_2dz_1)^2 \quad . \quad . \quad (2).$

Now the area of the triangle whose vertices are (0, 0), (z_1, z_2), (dz_1, dz_2) is $\frac{1}{2}(z_1, dz_2-z_2dz_1)$. Hence the quotient when the terms of the fourth order in (2) are divided by the square of this triangle is $4/3R^2$; hence, returning to general axes, the same is the quotient when the terms of the fourth order in (1) are divided by the square of the triangle whose vertices are $(0, 0, \ldots 0)$, $(z_1, z_2, z_3, \ldots z_n)$, $(dz_1, dz_2, dz_3\ldots dz_n)$. But $-\frac{3}{4}$ of this quotient is defined by Riemann as the measure of curvature.[2] Hence the measure of curvature is $-1/R^2$, *i.e.*, is constant and negative. The properties of parallels, triangles, &c., are as in the *Saggio*. It is also shown that the analogues of limit surfaces have zero curvature; and that spheres of radius ρ have constant positive curvature $1/R^2\sinh^2\frac{\rho}{R}$, so that spherical geometry may be regarded as contained in the pseudospherical (as Beltrami calls Lobatchewsky's system).

Transition to the Projective Method. The *Saggio*, as we saw, gives a Euclidean interpretation confined to two dimensions. But a consideration of the auxiliary plane suggests a different interpretation, which may be extended to any number of dimensions. If, instead of referring to the pseudosphere, we merely *define* distance and angle, in the Euclidean plane, as those functions of the

[1] His papers are "Saggio di Interpretazione della Geometria non-Euclidea," *Giornale di Matematiche*, vol. vi. 1868; "Teoria fondamentale degli spazii di curvatura costante," *Annali di Matematica*, vol. ii., 1868–69. Both were translated into French by J. Hoüel, *Annales Scientifiques de l'École Normale supérieure*, vol. vi., 1869.

[2] Beltrami shows also that this definition agrees with that of Gauss.

co-ordinates which gave us distance and angle on the pseudosphere, we find that the Geometry of our plane has become Lobatchewsky's. All the points of the limiting circle are now at infinity, and points beyond it are imaginary. If we give our circle an imaginary radius the Geometry on the plane becomes elliptic. Replacing the circle by a sphere, we obtain an analogous representation for three dimensions. Instead of a circle or sphere we may take any conic or quadric. With this definition, if the fundamental quadric be $\Sigma_{xx}=0$, and if $\Sigma_{xx'}$ be the polar form of Σ_{xx}, the distance ρ between x and x' is given by the projective formula

$$\cos\frac{\rho}{k}=\frac{\Sigma xx'}{\sqrt{\Sigma_{xx}\,.\,\Sigma_{x'x'}}}.$$

That this formula is projective is rendered evident by observing that $e^{-2i\rho/k}$ is the anharmonic ratio of the range consisting of the two points and the intersections of the line joining them with the fundamental quadric. With this we are brought to the third or projective period. The method of this period is due to Cayley; its application to previous non-Euclidean Geometry is due to Klein.

The projective method contains a generalization of discoveries already made by Laguerre in 1853 as regards Euclidean Geometry. Metrical properties, in Euclidean space, are projective properties relative, in two dimensions, to the circular points and the line at infinity considered as a degenerate conic, or, in three dimensions, to the circle and the plane at infinity considered as a degenerate quadric. Substituting a proper conic, or quadric, real or imaginary, we obtain the recognized non-Euclidean results. (In three dimensions some restriction as to the kind of quadric is necessary, if the measurement of angles is to be unchanged, and if a finite rotation is to cause a return to the initial position. Tangent lines from any point to the Absolute or fundamental quadric make an infinite angle with all other lines through the point; it is therefore necessary that they should be imaginary. Hence the absolute, when expressed as the sum or difference of squares, must have all its signs positive, or three positive and one negative. This excludes the hyperboloid of one sheet.)

The two kinds of elliptic space.

This method leads to a discrimination, first made by Klein,[1] of two varieties of Riemann's space; Klein calls these elliptic and spherical. They are also called the polar and antipodal forms of elliptic space. The latter names will here be used. The difference is strictly analogous to that between the diameters and the points of a sphere. In the polar form two straight lines in a plane always intersect in one and only one point; in the antipodal form they intersect always in two points, which are antipodes. Similarly two diameters always determine a plane, but two points on a sphere do not determine a great circle when they are antipodes, and two great circles always intersect in two points. Again, a plane does not form a boundary among lines through a point: we can pass from any one such line to any other without passing through the plane. But a great circle does divide the surface of a sphere. So, in the polar form, a complete straight line does not divide a plane, and a plane does not divide space, and does not, like a Euclidean plane, have two sides.[2] But, in the antipodal form, a plane is, in these respects, like a Euclidean plane. The polar form alone, among the various spaces, gives absolute duality between points and planes, or, in two dimensions, between points and lines. The reason of this is simple. The measurement of angles is always elliptic; among the lines or planes through a point, those that make an infinite angle with the rest are imaginary, and for real values angles are periodic. Thus it is only where the measurement of length is also elliptic that complete duality prevails.

Projective co-ordinates.

A question, similar to that which arises in connexion with Riemann, may be asked concerning the nature of the co-ordinates employed in the projective treatment of metrical properties. The co-ordinates of elementary Geometry are always metrically defined. But if metrical properties are to be defined in terms of our co-ordinates, these must be defined in a new way. Anharmonic ratio itself, as commonly defined, involves lengths, and therefore requires a new definition when lengths are to be defined by its means. Klein has shown[3] how to fulfil these requirements by an appeal to von Staudt's quadrilateral construction. This construction gives a purely projective definition of a harmonic range, and enables us, starting from three given points on a line, to obtain as many other points on the line as we please by successive repetitions of the construction. In this way an order is assigned among the points of a line (or the planes through a line). Our co-ordinates then express the position of our point (or plane) in the series so obtained, and are thus wholly free from metrical presuppositions. In like manner, by two sets of quadrilateral constructions, we can assign the co-ordinates of a point in a plane or a plane through a point; and by three sets we can assign the co-ordinates of any point or plane in space. Any point whose co-ordinates are given may thus be found, provided these co-ordinates are rational. If they are irrational, the point can of course be assigned as a limit.

Sophus Lie.

By means of the projective method and the theory of continuous groups, Sophus Lie[4] has been enabled to give a complete answer to the question which Helmholtz attempted to solve, namely: What axioms are involved in the possibility of rigid bodies with six degrees of freedom? Assuming that any two points have a distance, which is some function of their co-ordinates, the group of motions must be such as to leave this function invariant. Hence it can be proved that ds^2 must be an integral quadratic function of the co-ordinates, and that motions are collineations which transform a certain quadric (the Absolute) into itself. In non-Euclidean Geometry this condition is also sufficient; in Euclidean Geometry it is necessary further to exclude similarity-transformations.

The axioms from which Lie starts are the following: Let

$$x_1=f(xyza_1a_2\ldots)$$
$$y_1=\phi(xyza_1a_2\ldots)$$
$$z_1=\psi(xyza_1a_2\ldots)$$

be an infinite collection of *real* transformations of the space x, y, z, concerning which we make the following assumptions:—

A. The functions f, ϕ, ψ are to be *analytic* functions of the co-ordinates x, y, z, and the parameters a_1, a_2, a_3.

B. In regard to all transformations of the collection, any two points $x_1\,y_1\,z_1$, $x_2\,y_2\,z_2$ are to have an invariant

$$\Omega(x_1y_1z_1\ x_2y_2z_2).$$

C. There is to be free mobility in the sense of Riemann and Helmholtz; *i.e.* (1) the point xyz can be transformed into any other; (2) if a point $x_1y_1z_1$ is kept fixed, every other point $x_2y_2z_2$ (*of general position*) can take up ∞^2 positions, given by the equation

$$\Omega(x_1y_1z_1x'_2y'_2z'_2)=\Omega(x_1y_1z_1x_2y_2z_2)\,;$$

(3) if two points are fixed a third can take up ∞^1 positions,

[1] *Math. Annalen*, iv. vi. 1871–72.

[2] For an investigation of these and similar properties, see Whitehead, *Universal Algebra*, Cambridge, 1898, Bk. vi. chap. ii. The polar form was independently discovered by Newcomb in 1877.

[3] *Math. Annalen*, iv. vi. vii. xxxvii.; *Vorlesungen über nicht-Euklidische Geometrie*, Göttingen, 1893, vol. i. pp. 308 *ff.*

[4] "Ueber die Grundlagen der Geometrie," *Leipziger Berichte*, 1890.

determined by two such equations as the above; (4) if three (non-collinear) points are fixed every point is fixed.

From these assumptions it follows at once that the transformations considered form a six-membered group. By a completely exhaustive method it is shown that, if the assumptions are to hold *without exception* throughout a certain region, then the group considered can only be the group of Euclidean or non-Euclidean motions, and the invariant Ω is the Euclidean or non-Euclidean distance. Helmholtz, in investigating the same problem, required a fourth axiom, which he called *Monodromy;* this demands that the curves described in a rotation (*i.e.*, a motion which leaves two points fixed) should be closed. [See *Wiss. Abh.* vol. ii. p. 624.] This axiom Lie finds unnecessary if, in three dimensions, free mobility is to hold unreservedly throughout a certain region. But if we admit groups in which, when one point is fixed, a certain straight line also remains fixed, then Helmholtz's axiom becomes necessary, but not sufficient.[1] In two dimensions the axiom is necessary even if free mobility holds without exception throughout a certain region, but not if it holds throughout the whole two-dimensional space.

Spaces not allowing free mobility in Lie's sense.

Thus if free mobility, in the above sense, be taken to hold universally, the above three axioms suffice to characterize space as of one of four kinds—Euclidean, hyperbolic, and the two elliptic varieties. It has been pointed out by Klein, however, that there are other possible spaces, allowing free mobility in a wider sense, *i.e.*, permitting transformations which leave metrical properties unchanged, and transform a chosen point into any other chosen point, but not containing as many such transformations. Such spaces still have constant measure of curvature, and their infinitesimal geometry belongs to one of the usual types. Their differences from these types may be best illustrated by an example, which is important on its own account.

Clifford's surface of zero curvature and finite extent.

In elliptic space, the locus of points at a constant perpendicular distance from a given straight line is a ruled quadric, any two of whose generators of the same set have an infinite number of common perpendiculars, all of equal length, as have also any generator and the axis of the surface. This surface is of zero curvature, but of finite extent, and it is transformed into itself by only ∞^2 motions.[2] Its properties may be developed by elementary considerations, as follows. Let the Absolute be

$$x^2+y^2+z^2+w^2=0,$$

and let the axis of the surface be $z=0$, $w=0$. The plane through (x, y, z, w) perpendicular to the axis is $x'/x=y'/y$, which meets the axis in $(x, y, 0, 0)$. The distance of $(x, y, 0, 0)$ from (x, y, z, w) is ρ,

where
$$\cos^2\frac{\rho}{k}=(x^2+y^2)^2/(x^2+y^2)(x^2+y^2+z^2+w^2)$$
$$=(x^2+y^2)/(x^2+y^2+z^2+w^2).$$

The surface is defined by $\rho=$constant. Hence its equation is

$$x^2+y^2=\cot^2\frac{\rho}{k}\cdot(z^2+w^2).$$

Putting $\cot\frac{\rho}{k}=p$, the generators of this surface are

$$\left.\begin{array}{l}x-pz=\lambda(pw-y)\\ \lambda(x+pz)=pw+y\end{array}\right\}\text{ and }\left\{\begin{array}{l}x-pz=\mu(pw+y)\\ \mu(x+pz)=pw-y\end{array}\right.$$

It is easily shown that the perpendicular to $z=0$, $w=0$ from any point of a generator is also perpendicular to the generator. Again if we put

$$\lambda=\tan\theta,\ \mu=\tan\phi,$$

we find $x:y:z:w=p\cos(\theta-\phi):p\sin(\theta-\phi):\cos(\theta+\phi):\sin(\theta+\phi)$; whence, on the surface (for which p is constant),

$$\frac{ds^2}{k^2}=\frac{(x^2+y^2+z^2+w^2)(dx^2+dy^2+dz^2+dw^2)-(xdx+ydy+zdz+wdw)^2}{(x^2+y^2+z^2+w^2)^2}$$
$$=d\theta^2+d\phi^2-2\frac{p^2-1}{p^2+1}d\theta d\phi$$
$$=d\theta^2+d\phi^2-2\cos\frac{2\rho}{k}d\theta d\phi.$$

This formula shows that the surface has zero measure of curvature, that its geodesics are given by linear equations in θ and ϕ, and that any two generators $\theta=$constant, $\phi=$constant, make an angle $2\rho/k$ with each other. Hence the whole surface may be divided into similar parallelograms, and since the length of a generator is πk, the area of the surface is $\pi^2k^2\sin\frac{2\rho}{k}$. Again, motions are collineations which transform $x^2+y^2+z^2+w^2$ into itself. Those motions which transform the above surface into itself also leave $(x^2+y^2)/(z^2+w^2)$ unchanged. Hence they leave x^2+y^2 and z^2+w^2 each unchanged. Hence they are given by

$$\begin{array}{ll}qx'=\ \ x\cos\alpha+y\sin\alpha & qz'=\ \ z\cos\beta+w\sin\beta\\ qy'=-x\sin\alpha+y\cos\alpha & qw'=-z\sin\beta+w\cos\beta\end{array}$$

where q is an arbitrary factor. Hence

$$x':y':z':w'=p\cos(\theta-\phi-\alpha):p\sin(\theta-\phi-\alpha):\cos(\theta+\phi-\beta):\sin(\theta+\phi-\beta).$$

Thus generators are transformed into others of the same set; the transformation is given by

$$\theta'=\theta-\tfrac{1}{2}(\alpha+\beta),\ \phi'=\phi+\tfrac{1}{2}(\alpha-\beta).$$

If $\alpha\pm\beta=0$, one set of generators is unchanged, and every point of the surface moves along these generators. The same transformation gives the same result for surfaces corresponding to other values of p. Thus there are motions of elliptic space in which all points move along parallel lines; in this respect, also, Clifford's parallels resemble Euclid's. The combination of two such motions, one altering θ only, the other ϕ only, gives the general motion leaving $p=$const. unchanged; and thus only ∞^2 motions transform this surface into itself. Since, however, the surface is homogeneous, there is a possible two-dimensional space with the same properties. Thus within each type of space we have varieties, differing as regards connectivity and *analysis situs.* In the case of positive measure of curvature, there are only the two usual varieties; but in the negative case there is, as Klein has shown, an infinite number.

Three prevalent misconceptions.

The philosophical questions raised by non-Euclidean Geometry have been rendered unduly difficult by some very prevalent misconceptions. Three of these are especially important. The first concerns the phrase "measure of curvature," the second concerns the projective definition of distance and angle, and the third concerns the relation of the axiom of congruence to rigid bodies.

There are, as we have seen, two principal types of Euclidean analogues to non-Euclidean spaces. There is the type preferred by Beltrami, and, unfortunately, popularized by Helmholtz (*Mind*, O.S., vol. i.), which compares the non-Euclidean plane to a Euclidean surface of constant curvature. There is, secondly, the type introduced by Cayley and Klein, in which, within Euclidean space, we introduce a new definition of distance. Both are extremely useful as analogies, but both have a tendency to pass for something more.

Measure of curvature.

The confusion resulting from the first of these analogies has led to the view that the surface of a sphere actually *is* a plane in the antipodal form of elliptic space.[3] Similarly it has been supposed (*e.g.*, by Newcomb) that non-Euclidean spaces of three dimensions should be regarded as figures in a four-dimensional Euclidean space, being related to it as the sphere to ordinary space. This has made it appear to philosophers that they had to do only with an increase in the number of dimensions. The rest of the apparatus seemed a mere wilful change of nomenclature—a circle was to be called a straight line, a sphere was to be called a plane, and so on. The same error underlies all these views. The conception of a space is essentially the conception of a totality; a figure having points external to it must in no circumstances be regarded as itself a space.

---

[1] *i.e.*, in addition to Euclidean and non-Euclidean motions, there are other groups, of which some satisfy the axiom of Monodromy. See Lie, *Theorie der Transformationsgruppen*, Leipzig, 1893, vol. iii. p. 470.

[2] This surface was discovered by Clifford; its generators of one set are (in his sense) parallel to each other and to the axis. See Klein, "Zur nicht-Euklidischen Geometrie," *Math. Annalen*, vol. xxxvii.

[3] See, *e.g.*, Lechalas, "Identité des plans de Riemann et des sphères d'Euclide," *Annales de la société scientifique de Bruxelles*, t. xx. (1896).

Now the important and interesting fact (which Riemann pointed out) is that we can conceive a point-manifold in which the measure of curvature is not zero, and in which, nevertheless, there is no hint of a reference to elements not contained in this manifold. In the usual theory of Euclidean surfaces there is a perpetual reference to points not on those surfaces—we have normals, tangent planes, &c. But Riemann pointed out how, by Gauss's method, such external reference could be avoided, provided we were willing to regard as identical all surfaces having the same formula for ds^2. For, from this formula, the measure of curvature can be found, and thence the geodesic Geometry of our surface follows. (In the formula for ds^2, two co-ordinates should be chosen which have a geometrical meaning on the surface—*e.g.*, geodesic polars.) Nevertheless (though Riemann appears to have overlooked this), the self-dependence of our Euclidean surface is only real when it is possible to effect measurements without leaving the surface, and this requires that the measure of curvature should be constant. When this condition is fulfilled the Geometry of our surface involves no reference to external space. But our surface still has external space outside it, and is thus not a space. What we have shown is, therefore, that a manifold *might* exist having the same internal relations as our surface, but destitute of the external relations which our surface also possesses. Such a manifold would be a Euclidean or non-Euclidean space of two dimensions. Such a space is radically different from a plane in three-dimensional space. Thus, *e.g.*, a plane has two sides and has position, while a two-dimensional space has neither. Hence we have three things to distinguish: (1) a sphere or pseudosphere in Euclidean space, (2) an elliptic or hyperbolic space of two dimensions, (3) a plane in an elliptic or hyperbolic space of three or more dimensions. Similarity in symbolic treatment does not show identity in the subject-matter treated. But the fact that we *can*, in treating of surfaces of constant curvature, abstract from relations to external space, shows that there is a logical possibility of a space containing similar internal relations without any external spatial relations. And in like manner, the possibility follows of three-dimensional spaces whose planes formally resemble Euclidean surfaces of constant curvature. On this point clearness is very important; for otherwise there is a danger of losing the essential and interesting point in non-Euclidean Geometry. A mere increase in the number of dimensions affords nothing radically novel; what *is* novel, is the discovery that space of a given number of dimensions may be of various kinds. Indeed, it is the very absence of reference to a higher Euclidean space which is chiefly interesting about the non-Euclidean spaces. From this point of view a direct investigation, starting from axioms like those of Lobatchewsky, Bolyai, and Newcomb, is preferable to more powerful but more symbolic methods.

The same reckless reference to spaces of higher dimensions, in which a given space may be supposed to be contained, has concealed the logical absurdity of regarding the measure of curvature as possibly variable. A figure contained in a space may have variable measure of curvature, since spatial quantities may still be equal in different places. But where a *space* is supposed to have variable measure of curvature, no such possibility exists. For it follows, in this case, as we saw in connexion with Riemann, that equal quantities in different places are impossible. Lengths in general differ qualitatively, and are therefore not measurable in terms of each other. Consequently no two quantities in different places can have a numerical ratio, since ratio implies division into equal parts. Hence metrical Geometry would collapse, and instead of a variable measure of curvature, we should have *no* measure of curvature. The essential thing about lengths is, that they are divisible quantities of the same kind, and therefore any two are equal or unequal, and have a numerical ratio. But when there is not a constant measure of curvature this essential property is lost; we can no longer say, of two lengths, that they must be equal or unequal. Hence homogeneity, or constant measure of curvature, is essential to metrical Geometry.

Motion irrelevant to Geometry.

Again, it is important to notice that we cannot appeal to *motion* in anything concerning the foundations of metrical Geometry. Motion, as used in Geometry, is not the motion of a single point, but the motion of many points, or even of all points. Now, if we ask how a motion is distinguished from other transformations, the only reply is, that it leaves metrical properties unchanged (with the restriction, strictly speaking, that it can be generated by infinitesimal steps). Thus metrical properties are presupposed in the definition of motion, and must not be defined by its means. Thus when Riemann, for example, assumes that ds is unaltered by the same infinitesimal motion of all the points of the infinitesimal arc, his argument is circular; for the *same* infinitesimal motion of a number of points can only be defined in terms of ds. The existence of equal spatial quantities in different places is presupposed in the definition of motion, and motion is not presupposed in metrical Geometry.

Relation between different space-constants.

A somewhat perplexing question arises, in connexion with the necessary all-inclusiveness of a space, as regards different values of the space-constant. Are there different possible hyperbolic spaces or elliptic spaces, having different space-constants, or is there only one space of each kind? Considering two spaces each as a whole, there seems no possibility of quantitative comparison between them, and it seems absurd to speak of one as having a greater or smaller space-constant than the other. All lengths in either can only be estimated relatively to the space-constant, which itself, except in relation to those lengths, has no particular magnitude. Nevertheless, we speak of our actual space as approximately Euclidean, and in relation to empirically given lengths we may certainly speak of greater or smaller space-constants. The following account seems to satisfy both these apparently opposite requirements. The space-constant of a space is one among lengths in that space, and has magnitude accordingly. The question, What is the ratio of the space-constant to some given length? has therefore a definite answer. But lengths in different spaces (even where both spaces are elliptic or both hyperbolic) differ in quality—they differ in the same way as do two shades of red. As is the case with shades of red, the different possible qualities form a continuous series; and the space-constants, along with all other lengths in their respective spaces, share these qualities, and thus acquire a place in a continuous series. Although each space-constant is a magnitude, each differs in quality from every other space-constant. No length in one space is greater or smaller than a given length in another space, and this extends also to their space-constants.[1] But when we ask, in our actual space, what is the ratio of the space-constant to (say) the diameter of the earth's orbit, the different possible answers correspond to different qualities which all our actual lengths may have—all of them have the same quality, but since the possible qualities form a continuous series (like shades of

[1] It is this necessity for a qualitative difference between lengths corresponding to different space-constants which, as we saw, makes impossible the metrical treatment of spaces without a definite space-constant.

colour), we do not know exactly which of the possibilities is actual. Thus, though one space-constant is not greater or smaller than another, we may legitimately inquire what is the ratio of our actual space-constant to empirically given lengths.

The second confusion resulting from the undue use of Euclidean analogies has been suggested by the projective treatment. Since all non-Euclidean results can be obtained, in Euclidean space, by a new measure of distance and angle, it seems superfluous to invent new spaces for the interpretation of the results in question. Thus Cayley always maintained the exclusive validity of Euclidean *space*, holding that, in non-Euclidean *Geometry*, he had merely substituted new measures in the old space. Against this view much may be said in detail, but the most cogent argument may be briefly stated. If there are such quantities as distance and angle, their measure can only be arbitrary so far as concerns the choice of a unit, and any different measure must be simply false; while if there are no such quantities, then they can have no measure at all. Thus it is in no case open to us to choose arbitrarily, among several functions differing by more than a constant factor, which of them shall express distance or angle: either one such choice or none must be correct. Passing to the actual case, we find that, when our co-ordinates express anharmonic ratios obtained by Staudt's construction, the distance of two arbitrary points on a line is obtained by keeping two of the points required for anharmonic ratio fixed. Thus only two variable points remain, and the logarithm of the anharmonic ratio thus obtained has always, however our fixed points are chosen, a certain resemblance to distance, consisting chiefly in the fact that it is additive. It may then be doubtful what pair of points on our line are to be fixed, but only one such pair can actually give the distance, unless indeed there be no such thing as distance. This may be easily seen by considering that our two fixed points, in virtue of the formula, are at an infinite distance from all other points on the line. If there be such a thing as distance, it is therefore necessary that our fixed points should be at infinity in some not purely conventional sense. The different types of straight line are really, and not merely artificially, distinguished by the property of having their points at infinity real and distinct, imaginary, or coincident. It is true we may take the other alternative, and deny the existence of distance altogether: there is nothing in pure projective Geometry to imply its existence. But then we cannot know that *all* the points of our line form a series. Only those obtained by successive quadrilateral constructions will form a series, unless we introduce order by Pieri's method (*I principii della Geometria di Posizione*, Turin, 1898—a work which marks a great advance in logical purity). And thus our arbitrary definition does not necessarily give a distance to every pair of points. It should be observed that we cannot, without assuming the metrical order obtained from distance, legitimately ask whether the points obtained by repeated quadrilateral constructions are evenly distributed (*überall dicht*), or whether they leave gaps. For such a question implies that our points have an order independent of that obtained by the quadrilateral construction, and this in turn implies distance. We can only ask whether the points we obtain are *all* the points of the line, but to this question projective Geometry gives no answer. Metrical Geometry, however, gives a negative answer, for the points projectively obtained form a denumerable series, while *all* the points form, in Cantor's phrase, a series of the power of the continuum (see NUMBER). Thus only a vanishing proportion of the points of a line form, with three given points, a range having, in the pure projective sense, an anharmonic ratio. Finally, there is a last curious restriction to the projective method. The uniqueness of the quadrilateral construction cannot be *projectively* proved without three dimensions, and hence there is no pure projective Geometry of spaces having only one or two dimensions.

Projective theory of distance.

A third confusion remains as regards the relation of the axiom of congruence to rigid bodies. The axiom of congruence is the axiom in virtue of which superposition may be used (as in Euclid's fourth proposition) to prove the equality of two figures. But there is some difficulty in stating precisely the requisite axiom. Helmholtz maintained (*e.g.*, *Wiss. Abh.* Bd. ii. pp. 614, 616) that it asserts the actual existence of rigid bodies, and thence inferred that Geometry is dependent upon Mechanics. He supported his view by reference to the process of measurement, in which the measure must be, at least approximately, a rigid body. In so far as it is not rigid our results are inaccurate—unless, indeed, we know how to allow for its changes of shape, which would imply some still more rigid body by which our measure is itself measured. Thus, in so far as measurement is trustworthy, it implies the existence of bodies which, during the motion required for superposition, do not greatly change in shape. But this is not an analysis of what is *meant* by spatial equality, and is not relevant to Geometry. The definition of a rigid body, like the definition of. geometrical motion, presupposes what is really meant by the axiom of congruence. A rigid body is one which, at different times, occupies equal spaces. Thus equality of spaces is logically prior to rigidity of bodies. How we discover two actual spaces to be equal is no concern of the geometer; all that concerns him is the existence of equal spaces, the fact that two spatial quantities may be equal or unequal. And this is indeed the true meaning of the axiom. Given two points at a certain distance apart, and any third point, the axiom asserts that there are, on any straight line through the third point, two points whose distance from the third point is equal to the given distance; it makes also similar assertions as regards areas and volumes. This is all that metrical Geometry requires as regards an axiom of spatial equality. The apparent use of motion is deceptive; what, in Geometry, is called a motion, is merely the transference of our attention from one figure or set of elements to another. Actual superposition, which is nominally employed by Euclid, is not required; all that is required is the transference of attention from the original figure to a new one, defined by the position of some of its elements and by certain properties which it shares with the original figure. This may be enforced by two simple considerations: (1) What is purely spatial cannot move: a given point, line, or plane is what it is in virtue of its place, and can never change that place. It is only what *occupies* space, *i.e.*, matter, that can move. (2) If rigid bodies formed any part of the *meaning* of congruence, it would be self-contradictory to assert, as science does assert, that no body is perfectly rigid. For before we can discuss whether or not a body is rigid, we must be able to decide as to its dimensions at different times; and if this *means* a comparison with a standard body, then it is a logical impossibility that the standard body should itself be supposed changeable. The standard body would be itself the unit, and could no more suffer change than any other absolute unit. The whole confusion appears to be due to not distinguishing between the process of measurement, which is of purely practical interest, and the meaning of equality, which is essential to all metrical Geometry.

Rigid bodies unnecessary in Geometry.

Four stages in specifying a space.

We may now proceed to specify the various stages in the particularization of spaces, pointing out what axioms lead to given portions of Geometry. We may distinguish four stages, each with its appropriate axioms. In the first stage we assume only the purely projective properties; in the second, we further assume distance; in the third, we assume that, in a space of n dimensions, there are $\infty^{\frac{1}{2}n\cdot\overline{n+1}}$ motions (*i.e.*, transformations leaving all distances unchanged); in the fourth, finally, we distinguish between the four usual types of space, and become confined to one among them. Thus all the axioms of the first three stages are common to Euclidean, hyperbolic, and elliptic spaces.

Projective axioms.

I. The pure projective theory knows nothing of distance, nor, consequently, of any order among points, lines, or planes, except that introduced by the quadrilateral construction. By means of this construction it defines a harmonic range, pencil, or sheaf; by the series of quadrilateral constructions (where any such series exists) required to reach a given point from three original points in the same straight line, it defines the anharmonic ratio of a range (with similar definitions for a pencil or sheaf). We can show that, where four elements have an anharmonic ratio at all, this is unaltered by projection; and we can establish the usual propositions concerning homography. For that (unknown) proportion of elements projectively obtainable from the requisite number of original elements, we can, in short, in a space of three or more dimensions, establish all the usual propositions of projective Geometry. In three dimensions the axioms required for this most general Geometry will be found to be the following:—

(1) Any two points (planes) in general determine a straight line, and any three which are not collinear in general determine a plane (point). The same line is determined by an infinite number of other pairs of points (planes), and the same plane (point) by an infinite number of other triplets of points (planes). A plane or line is said to contain any point which is one of those determining it, and a point or line is said to lie on any plane which is among those determining it.

(2) When two planes (points) both contain (lie on) two points (planes), they contain (lie on) the line determined by the two points (planes).

(3) A plane may also be determined by a determining point and the line joining two others of its determining points; and conversely, a point is determined by a plane and a line.

In these axioms the dualistic assertions regarding planes and points are not alternatives, but are both necessary. The corresponding axioms for any number of dimensions are of the same form, and are necessary to any Geometry of that number of dimensions; but in the case of two dimensions, they are not, by themselves, sufficient to found a Geometry. In order to apply the axioms to hyperbolic space it is necessary to take account of ideal elements.[1]

Axioms of distance.

II. With the assumption of distance a new set of axioms is introduced, and metrical Geometry becomes possible. Projective Geometry assumes one relation, the straight line, between any pair of points; we now introduce another relation, namely distance, which, unlike the straight line, is a quantity. All distances are regarded as quantities of the same kind, and thus the metrical homogeneity of space is involved. We are restricted, therefore, to spaces having a space-constant. In all of these, the angle-sum of a triangle differs from two right angles by some constant multiple of the area of the triangle. When this multiple is zero, the geometry of figures not exceeding some finite size is always Euclidean. But the space is not yet wholly specified; it may differ as to connectivity, as to finitude or infinity, and as to the number of degrees of freedom in motions. The axioms by which the nature of distance is specified are the following:—

(1) Any two points have a quantitative relation called distance, which, if both points are real, only vanishes when they coincide. Any two distances are quantities of the same kind. (Thus, if both are real, either they are equal, or one is greater than the other.)

(2) If p, q, r be three points in one straight line, the sum of the distances pq, qr is equal to the distance pr (distances in different directions being defined to have different signs, so that $pq+qp=0$).

(3) If a, b, c be any three points, and the distances ab, bc are finite, then the distance ac is finite. If ab is finite, and bc infinite, or *vice versâ*, then ac is infinite. Also if ab, bc are real, then ac is real.[2]

Free mobility.

III. The next step is to introduce free mobility in the sense defined by Lie's axiom C (*v. supra*). Free mobility in the general sense was already introduced by homogeneity, that is, any figure could be freely moved in $\infty^{\frac{1}{2}n\cdot\overline{n+1}}$ ways (supposing our space to have n dimensions). But Klein has pointed out that it does not follow from this that a space as a whole can be transformed into itself in the same number of ways. The addition of this further axiom to those given above shows that our space is of one of the four usual types.[3] All the spaces excluded by this axiom differ from those that remain in some discontinuous respect—*i.e.*, as regards their connectivity and *analysis situs*. The four types which remain, on the other hand, contain Euclidean space as a limiting case between hyperbolic space and either form of elliptic space, and are thus in a different position from the excluded types.

Differences among the four principal spaces.

IV. It remains to specify the differences between the four remaining types. These differences are chiefly metrical, but each space may also be distinguished by projective properties, provided we exclude ideal elements. Thus (1) in the antipodal form of elliptic space two straight lines in a plane intersect always in two points; in the other spaces they intersect at most in one point. (2) In the polar form of elliptic space two straight lines in a plane always intersect; in Euclidean and hyperbolic space they may or may not intersect. (3) In hyperbolic space intersection and non-intersection are equally general cases; in Euclidean space non-intersection is a limiting case. But these projective distinctions are overcome by introducing ideal elements wherever required, and by identifying antipodal points in antipodal elliptic space, and by this means projective propositions become identical for all four spaces. The metrical differences are more serious. In the first place, all non-Euclidean spaces have an absolute unit of length, the space-constant, just as all spaces, including Euclid's, have an absolute unit of angle. Hence lengths, in non-Euclidean geometries as in spherical trigonometry, appear only in their ratios to an absolute unit. The geometrical meaning of the space-constant, in the two forms of elliptic space, is simple: the length of a complete straight line is, in the polar form, πk, in the antipodal form, $2\pi k$ (where k is the space-constant). (In hyperbolic space, where the straight line is infinite, the geometrical meaning is less simple.) All questions concerning

[1] For the way in which this is done, see Pasch, *Neuere Geometrie*, Leipzig, 1882, esp. §§ 6–9.

[2] See Whitehead, *Universal Algebra*, Bk. vi. chap. i.

[3] See Klein, *Math. Annalen*, vol. xxxvii. pp. 554–565.

parallelism are of course metrical, as is the question concerning the sum of the angles of a triangle. Thus, speaking broadly, projective theorems are the same in all the spaces, while metrical theorems are different. But the measurement of angles and the Geometry in a point (*i.e.*, of lines through a given point) are the same in all spaces, being in fact elliptic. This is due to the fact that angular measurement is determined by those properties of linear measurement which are the same in all spaces. The circle is always a closed curve, since all lines through its centre always meet it in two points. Hence the lines in a plane through a point form a closed series, and the measurement of angles is elliptic.[1]

Two general questions.

The various possibilities which we have reviewed raise two distinct questions. The first of these is philosophical: Have we, as Kant maintained, any *à priori* ground for excluding all or some of the non-Euclidean spaces? The second, which presupposes a decision that some, at least, of the non-Euclidean spaces are *à priori* possible, is scientific: What empirical means have we for deciding which of the possible spaces is actual? What are the best observations, or are there any observations, upon which we may base an opinion? These questions are radically distinct, and it is important to discuss them separately.

Supposed à priori grounds for Euclidean space.

Kant had contended that space, on grounds independent of Geometry, is an *à priori* form of intuition, and that Geometry, consequently, has apodeictic certainty; while conversely he inferred, from the then admitted apodeictic character of Geometry, that space must be an *à priori* form of intuition. These two lines of argument, which supported one another, were called respectively the metaphysical and the transcendental deductions of space (*Critique of Pure Reason*, 2nd ed.) Against this theory non-Euclidean Geometry has, from the first, been regarded as a very powerful argument, and its promoters—Gauss, Lobatchewsky, Bolyai, Riemann, Helmholtz—have all pointed out the supposed refutation of Kant. Riemann and Helmholtz, who deal explicitly with the philosophical question, consider all geometrical axioms to be empirical,[2] though Riemann, at least, appears to regard arithmetic and algebra as *à priori*. It would seem, however, that non-Euclidean Geometry, though it gives Kant's doctrine something of the air of a paradox, cannot, strictly speaking, be considered as logically affecting that doctrine. A purely philosophical theory, such as that of Kant, can only be met by purely philosophical arguments; mathematics, though capable of *suggesting* new views, can hardly be capable of *proving* them. If the reasons which Kant adduces, in the metaphysical deduction, for holding space to be an *à priori* form of intuition be found valid, they are alone sufficient to prove his conclusion, and these reasons are wholly unaffected by non-Euclidean Geometry. Even the transcendental deduction, though robbed of most of its plausibility, can hardly be disposed of by mathematics alone—for mathematics alone, however many new Geometries it may invent, can never prove that the truth of Euclid is uncertain. Indeed, Kant's doctrine, as compared with those of the earlier idealists, is peculiarly adapted to meet the opponents of Euclid—so much so, indeed, as to suggest a possible influence of Lambert (*v. supra*), with whom Kant carried on a correspondence. In Kant's first published work (ed. Hartenstein, 1867, vol. i. pp. 21 *ff.*), he maintained the possibility of space with more than three dimensions, this being the only departure from Euclid with which he was then acquainted.

[1] See an article by B. Russell in the *Revue de métaphysique et de morale*, November 1899.

[2] See also Erdmann, *Axiome der Geometrie*, Leipzig, 1877.

In the *Critique of Pure Reason*, on the contrary, it is precisely the axiom of three dimensions which he instances as an example of apodeictic geometrical propositions (*ib.* vol. iii. p. 61). It was not the logical possibility of other spaces than Euclid's which could shake his doctrine; indeed, this was expressly admitted by the theory that all geometrical propositions are synthetic, *i.e.*, can be denied without contradiction. The essence of his answer to scepticism lay in the contention that we may be certain *à priori* of some propositions whose contradictory is not logically absurd. Thus Kant must be met, not by a simple appeal to non-Euclidean Geometry, but by the establishment of some philosophical proposition, *e.g.*, by one of the following three: (1) We have an intuition of non-Euclidean spaces; (2) in the sense in which Kant uses the word, we have no intuition of Euclidean space; (3) our intuitions are irrelevant in a logical inquiry concerning space. No one of these three propositions follows from non-Euclidean Geometry alone. Helmholtz maintained the first, but seems to have misunderstood Kant's meaning.[3] Both the second and third seem to be capable of proof; but their discussion, which belongs properly to the criticism of Kant, would carry us too far from our subject to be attempted here.

It remains to inquire whether spaces not belonging to the four main types are logically possible, and if so, why they have received so little attention from mathematicians. The reply seems to be, as regards those which have no space-constant, that, though they are logically possible, they differ from Euclidean space so materially as to be destitute of the interest belonging to spaces more akin to that in which we live. The spaces which have a space-constant, but do not fulfil Lie's axiom of free mobility, appear, however, to deserve just as much consideration as the four usual types, and to have failed to receive it only because of their recent discovery.[4] These types allow, so far as figures not exceeding a certain size are concerned, the usual kind of mobility throughout a certain region, and this is all that experience can warrant us in demanding. But spaces (if so they can be called) which have no space-constant, though possible logically, would be incapable, as we have seen, of metrical treatment. Although pure projective Geometry would still be possible, we have seen how narrow are the limits of this science. Thus the axioms of distance, as well as the projective axioms, are necessary to any Geometry at all closely resembling the Geometry of our actual space.

Scientific evidence as to the nature of actual space.

The scientific question, as to the best available evidence concerning the nature of actual space, is one beset with difficulties of a peculiar kind. Admitting non-Euclidean spaces to be possible, we must also admit, since Euclidean space is merely a limiting case to which other spaces may indefinitely approximate, that the space we live in, though approximately Euclidean, may be found, on closer examination, to be of one or other of the non-Euclidean types. But in making this closer examination, we are obstructed by the fact that all existing physical science assumes the Euclidean hypothesis. This hypothesis has been involved in all actual measurements of large distances, and in all the laws of astronomy and physics. The principle of simplicity would therefore lead us, in general, where an observation conflicted with one or more of those laws, to ascribe this anomaly, not to the falsity of Euclidean Geometry, but

[3] *Mind*, O.S., vols. i. iii.; see also Land's reply, *ib.* vol. ii.

[4] One of them, the surface of zero curvature in elliptic space, was discovered by Clifford, and expounded in a paper at the British Association in 1873, but the first publication on the subject was Klein's in 1890 (*Math. Annalen*, vol. xxxvii.)

to the falsity of the laws in question. This applies especially to astronomy. On the earth our means of measurement are many and direct, and so long as no great accuracy is sought they involve few scientific laws. Thus we acquire, from such direct measurements, a very high degree of probability that the space-constant, if not infinite, is yet large as compared with terrestrial distances. But astronomical distances and triangles can only be measured by means of the received laws of astronomy and optics, all of which have been established by assuming the truth of the Euclidean hypothesis. It therefore remains possible (until a detailed proof of the contrary is forthcoming) that a large but finite space-constant, with different laws of astronomy and optics, would have equally explained the phenomena. We cannot, therefore, accept the measurements of stellar parallaxes, &c., as conclusive evidence that the space-constant is large as compared with stellar distances. For the present, on grounds of simplicity, we may rightly adopt this view; but it must remain possible that, in view of some hitherto undiscovered discrepancy, a slight correction of the sort suggested might prove the simplest alternative. But conversely, a finite parallax for very distant stars, or a negative parallax for any star, could not be accepted as conclusive evidence that our space is non-Euclidean, unless it were shown—and this seems scarcely possible—that no modification of astronomy or optics could account for the phenomenon. Thus although we may admit a probability that the space-constant is large in comparison with stellar distances, a conclusive proof or disproof seems scarcely possible.

Finally, it is of interest to note that, though it is theoretically possible to prove, by scientific methods, that our space is non-Euclidean, it is wholly impossible to prove by such methods that it is accurately Euclidean. For the unavoidable errors of observation must always leave a slight margin in our measurements. A triangle might be found whose angles were certainly greater, or certainly less, than two right angles; but to prove them *exactly* equal to two right angles must always be beyond our powers. If, therefore, any man cherishes a hope of proving the exact truth of Euclid, such a hope must be based, not upon scientific, but upon philosophical considerations.

If we ask what is, for philosophy, the main value of non-Euclidean Geometry, two points may be mentioned.

Philosophical value of non-Euclidean Geometry.

The first lies in the clear separation of different sets of axioms, and the resulting logical analysis of geometrical results. We have seen how to separate clearly the portions of Geometry involving any assumption from those which are independent of it, and how to construct a hierarchy of more and more specialized systems, beginning with projective Geometry and ending finally with Euclid. By this means we discover more clearly than was formerly possible whether any two propositions in Geometry are logically connected, or are independent of one another. The attempts which, down to Legendre, occupied a long series of great mathematicians, to deduce the postulate of parallels from the rest of Euclid's assumptions, are now known to be vain; and the same impossibility has gradually appeared in regard to the passage from any one of the four stages enumerated above to a later stage. A restraining influence is thus exercised upon the wholesale deductions of philosophers, and an example is afforded of the synthetic nature of mathematical propositions. The second point which non-Euclidean Geometry elucidates is of more strictly philosophical interest. We have seen that there are a number of possible Geometries, each of which may be developed deductively with no appeal to actual facts. But no one of them, *per se*, throws any light on the nature of our space. Thus geometrical reasoning is assimilated to the reasoning of pure mathematics, while the investigation of actual space, on the contrary, is found to resemble all other empirical investigations as to what exists. There is thus a complete divorce between Geometry and the study of actual space. Geometry does not give us certain knowledge as to what exists. That peculiar position which Geometry formerly appeared to occupy, as an *à priori* science giving knowledge of something actual, now appears to have been erroneous. It points out a whole series of possibilities, each of which contains a whole system of connected propositions; but it throws no more light upon the nature of our space than arithmetic throws upon the population of Great Britain. Thus the plan of attack suggested by non-Euclidean Geometry enables us to capture the last stronghold of those who attempt, from logical or *à priori* considerations, to deduce the nature of what exists. The conclusion *suggested* is, that no existential proposition can be deduced from one which is not existential. But to *prove* such a conclusion would demand a treatise upon all branches of philosophy.

In addition to the works already referred to, the following are among the most important for a study of the subject:—FLYE, STE. MARIE. *Études analytiques sur la théorie des parallèles.* Paris, 1871.—FRISCHAUF. *Absolute Geometrie nach Johann Bolyai.* Leipzig, 1872; *Elemente der absoluten Geometrie*, Leipzig, 1876.—CLIFFORD. "Preliminary Sketch of Biquaternions," *Proc. Lond. Math. Soc.*, 1873; and *Collected Mathematical Papers.*—KILLING. *Die nicht-Euklidischen Raumformen in analytischer Behandlung.* Leipzig, 1885.—CLEBSCH-LINDEMANN. *Vorträge über Geometrie*, vol. ii., Leipzig, 1891.—KLEIN. *Vorlesungen über höhere Geometrie.* Göttingen, 1893.—VERONESE. *Grundzüge der Geometrie*, Leipzig, 1894 (translation from the Italian).—LIE. *Theorie der Transformationsgruppen*, Leipzig, 1893 (third section).—A bibliography of non-Euclidean literature down to the year 1878 was given by Halsted, *American Journal of Mathematics*, vols. i. ii. (B. A. W. R.)

George, Friedrich August, KING OF SAXONY (1832-——, the youngest son of King John of Saxony (died 1873) and the Queen Amelia, was born at Dresden on 8th August 1832. From an early age he received a careful scientific and military training, and in 1846 entered the active army as a lieutenant of artillery. In 1849–50 he was a student at the University of Bonn, but soon returned to military life, for which he had a predilection. In the Austro-Prussian war of 1866 he commanded the first Saxon cavalry brigade, and in the early part of the war of 1870–71 the first division of the Saxons, but later succeeded to the supreme command of the 12th (Saxon) Army Corps in the room of his brother, Albert (afterwards king) of Saxony. His name is inseparably associated with this campaign, during which he showed undoubted military ability and an intrepidity which communicated itself to all ranks under his command, notably at the battles of St Privat and Beaumont, in which he greatly distinguished himself. On his brother succeeding to the throne he became commander-in-chief of the Saxon army, and was in 1888 made a field-marshal by the Emperor William I. He married in 1859 the Infanta Maria, sister of King Louis of Portugal, and King Albert's marriage being childless, succeeded on his death in 1902 to the throne of Saxony.

George I., KING OF THE HELLENES (1845-——), second son of King Christian IX. of Denmark, was born at Copenhagen, 24th December 1845. After the expulsion of King Otho in 1862, the Greek nation, by a plebiscite elected the British prince, Alfred, duke of Edinburgh (subsequently duke of Coburg), to the vacant throne, and on his refusal the national assembly requested Great Britain to nominate a candidate. The choice of the British Government fell on Prince Christian William

Ferdinand Adolphus George of Schleswig-Holstein-Sonderburg-Glücksburg, whose election as King of the Hellenes, with the title George I., was recognized by the Powers 6th June 1863. The sister of the new sovereign, Princess Alexandra, had a few months before (10th March) married the Prince of Wales, afterwards King Edward VII., and his father succeeded to the Crown of Denmark in the following November. Another sister, the Princess Dagmar, subsequently married the Grand Duke Alexander Alexandrovitch, afterwards Emperor Alexander III. of Russia. On his accession, King George signed an act resigning his right of succession to the Danish throne in favour of his younger brother Prince Waldemar. He was received with much enthusiasm by the Greeks. Adopting the motto, "My strength is the love of my people," he has always ruled in strict accordance with constitutional principles, though not hesitating to make the fullest use of the royal prerogative when the intervention of the Crown seemed to be required by circumstances. His influence with foreign Courts and Governments has been largely instrumental in saving the country from the consequences of political aberrations, and proved invaluable after the misfortunes of 1897. King George married, 27th October 1867, the Grand Duchess Olga Constantinovna of Russia. His surviving children are Prince Constantine, Duke of Sparta, born 1868, married in 1889 to Princess Sophia of Prussia, daughter of the Emperor Frederick, and granddaughter of Queen Victoria; Prince George, born 1869, since November 1898 High Commissioner of the Powers in Crete; Prince Nicholas, born 1872; Prince Andrew, born 1882; Prince Christopher, born 1888; and a daughter, Princess Marie, born 1876, and married in 1900 to the Grand Duke George Michaïlovitch of Russia. Queen Olga, who is distinguished for her beneficence, has founded many charitable institutions in Greece. (See also GREECE: *History*.)

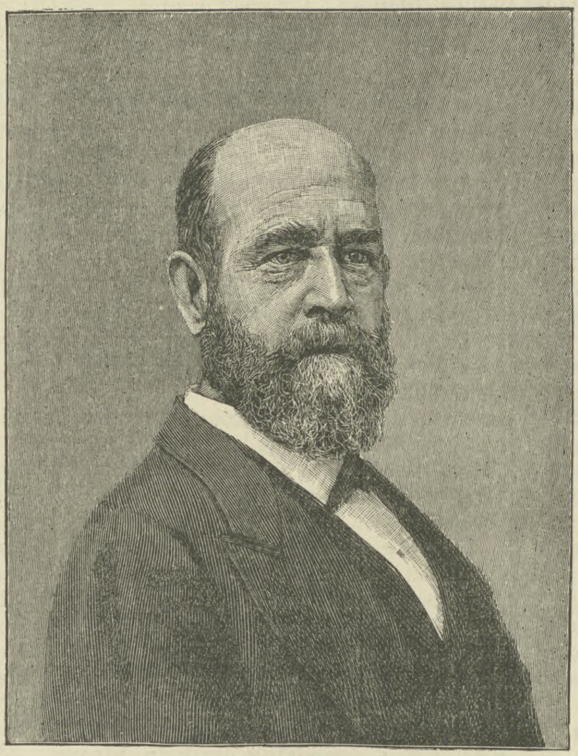
George V., KING OF HANOVER (1819–1878), only son of Ernest Augustus, duke of Cumberland, was born at Berlin on the 27th of May 1819. His mother was Princess Frederike of Mecklenburg, sister to Queen Louise of Prussia. He was educated partly in Berlin and partly in England. His father, the ablest of the sons of George III., on the death of William IV. became king of Hanover, which was henceforth separated from the British crown. George, while a child, lost the sight of one eye during an illness, and in 1833, while playing with Prince George of Cambridge (the duke of Cambridge) at Kew, struck his other eye with a purse which he was swinging; the injury, which was increased by an unsuccessful operation, resulted in total blindness. There were doubts whether he was qualified to succeed to the government, but his father decided that he should do so, as the law of the old empire only excluded princes who were born blind. The decision was a fatal one to the dynasty. Both from his father and still more from his uncle, Prince Charles of Mecklenburg, one of the most influential men at the Prussian Court, George had learnt to take a very high view of royal authority. His blindness prevented him from having that shrewdness and knowledge of the world which had been of such assistance to his father, and he easily fell into the hands of unwise, and perhaps disloyal and dishonest, advisers. A man of deep religious feeling, he formed a fantastic conception of the great place assigned to the house of Guelph in the Divine economy. It is therefore not surprising that from the time of his accession (1851) he was constantly involved in constitutional disputes with the Estates of his kingdom. When the crisis of 1866 came the Hanoverian Government had therefore a bad reputation in Germany as being opposed to the Liberal and National ideals of the time. George, wishing to adhere to the federal treaties, refused all offers both from Prussia and from Austria to enter into a special alliance, and especially declined to enter into any fresh union with Prussia in which he would be required to surrender any of his sovereign rights. The outbreak of war therefore found Hanover without allies, and unprepared. Prussia then, on 15th June, addressed to the king a summary demand that within twelve hours he should undertake to disband his army, observe neutrality during the war, and enter into an alliance with Prussia. This the king refused to do, contrary to the wishes of the Hanoverian Parliament and the petition of the municipality of the city. The Prussian envoy then declared war, but before he had done so Prussian troops had crossed the frontier. George ordered his army to assemble at Göttingen, and then on 19th June, with a force of 18,000 men, began an adventurous march, hoping to be able to make his way south and join the Bavarians. Owing to the faulty strategy of the Prussians this would probably have been possible had not the king allowed himself to be persuaded to enter into negotiations; the delay enabled fresh troops to be brought up. The king, when he was informed of this, broke off the negotiations. The Hanoverians succeeded in inflicting a severe defeat on the Prussian forces which attacked them at Langensalza on 27th June, but before they were able to continue the march so many fresh Prussian troops had come up that they were obliged to capitulate. The terms of the capitulation determined that the king should not return to Hanover, which was now in the hands of the Prussians. After a few days he proceeded to Vienna, but when, at the conclusion of the war, he addressed a letter to the king of Prussia requesting to know the terms of peace, it was not accepted, and on 20th September a law was introduced in the Prussian Parliament decreeing the annexation of Hanover. It was a step which could only be justified on the ground of political expediency. The king's indignant protest and his appeals for help to France, Great Britain, and Russia were equally in vain. An inquiry whether it would be of any use if the king abdicated in favour of his son was met by the answer that it was too late. His protests were supported by a large party among his subjects, and he began an agitation which for a time caused serious embarrassment to the Prussians. Unfortunately he allowed himself also to be led into fantastic schemes, such as the formation of a Guelph Legion, consisting of Hanoverian officers and soldiers who refused to enter the Prussian service. To the number of 1200 they were maintained at the king's expense in France, and his agents also founded a paper, *La Situation*, and a speculative bank in Vienna. All hopes of being able to bring about a rising in Hanover and recovering the kingdom were destroyed by the war with France, and in 1870 the Guelph Legion was disbanded. None the less George always refused any reconciliation with the Prussian Government. He passed the rest of his life at Gmünden in Austria, but in 1876 went to Paris for medical advice, and died there on the 12th of June 1878. He was buried in St George's Chapel at Windsor.

He had married in 1843 Marie, daughter of the duke of Saxe-Altenburg. He left one son, Ernest Augustus, duke of Cumberland, who married in 1878 Princess Thyra of Denmark, and still maintains the claims of his house to the kingdom of Hanover. (See GERMANY: *History*.)

By the capitulation of Langensalza the enjoyment of his personal property was secured to the king. A large sum, including nearly £1,000,000 in securities, nearly £200,000 in specie, and £100,000 in bank-notes, was safely removed before the Prussians entered Hanover, sent to England, and deposited in the Bank of England. The valuable plate was buried at Herrenhausen, and remained safely hidden till the end of 1867, when it was restored to the king. The Crown jewels were also secretly carried to England during 1866. The rest of the king's property consisted of landed estate. The British Government offered to help in bringing the settlement of his claims to a conclusion, and in 1867 the king agreed to accept 11 million thalers (£1,600,000) in 4½ per cent. Prussian bonds. After the agreement had been signed the Prussian Government, in consequence of the continued acts of hostility on the part of the king, was obliged to sequestrate this property. It was administered by a special commission, and the accounts were not published, and was therefore available as a secret service fund, known as the *Welfenfonds*, or more colloquially the *Reptilienfonds*. In 1892, however, the sequester was removed, and it was arranged to pay the interest derived from the fund to the duke of Cumberland. The palace of Herrenhausen near Hanover is also reserved as the property of the duke, and has been uninhabited since 1866.

See W. v. Hassell. *Geschichte des Königreichs Hannover.* Leipzig, 1897–1901.—Meding. *Memoiren zur Zeitgeschichte*, 3 vols. 1881–84.—O. Klopp. *König Georg V.* (J. W. He.)

George, Henry (1839–1897), American author and political economist, was born in Philadelphia, U.S.A., 2nd September 1839. He settled in California in 1858; removed to New York, 1880; was first a printer, then an editor, but finally devoted all his life to economic and



Henry George.
(From a photograph by Sarony, New York.)

social questions. In 1871 he published *Our Land Policy*, which, as further developed in 1879 under the title of *Progress and Poverty*, speedily attracted the widest attention both in America and Europe. In 1886 he published *Protection or Free Trade.* Henry George had no political ambition, but in 1886 he received an independent nomination as Mayor of New York City, and became so popular that it required a coalition of the two strongest political parties to prevent his election. He received 68,000 votes, against 90,000 for the coalition candidate. His death on 29th October 1897 was followed by one of the greatest demonstrations of popular feeling and general respect that ever attended the funeral of any strictly private citizen in American history. The fundamental doctrine of Henry George, the equal right of all men to the use of the earth, did not originate with him; but his clear statement of a method by which it could be enforced, without increasing state machinery, and indeed with a great simplification of government, gave it a new form. This method he named the *Single Tax.* His doctrine may be condensed as follows: The land of every country belongs of right to all the people of that country. This right cannot be alienated by one generation, so as to affect the title of the next, any more than men can sell their yet unborn children for slaves. Private ownership of land has no more foundation in morality or reason than private ownership of air or sunlight. But the private occupancy and use of land are right and indispensable. Any attempt to divide land into equal shares is impossible and undesirable. Land should be, and practically is now, divided for private use in parcels among those who will pay the highest price for the use of each parcel. This price is now paid to some persons annually, and it is called *Rent.* By applying the rent of land, exclusive of all improvements, to the equal benefit of the whole community, absolute justice would be done to all. As rent is always more than sufficient to defray all necessary expenses of government, those expenses should be met by a tax upon rent alone, to be brought about by the gradual abolition of all other taxes. Landlords should be left in undisturbed possession and nominal ownership of the land, with a sufficient margin over the tax to induce them to collect their rents and pay the tax. They would thus be transformed into mere land agents. Obviously this would involve absolute free trade, since all taxes on imports, manufactures, successions, documents, personal property, buildings, or improvements would disappear. Nothing made by man would be taxed at all. The right of private property in all things made by man would thus be absolute, for the owner of such things could not be divested of his property, without full compensation, even under the pretence of taxation. The idea of concentrating all taxes upon ground-rent has found followers in Great Britain, North America, Australia, and New Zealand. In practical politics this doctrine is confined to the "Single Tax, Limited," which proposes to defray only the needful public expenses from ground-rent, leaving the surplus, whatever it may be, in the undisturbed possession of land-owners.

The principal books by Henry George are: *Progress and Poverty* (1879), *The Irish Land Question* (1881), *Social Problems* (1884), *Protection or Free Trade* (1886), *The Condition of Labor* (1891), *A Perplexed Philosopher* (1892), *Political Economy* (1898). The Single Tax theory is fully discussed on the basis of statistics in Shearman's *Natural Taxation* (1895). (T. G. S.)

Georgia, one of the south Atlantic states of the American Union, bounded on the N. by Tennessee and North Carolina, on the E. by South Carolina and the Atlantic, on the S. by Florida, and on the W. by Alabama. The period of reconstruction after the Civil War—from 1865 to 1870—found everything in an unsettled condition, with the negroes newly enfranchised and the state under military control. The administration of affairs was largely in the hands of "carpet-baggers"—new-comers who had either been left in the state as a heritage of war, or were imported to assist in the distribution of the political loaves and fishes. Many negroes were elected to the Republican legislature and to the constitutional convention which assembled during that period, and the Democrats were practically eliminated from state affairs. In 1870 by compact organization of the whites the Democrats obtained control, and in 1877 the Reconstruction constitution of 1868 was superseded by the new state constitution. Since then the average number of Republican legislators out of a total of 219 has probably not exceeded half-a-dozen. In handling the racial and political problems introduced by the enfranchisement of the negroes Georgia has been fortunate. While there have been occasional outbreaks of popular feeling, they have been sporadic, and have only increased the determination of the whites to bring order out of chaos. Georgia has emphatically refused to join in legislation looking to either disfranchisement of the blacks or discrimination against them. The public funds for education are divided between whites and blacks in just proportion, and in the courts absolute justice prevails. At the same time the whites have upheld Caucasian civilization through moral force, the justice of which has given it victory.

Population.—Under the new constitution the state has advanced rapidly. In 1890 the population was 1,837,353, of whom 978,357 were whites and 858,996 negroes; 919,925 were males and 917,428 females; 1,825,216 native-born and 12,137 foreign-born. In 1900 the population was 2,216,331, showing an increase of 20·6 per cent. for the decade. Three-quarters of the growth of population was made up of white immigrants from other states. The land surface of Georgia is approximately 58,980 square miles, so that the number of persons to the square mile was 37·5 in 1900, as compared with 31·1 ten years before. Of the total population in 1900, 1,103,201 (49·8 per cent.) were males and 1,113,130 (50·2 per cent.) females; 2,203,928 were native-born and 12,403 (0·6 per cent.) foreign-born; 1,181,109 were white and 1,035,222 (46·7 per cent.) coloured, of whom 1,034,998 were negroes, 204 Chinese, 1 Japanese, and 19 Indians. There were 372 incorporated cities, towns, or villages in the state in 1900, of which 13 had a population exceeding 5000, and 3 a population exceeding 25,000. These three are Atlanta with 89,872, Savannah with 54,244, and Augusta with 39,441. In 1890 the urban population — classing as such all persons in cities of 8000 inhabitants or more—was 10·8 per cent.; of the total population in 1900 it was 11 per cent. The death-rate in 1900 was 12·1. The increase of city population in 1900 was due to natural growth, and not to any marked exodus from the country.

Education.—A fund of $1,900,000 per annum for education, furnished from various sources by the state government, is divided among the counties on the basis of school population between the ages of six and eighteen. There are special systems in Atlanta, Savannah, Augusta, Macon, Columbus, Rome, Brunswick, and many other cities and towns, so that the aggregate of annual expenditures for public schools may be placed at $3,000,000. Throughout the entire state the whites and blacks are educated separately, and there is an ascertained division of the funds between them. The number of persons of school age (5 to 20 years inclusive) in 1900 was 885,725. The number in attendance at the grammar and high schools is 423,467. Of these 251,093 are white and 172,374 black. Of the total of illiterates above ten years of age, 93,614 are white and 331,814 are coloured. Out of 500,752 males of voting age (21 years and over) in 1900, 158,247 were illiterate (unable to write), of whom 32,456 were white and 125,712 were negroes. The University of Georgia, situated at Athens, is the recipient of the United States agricultural fund, besides annual appropriations of from $8000 to $25,000 from the state government, and is the centre of other high institutions. Under its patronage there have been established a state normal school in Athens, a normal technical school at Milledgeville for women, and a school of technology in Atlanta for men, to each of which is appropriated from $20,000 to $30,000 a year. In 1900 the legislature inaugurated a large increase of these appropriations, especially to the cause of technological education. There are branch colleges at Dahlonega and Milledgeville for whites, an agricultural college near Savannah for blacks, and a medical college in Augusta of high standing. The Methodist Church South conducts Emory College in Oxford, the Baptist Church maintains Mercer University in Macon, and in almost every considerable town there exist flourishing colleges of lesser grade for young men and women. The total number of undergraduate and graduate students in the institutions of higher education in 1898 was 2177, and of instructors 135. Two-thirds of the religious population, white and black, are about equally divided between Baptists and Methodists. The rest are divided between Protestant Episcopal, Roman Catholic, Presbyterians, and others. The Georgia Sanitarium, for the insane, situated in Milledgeville, accommodates white and black separately, and has an average of 2000 patients. The Georgia Academy for the blind is at Macon; and the Georgia Institute for the deaf and dumb at Cave Spring.

Agriculture.—The commercial and industrial development of the state has been very remarkable. During 1893, 1895, and 1896, $8,000,000 a year were spent for commercial fertilizers, most of which were applied to cotton. In 1897–98 (the cotton year ending 1st September) the crop amounted to 1,536,000 bales, the average gross weight per bale being 506 lb. The average price for middling cotton in New York City during the year was 6·22 cents so the commercial value of that year's crop was $48,337,920. A steadily increasing crop had the effect of lowering the price; in 1885 a crop of 950,025 bales brought the farmers $39,413,825, and in 1893 a crop of 1,250,000 bales brought them only $35,386,875. This compelled attention to other crops. Larger areas were planted in wheat, corn, and oats, and the raising, and especially fattening, of cattle for market was successfully followed. The cotton crop of 1899–1900 was somewhat smaller (1,345,699 bales), but the prices were much more satisfactory, ranging in New York from 6¼ cents for middling upland cotton at the beginning of the season to 9⅝ cents at the close. In 1900 Georgia produced 34,119,530 bushels of Indian corn worth $19,448,132, with an average yield per acre of 10 bushels; 7,010,040 bushels of oats worth $3,434,920, with an average yield per acre of 15 bushels; 5,011,133 bushels of wheat worth $4,760,576, with an average yield per acre of 9·1 bushels. These averages are for the state at large; throughout the wheat belt the average yield is 25 bushels per acre, with a correspondingly increased percentage for the corn and oat belts. On 1st January 1900 the number and value of farm animals was as follows: 109,935 horses, $6,001,626; 157,008 mules, $10,826,032; 294,826 sheep, $518,893; 285,431 milch cows, $6,836,072; 380,716 other cattle, $4,216,054.

Manufactures.—The following table shows the manufacturing and mechanical industries as returned at the censuses of 1890 and 1900, and the percentage of increase for the decade:—

	1890.	1900.	Percentage of Increase.
Number of establishments	4,285	7,504	75·1
Capital	$56,921,580	$89,789,656	57·7
Wage earners, average number	52,298	83,842	60·3
Total wages	$14,623,996	$20,290,071	38·7
Cost of material used	$35,774,480	$68,232,202	62·8
Value of products	$68,917,020	$106,654,527	54·8

The principal products were textiles, especially cotton goods, valued in 1900 at $20,266,712; lumber and timber products, $13,704,923; flour and grist mill products, $8,330,439; turpentine and rosin, $8,110,468; and cotton-seed oil and cake, $8,064,112. The growth of the cotton manufactures has been remarkable. In 1879 the cotton factories were valued at $1,640,000. The spindles in operation in 1890 numbered 445,452, or 28 per cent. of the total in the south. In 1899 they numbered 926,044, or almost one-fourth of the total in the south, namely, 4,057,244. Of the 251,343 spindles in construction, 152,978, or over half, were in Georgia.

Mineral Resources.—Gold occurs in workable quantities in the north-eastern part of the state, usually in belts, from 1 to 5 miles wide, running north-east and south-west. In 1899 a company of capitalists from Ohio erected at Dahlonega a 120-stamp mill, with a capacity of 400 tons of ore per day, and a chlorination plant for treating sulphide ores, which will treat 40 tons of concentrates a day. Magnetic iron ore occurs in several counties. Extensive deposits of aluminum ore, in the form of bauxite, yield a large part of the aluminum produced in the United States. The bauxite is also extensively used for the manufacture of alum. Georgia is also one of the largest producers of manganese in the Union, the ore occurring in extensive masses as pyrolusite and psilomelane. The manganese ore is of high grade, being generally free from impurities. Corundum has been successfully produced. Bituminous coal has been worked continuously for many years, principally for the manufacture of coke for furnace use. There are extensive and very valuable clay deposits, which investigations by the State Geological Survey show to be second to none in the United States. Their fusion-point is exceptionally high, and the amount of impurities included is generally quite small. Abundance of marl and some phosphate rock are found in the southern part of the state. Beds of white, black-and-white mottled, and white-pink-and-grey mottled marbles, of endless variety, are worked on a large scale in Pickens county. Much of the black-and-white mottled marble is used for monumental work, on account of its richness and the sharp outline and contrast of its eccentric figures; and as a building stone this marble is probably not equalled. The Corcoran Art Gallery in the city of Washington, the Rhode Island State Capitol, the Minnesota State Capitol, and many handsome private buildings are constructed of Georgia marble. Large areas of granite and gneiss occur. A dark-green serpentine, of great beauty, has been quarried at Holly Springs, and turned into polished columns, slabs, &c., for interior decoration. A slate of fine texture and easy cleavage has for a long time been quarried at Rockmart. A very good cement has for several years been manufactured from limestone. Yellow ochre, asbestos, pyrite, steatite, and graphite are mined in various parts of the state, and rock crystal, rose quartz, chalcedony, agate, and moonstone exist in considerable quantities.

Railways.—In 1878 a state railway commission was established with mandatory powers for the settlement of all questions.

After consultation the commission fixes tariff, orders betterments, and transacts without appeal all business into which the interests of the public enter. The mileage of the south Atlantic states, consisting of Virginia, West Virginia, North and South Carolina, Florida, and Georgia, is 20,496, of which Georgia has a mileage of 5414, or more than 25 per cent. of the total. The mileage of the principal lines is as follows: Central Railroad, 1581·50; Western and Atlantic, 138; Plant system, 1391; Georgia Pacific, 557; Seaboard Airline, 926; Southern Railroad, about 1000 miles in Georgia. The gross earnings of the Georgia railways for the year ending 30th June 1899 were $21,087,310·36, leaving net earnings of $6,347,554·39. This gives a gross earning per mile of $3,937·85, or a net earning of $1,175·85. *Per contra*, the working expenses absorbed 70·14 per cent. of the gross earnings. There are fifty-one separate companies or systems in the state. During the year ending 30th June 1899 only six companies showed a deficit, the total deficit being $50,962·88. This would make the net earnings $6,296,591·51. Development of railways has resulted in the settlement and building up of considerable towns and manufacturing communities. Along the Georgia and Alabama railway, and especially in the dense pine belt between Montgomery and Savannah, there has been phenomenal growth.

Steamships.—The Central Railway system has a regular tri-weekly steamship service from Savannah to New York and Boston, with well-appointed passenger steamers. Calls are made at Philadelphia. The Merchants and Miners' Line plies regularly between Savannah and Baltimore. There are ship-lines by river: On the Chattahoochee, from Columbus to Apalachicola; on the Coosa, from Rome into the Alabama; on the Altamaha and the Ocmulgee, to their mouths.

Banking.—Charters for state banks are granted by the Secretary of State upon the payment of a fee of $50, which is covered into the state treasury; but $15,000 must first have been subscribed and actually paid, and there must be a capital stock of $25,000. No state banks of issue exist, because of a prohibitory tax of 10 per cent. on circulation medium by the national government. There were in 1900 171 state banks in operation, with a capital of $9,634,659; 22 private banks, with a capital of $605,123; and 11 loan and trust companies, with a capital of $1,194,650. There were 27 national banks, with a capital of $3,556,000. There are clearing houses in Savannah, Atlanta, Augusta, and Macon. Their combined clearings in 1899 aggregated $297,763,629.

Finances.—The total valuation of property in 1880 was $251,424,651; in 1890 it was $415,828,945; in 1900 it was estimated at $435,000,000. Taxation by legislative enactment has been limited to $5 on the thousand, and owing to the absence of a sufficient floating element in all parts of the state, propositions to increase public burdens, by either taxation or bond issues, undergo very strict inquiry. The proceeds of taxation in 1900 were $2,605,569. The state debt amounted to $7,831,500.

Constitutional Reform.—Under the constitution of 1877 the term of the governor was shortened from four years to two; the state was given power to organize a railway commission; the establishment of public schools was made obligatory; municipalities were restricted in the contracting of public debts to an amount not more than 7 per cent. of the value of assessment; all issues of bonds were made subject to a vote of the people; and the power of expending money was limited to certain well-defined public necessities. There are departments of state, treasury, law, agriculture, education, and accounts and insurance. Of the sub-departments the most important are the state railway commission; the penitentiary commission, which has control of the question of pardons as well as of penal matters; and a confederate pension bureau, which has the expenditure annually of $700,000 to the needy wounded veterans and their widows. A new department is that of geology. The state supreme court has been increased from three to six members, and the governing authority of the counties, formerly vested in an inferior court, is now in the hands of a central officer known as the ordinary.

Liquor Laws.—The growth of the anti-liquor sentiment has been marked by the adoption by the counties of local option. Ever since colonial times all matters affecting local government have been referred to the grand jury of each county; and, extending the practice to larger questions of public policy, the state adopted a law by which each county, moving for itself, with the power of biennial reconsideration, can take a vote upon the sale of liquors. One hundred and seventeen out of the one hundred and thirty-seven counties have barred the liquor traffic. The other twenty counties are substantially within prohibition ground, because of a general law which prohibits the sale of liquor in rural districts within three miles of church or school, so that in effect liquor is only sold in the larger cities. (C. Ho.)

Georgievsk, a district town of Russia, North Caucasia, province of Terek, 23 miles north-east of Pyatigorsk railway station. Here the Georgian prince, Heraclius, concluded in 1783 a treaty of federation with Russia. Population in 1897, 10,608.

Georgswalde, a town of Northern Bohemia (Austria), on the borders of Saxony. Together with Rumberg, it is one of the principal centres of the Bohemian linen industry. There are also an iron-foundry, cotton-spinning, brick-making, &c. Population (1900), 8131.

Gera, a town of Germany, capital of the principality of Reuss the Younger, on the White Elster, 45 miles by rail south-south-west from Leipzig. The church of St John's was built in 1885; in front of it stands an equestrian statue of the Emperor William I., unveiled in 1894. There is a municipal museum. Wool-weaving and spinning, iron foundries and machine shops, printing (books and maps), and flower gardening are the distinctive industrial features. Population (1885), 34,152; (1900), 45,640.

Geraldton, the chief port of the northern portion of West Australia, in the district of Victoria, in Champion Bay, about 290 miles north-west from Perth. The chief exports are wool, copper, and lead. The harbour is safe and roomy. The town is the centre of a railway system. The mean temperature for the year is 65·5° F.; for February, 74·6° F.; for July, 57·5° F.; the mean annual rainfall is 17·13 inches. Population (1901), 2593.

Gerasa, now Jerash, one of the cities of Decapolis in Syria, and possibly the Biblical Ramoth Gilead, built on both banks of the Kerwán (Chrysorrhoas), and called in an inscription Γέρασα 'Αντιόχεια. It is now occupied by a colony of Circassians, whose houses have been built with materials from the earlier buildings, and there has been much destruction of the interesting ruins.

German Reed.—The dramatic and musical entertainment, which for so many years was known in London by the title of "German Reed," may be mentioned here in connexion with the principal names of those who made it so successful. Mr THOMAS GERMAN REED (born in Bristol in 1817, died 1888) married in 1844 Miss PRISCILLA HORTON (1818–1895), and in 1855 they started their entertainment at the "Gallery of Illustration," in Waterloo Place, London. From 1860 to 1877 they were assisted by JOHN ORLANDO PARRY (1810–1879), an accomplished pianoforte player, mimic, parodist, and humorous singer; and the latter created a new type of musical and dramatic monologue which became very popular. His tradition was carried on after 1870 by Mr CORNEY GRAIN (1844–1895), who, as a clever, refined, and yet highly humorous society entertainer (originally a barrister), was one of the best-known figures of his day. After the retirement of the elder German Reeds, their son, ALFRED GERMAN REED (1846–1895), himself a capital actor, carried on the business in partnership with Corney Grain. The "German Reed Entertainment"—which was always patronized by a large class of people, many of whom objected on principle to going or taking their children to a regular theatre or a music-hall—retained its vogue for forty years at Waterloo Place and at the St George's Hall, Regent Street. But the death of Mr Corney Grain almost simultaneously with Mr Alfred German Reed, in 1895, together with the changed public attitude towards the regular theatre, ended its career, though more recently Mr Albert Chevalier has to some extent revived this type of entertainment in modified conditions. The success, however, of John Parry and Corney Grain had meanwhile resulted in many others—among them Mr George Grossmith, who had made a reputation in the Gilbert and Sullivan operas at the Savoy Theatre—starting independently as "entertainers" with what were known as "musical sketches."

Germantown, Pennsylvania, a residential district in the northern part of the city of Philadelphia, U.S.A.

GERMANY.

I.—Geography and Statistics.

Geography.—The present German Empire extends from 47° 16′ to 55° 54′ N. lat., and from 5° 53′ to 22° 53′ E. long., therefore the 15th meridian, fixing Central European time, does not divide it in the middle. The difference in time between the most eastern point and the 15th degree E. is 36½ minutes, and between the most western point and the 15th meridian only 31½ minutes. The empire is bounded on the E. by Russia (735 miles according to Strelbitski, 1881), on the S.E. and E. by Austria and Switzerland (together 1647 miles), on the S.W. by France (251 miles), and on the W. by Luxemburg, Belgium, and Holland (together 530 miles). The length of German coast on the North Sea is 460 miles, and on the Baltic (without reckoning the coasts of the "haffs") 735 miles, the intervening land boundary on the north of Schleswig being only 72 miles. The total area of the empire, including rivers and lakes, but not the "haffs" and lagoons on the Baltic (called *Bodden* on the coast of Pomerania) nor other coast waters (together 2590 square miles), is 208,790 English square miles, or 540,743 square kilometres, according to the most recent estimates. As regards the *physical features*, there is little to add to the earlier article (*Ency. Brit.*, x. 447–450).

Area and Population.—Since the constitution of the German Empire in 1871 the territory has been enlarged only by the island of Heligoland (about ¼ square mile), ceded by Great Britain under the treaty of 1st July 1890. The changes in cadastral measurements have been numerous in the several German states, but of small amount.

Table I.—*Population and Growth of the German Empire 1870 to 1900.*

(Population at the beginning of December; 000 omitted.)

Year.	Population.	Increase Percentage Per Annum.	Year.	Population.	Increase Percentage Per Annum.
1870	40,818	0·58	1890	49,428	1·07
1875	42,729	0·91	1895	52,280	1·12
1880	45,236	1·14	1900	56,367	1·50
1885	46,858	0·70			

The following table gives the area and population of the twenty-six states of Germany, in their official order, as returned at the census of 1st December 1900:—

Table II.—*Area and Population of the German Empire.*

States of the Empire.	Area, English Square Miles.	Population.
Kingdoms.		
1. Prussia	134,622	34,472,509
2. Bavaria	29,295	6,176,057
3. Saxony	5,789	4,202,216
4. Würtemberg	7,534	2,169,480
Grand-Duchies.		
5. Baden	5,823	1,867,944
6. Hesse	2,966	1,119,893
7. Mecklenburg-Schwerin	5,069	607,770
8. Saxe-Weimar	1,397	362,873
9. Mecklenburg-Strelitz	1,131	102,602
10. Oldenburg	2,482	399,180
Duchies.		
11. Brunswick	1,418	464,333
12. Saxe-Meiningen	953	250,731
13. Saxe-Altenburg	511	194,914
14. Saxe-Coburg-Gotha	764	229,550
15. Anhalt	888	316,085
Carry forward	200,642	52,936,137
Brought forward	200,642	52,936,137
Principalities.		
16. Schwarzburg-Sondershausen	333	80,898
17. Schwarzburg-Rudolstadt	363	93,059
18. Waldeck	433	57,918
19. Reuss-Greiz	122	68,396
20. Reuss-Gera	319	139,210
21. Schaumburg-Lippe	131	43,132
22. Lippe	469	138,952
Free Towns.		
23. Lübeck	115	96,775
24. Bremen	99	224,882
25. Hamburg	160	768,349
Imperial Territory.		
26. Alsace-Lorraine	5,604	1,719,470
German Empire	208,790	56,367,178

The population doubled within the period 1825–1900, but there are great differences in the growth. It appears from the following table that the inhabitants of the kingdom of Saxony and the eight old provinces of Prussia have increased three or four times more than those of the South German States and Hanover since 1836.

Table III.—*Increase of Population in States or Provinces.*

(000 omitted.)

Provinces or States.	Population Census, 1831–1900.			Total Increase Per Cent.	
	1831–34.	1875.	1900.	1831–75.	'31–1900
Saxony	('34) 1,596	2,760	4,202	73	169
The eight old Prussian Provinces:	('31) 13,040	21,116	28,528	62	119
Brandenburg (including Berlin)	,, 1,612	3,126	4,997	84	209
Saxony	,, 1,450	2,169	2,832	50	195
Rhineland	,, 2,250	3,804	5,760	70	155
Westphalia	,, 1,270	1,905	3,188	52	151
Silesia	,, 2,461	3,844	4,669	56	90
Pomerania	,, 910	1,462	1,635	63	80
Prussia (E. and W.)	,, 2,015	3,199	3,560	59	77
Posen	,, 1,070	1,606	1,887	50	76
Hanover	('33) 1,663	2,017	2,591	21	56
Baden	('34) 1,228	1,507	1,868	23	52
Hesse	,, 750	884	1,120	18	49
Bavaria	,, 4,245	5,022	6,176	18	45
Würtemberg	,, 1,573	1,882	2,169	20	38

Of the total population, the females exceed the males in the ratio of 1032 to 1000, as in most European states of Teutonic origin.

According to the occupation census of 14th June 1895, the distribution as regards conjugal condition was as follows (the regular census of 2nd December 1895 did not give such returns):—

Table IV.—*Conjugal Condition*, 1895.

(000 omitted.)

	Males.		Females.		Total.	
	Total.	Per Cent.	Total.	Per Cent.	Total.	Per Cent.
Unmarried	15,784	62·1	15,368	58·3	31,152	60·0
Married	8,849	34·8	8,785	33·3	17,634	33·9
Widowed (and Divorced)	776	3·0	2,209	8·4	2,985	6·1

Table V.—*Marriages, Births, and Deaths*, 1871–99.
(000 omitted.)

Year.	Marriages.	Births (including Still-born).	Deaths.	Still-born.	Surplus of Births.
1871–80 .	369	1744	1233	69	511
1881–90 .	368	1799	1247	67	551
1891–99 . or	426	1953	1226	64	727
1897 . .	448	1991	1206	64	785
1898 . .	459	2030	1183	65	847
1899 . .	472	2045	1250	65	795

The mean number of marriages for each 1000 persons living was, for the whole period, 8·2; the annual number rose (1872) soon after the great war to 10·3, and descended in the period of economic depression (1879–81) to 7·5. Regarding the births, the average annual rate was 38·8. The rate per 1000 ascended slowly to 42·6 (1876), but afterwards decreased (37·1 in 1899). The average death-rate was 26·4. In later years the deaths have regularly diminished, the rates per 1000 from 1894 to 1899 being as follows: 23·5, 23·4, 22·1, 22·5, 21·8, 22·7, still-born included; or 22·3, 22·1, 20·8, 21·3, 20·6, 21·5 without reckoning the still-born. This death-rate is not so favourable as that in Great Britain and Ireland. In Germany, as in most European states, the surplus of females is due to their lower death-rate, for more boys are born than girls.

Table VI.—*Excess of Boys for* 1000 *Girls*.

Year.	Births.	Deaths.
1897 . .	1060	1103
1898 . .	1058	1106
1899 . .	1059	1099

The rate of illegitimacy has generally decreased in the last thirty years from 11 or 12 per cent. (1841–71) to about 9–9¼, but it is still higher than in any other European state, except Denmark, Sweden, and Austria. For the ten years 1889–98 the proportion was 3 to 3·5 per cent. in Western Germany (Rhineland and Westphalia), 6–7 in the north-western and the extreme eastern provinces, 8–10 in the south-western, and 10–12 in most of the provinces round Brandenburg, and 15 per cent. in Bavaria.

The surplus of births over deaths being much greater than the growth of the population, there is a great loss by emigration. Between 1820 and 1900 about 5 or 5½ millions of Germans appear to have emigrated across the sea:—

Table VII.—*Emigration of Germans from German and Foreign Ports.*
(000 omitted.)

Year.	Total.	Average.
1820–70 .	2770	...
1871–75 .	395	79
1876–80 .	231	46
1881–85 .	857	171
1886–90 .	485	97
1891–95 .	403	81
1896–1900 .	127	22

There have been great oscillations in the actual emigration by sea. It first exceeded 100,000 soon after the war (1872, 126,000), and this occurred again in the years 1880 to 1892. Germany lost during these thirteen years more than 1,700,000 inhabitants by emigration. In recent years the emigration has been insignificant. The total number of those who sailed for the United States from 1820 to 1900 may be estimated at more than 4,500,000. The number of German emigrants to Brazil between 1870 and 1900 was about 52,000. The greater number of the more recent emigrants were from the agricultural provinces of Northern Germany — Western Prussia, Posen, Pomerania, Mecklenburg, Schleswig-Holstein, and Hanover. Sometimes the emigration reaches 1 per cent. of the total population of these provinces.

The number of foreigners naturalized during the years from 1872 to 1885 was 65,931; the returns have not been continued. The number of foreign residents in the empire has considerably increased from one census to the other. In 1871 there were 40,852,000 natives and 206,700 foreigners, or 5 per 1000; in 1895, 51,793,711 natives, and 486,185 foreigners, or 9·3 per 1000. The census returns of 1895 show that of these foreigners, 222,952 came from Austria-Hungary, 50,743 from the Netherlands, 44,870 from Switzerland, 28,146 from Denmark, 26,559 from Russia, 22,693 from Italy, 19,619 from France, 15,788 from the United States, 15,290 from Great Britain, 11,755 from Luxemburg, 11,091 from Sweden and Norway, 8947 from Belgium, and 7732 from other countries.

The following table [VIII. (*a*) and (*b*)] shows the density of population. It is not possible to do this properly for the actual states under Table II., but a fairer estimate is obtained if we take into consideration the leading political or natural subdivisions of the whole country.

Table VIII.—*Abstracts for the most important Political or Natural Groups.*
(000 omitted in the Population Returns.)

(*a*) Political Groups.	Area. Sq. Miles.	Population, 1900.	Population per Square Mile.
Prussia, including the minor States of North Germany	147,018	37,695	256
Saxony	5,789	4,200	725
Thuringian States . .	4,762	1,420	298
Bavaria	29,295	6,176	211
Würtemberg . .	7,534	2,169	288
Baden	5,823	1,868	320
Alsace-Lorraine . . .	5,603	1,719	307
Hesse	2,966	1,120	378
Total (1900) . .	208,790	56,367	270

(*b*) Natural Groups.	Area. Sq. Miles.	Population, 1895.	Population per Square Mile.
Baltic Countries . . .	49,624	7,179	145
Middle East Germany .	43,107	11,128	256
North-western Plains . .	17,941	3,693	205
Hills between Weser and Elbe . . .	11,446	3,110	272
Saxony-Thuringia . .	13,724	6,018	438
Hesse	5,593	1,180	228
Lower Rhineland . .	15,756	7,575	479
Western Upper Rhineland .	8,421	2,730	329
Eastern Upper Rhineland .	12,545	3,820	306
Franconia	10,042	2,252	225
Danubian Countries . .	20,552	3,593	174
Total (1895) . .	208,751	52,278	251

The difference in the density of population is much greater than can be seen from the above table if we take the minor districts into consideration. Without mentioning the true mountain circles belonging to the Bavarian Alps, there are some rural districts in the moorlands of Oldenburg and Hanover where the inhabitants number scarcely 50 per square mile. For the purely agricultural districts of the north-eastern lowlands, or those of the Upper German plateau (Danubian plateau), 150 is the number. It seems that a density of about 250 is the highest for a truly rural population in Germany. More thickly populated districts are to be found in the Upper Rhine plain, the Neckar valley, and the plains bordering the midland mountains in the north. But the density attains an extreme degree in the different coal districts. In the Ruhr basin, a district of about 600 square miles, the population equals that of Lancashire, the mean being not under 2500 per square mile.

The number of inhabited houses in 1890 was 5,791,000; in 1871 it was about 5,330,000, so that the average number of inhabitants per house is 8·45 persons. In Great Britain and Ireland in 1891 the average was only 5·28.

Table IX.—*Town and Rural Population.*

Classes of Towns.		Number of Towns.	Population. (000 omitted.)	Per Cent. of Total.
Large Towns of more than 100,000 Inhabitants .	1871	8	1,969	4·8
	1895	28	7,277	13·9
Middle-sized Towns from 20,000 to 100,000 Inhabitants . . .	1871	75	3,147	7·7
	1895	150	5,580	10·7
Small Towns from 5000 to 2000 Inhabitants .	1871	529	4,588	11·1
	1895	796	7,048	13·5
Rural Towns from 2000 to 5000 Inhabitants .	1871	1716	5,087	12·4
	1895	2068	6,158	11·8
Town Population .	1871	2328	14,791	36·1
	1895	3042	26,063	49·9
Rural Population .	1871	...	26,219	63·9
	1895	...	26,217	50·1

The differences in the distribution of the population have become much greater than they were formerly. The mean density has increased from about 120 inhabitants per square mile in 1820 to 150 in 1840, 200 in 1875, and 270 in 1900. In the same period the population of the cities has greatly risen, the natural increase of the inhabitants in the rural districts from the surplus of births being neutralized by the steady migration to the cities. It must be remembered that the official statistics designate all inhabitants of communes with more than 2000 souls as "town population"; the term "rural population" is applied to those of the smaller places. (For further details see *Ency. Brit.*, x. p. 457.)

The figures exhibit the extremely unequal increase of the different groups from 1871 to 1895. In the rural towns it was at the rate of 21 per cent., in the small towns 53·6 per cent., in the middle-sized towns 43·6 per cent., and in the large towns 269 per cent.

The following is a list of the large towns in 1900; the total population of these 33 towns was 9,108,815 in 1900, or 16·2 per cent. of the total population (000 omitted):—

Greater Berlin	2500	Charlottenburg, *see* Berlin.	
Berlin	1884	Königsberg	188
Charlottenburg	189	Stuttgart	176
Hamburg	706	Bremen	163
Altona	162	Altona, *see* Hamburg.	
Munich	500	Elberfeld	157
Leipzig	455	Barmen	157
Breslau	423	Halle-on Saal	157
Dresden	395	Strassburg	150
Cologne	372	Dortmund	142
Hanover	236	Danzig	140
Linden	51	Mannheim	140
Frankfurt-on-Main	288	Aachen (with Burtscheid)	135
Nürnberg	261	Brunswick	128
Magdeburg	230	Essen	119
Düsseldorf	214	Kiel	108
Stettin	211	Crefeld	107
Chemnitz	207	Kassel	106

TABLE X.—*Occupations*, 1882 *and* 1895.
(000 omitted.)

Occupations.	Total.		Engaged in the Several Occupations.		Total in Per Cent.	
	1882.	1895.	1882.	1895.	1882.	1895.
A. Agricultural Class	19,225	18,501	8,236	8,293	42·5	35·7
B. Industrial Class	16,058	20,253	6,396	8,281	35·5	39·1
C. Commercial Class	4,531	5,967	1,570	2,339	10·0	11·5
D. Domestic and other Service	938	887	398	432	2·1	1·7
E. Professions	2,223	2,835	1,031	1,426	4·9	5·5
P. Without Profession or Occupation	2,246	3,327	1,354	2,143	5·0	6·4
Total	45,221	51,770	18,985	22,914	100	100

Germany made a great step in her development as an industrial state between the years 1882 and 1895. The number of persons engaged in agriculture, cattle-rearing, forestry, and fishing was not more in 1895 than the number of those engaged in mining, metal works, and other industries, but with respect to the attendants and other members of families the two branches were in the ratio of 36 to 39 in 1895, while the agricultural class included in 1882 7 per cent. of the total population more than the industrial class.

Constitution and Government.—By the law of 19th March 1888, which came into force in 1890, the members of the Reichstag are elected for the term of five years (previously for three years). The duration of the legislative period is also five years. The average number of inhabitants for each of the 397 electoral districts increased from 103,000 in 1871 to 131,600 in 1898. The total number of electors to the Reichstag inscribed on the lists was 8,523,000 at the general election of 1874 (in 1871 Alsace-Lorraine did not take part in the elections) or 20·8 per cent. of the population of 1871. In 1898 the number of electors was 11,441,000, or 21·9 per cent. of the population according to the census of 1895. In 1874 the number of effective voters was 61·2 per cent. of the whole electoral body, and the rate was about the same in the following elections till 1884. In 1887 the number rose to 78·2 per cent.; in 1898, with 7,787,000 voters (in the first vote), it was 68·1 per cent. The following table shows the number of votes given to the several political parties and the composition of the Reichstag after the elections of 1874, 1887, 1898:—

TABLE XI.—*Number of Votes and Deputies.*

Parties.	Legal Votes (000 omitted)			Deputies.		
	1874.	1887.	1898.	1874.	1887.	1898.[1]
Conservatives	360	1147	859	22	80	52
Reichspartei (Liberal-Conservatives)	430	736	344	36	41	22
National Liberals	1542	1678	971	155	99	47
Freisinnige (Liberals)	447	973	754	49	32	40
Volkspartei (Democrats)	22	89	108	1	...	7
Centrum (Clerical)	1568	1516	1455	101	98	102
Poles	198	220	244	14	13	14
Social Democrats	352	763	2107	9	11	57
Anti-Semites	...	12	284	...	1	10
Welfen, Danes	138	113	105	4	5	9
Alsatians	86	234	107	6	15	10
Other Parties	46	60	413	...	2	23
Total	5189	7541	7751	397	397	393

The multiplicity of parties has been a peculiarity of the German Reichstag from the beginning, and has increased still more since 1874.

Languages.—The number of German-speaking people in the world, including the various branches, such as Dutch and Flemish, may be roughly estimated for the year 1900 at 90,000,000. They are distributed somewhat as follows:—

TABLE XII.—*Distribution of German-speaking People.*

German Empire	51,800,000
Austria-Hungary	11,000,000
Netherlands	5,100,000
Belgium	3,900,000
Luxemburg	200,000
Switzerland	2,300,000
France	500,000
Other European Countries	2,300,000
America	12,000,000
Asia	100,000
Africa	600,000
Australia	100,000

No imperial census relating to the mother tongue yet exists. Apart from the foreigners residing in the various German states, Germans speaking another language than German are found only in Prussia, Saxony, and Alsace-Lorraine. According to the Prussian census of 1st December 1890, there were 29,815,938 persons speaking commonly one language and 137,531 speaking two languages:—

TABLE XIII.—*Languages spoken in Prussia*, 1890.

Germans	26,438,070
Poles	2,816,657
Masurians	105,755
Cassubians	55,540
Moravians and Czechs	66,078
Wends	74,069
Lithuanians	121,345
Danes and Norwegians	139,399
Walloons	11,058
Other Languages, including Frisian (48,828)	125,498
Total	29,953,469

In the kingdom of Saxony, according to the census of 1885, there were 49,916 Wends, most in the Lausitz. With respect to Alsace-Lorraine, detailed estimates (but no census) gave the number of French in the territory of Lorraine at about 170,000, and in that of Alsace at about 46,000. Combining these statistics with those of the foreign residents, it may be estimated that the whole population of the German Empire for 1900 according to language was as follows:—

[1] Composition on 18th January 1900, four seats being vacant.

TABLE XIV.—*Languages spoken in Germany*, 1900.

(000 omitted.)

Languages.	Population.	Per Cent.
Germans	51,900	92·7
Poles, &c.	3,200	5·7
Wends	120	0·2
Czechs, &c.	70	0·1
Lithuanians	120	0·2
Danes	140	0·3
French	250	0·5
Walloons	10	...
All other Peoples	190	0·4
Total	56,000	100

The Poles have increased very much, owing to a greater surplus of births than in the case of the German people in the eastern provinces of Prussia, to immigration from Russia, and to the Polonization of many Germans through clerical influence. The Poles are in the majority in Upper Silesia (Government district of Oppeln, 55 per cent.) and the province of Posen (60 per cent.). They are numerous in West Prussia (34 per cent.) and East Prussia (20 per cent.). In recent years, however, there has been a great emigration of Poles to the western industrial provinces of the empire.

Religion.—The following table gives the results of the religious census of 1890 compared with previous years :—

TABLE XV.—*Religious Statistics.*

(000 omitted.)

Creeds.	1871.	1880.	1890.
Protestants	25,582	28,331	31,027
Roman Catholics	14,868	16,233	17,675
Dissenters	82	78	146
Jews	512	561	568
Other Creeds or not stated	17	31	13
Total	41,061	45,234	49,429

TABLE XVI.—*Religion. Ratio to* 1000 *Inhabitants.*

Year.	Protestants.	Catholics.	Dissenters.	Jews.
1871	623	362	2·0	12
1880	626	359	1·7	12
1890	628	358	2·9	11

Three states in Germany have a decidedly predominant Catholic population—namely, Alsace-Lorraine, Bavaria, and Baden. In four states the Protestant element prevails, but there are from 23 to 33 per cent. of Catholics —namely, Prussia, Würtemberg, Hesse, and Oldenburg. In Saxony and the eighteen minor states the number of Catholics is only from 0·3 to 3·3 per cent. of the population.

TABLE XVII.—*Protestants and Catholics according to the Census of* 1890.

State.	Protestants.	Roman Catholics.	Rate per 1000 of Population.	
			Prot.	Cath.
Alsace-Lorraine	337,476	1,227,225	210	765
Bavaria	1,571,863	3,962,941	281	708
Baden	598,678	1,028,222	361	620
Prussia	19,232,449	10,252,818	642	342
Würtemberg	1,407,176	609,794	691	299
Hesse	666,118	293,651	671	296
Oldenburg	274,410	77,769	773	219
Saxony and Minor States	6,938,640	221,521	961	31
Total	31,026,810	17,673,941	628	358

TABLE XVIII.—*Dissenters.*

The census of 1890 gives the following details about the "Other Christians" :—

Herrnhuters (Moravian Brethren)	6,716
Mennonites	22,365
Baptists	29,074
Church of England	5,249
Methodists and Quakers	10,144
Apostolics (Irvingites)	21,751
German Catholics	5,714
Freethinkers	14,347
Dissidents	23,698
Others	6,482

No official return exists as to the Old Catholics. They are estimated to have numbered not more than 30,000 in 1890.

Education.—School instruction is obligatory upon all, but the administration of all the degrees of instruction is not imperial. An imperial school committee designates those schools which possess the right of granting certificates to pupils entitling them to serve in the army as one-year volunteers.

The number of primary schools is not exactly known; it is about 60,000. The pupils attending them number about 8,000,000, and the teachers 125,000. There were 184 seminaries for the training of teachers in 1900. The progress in education will be seen from the diminishing number of the illiterate army recruits since 1871 :—

TABLE XIX.—*Decreasing Number of Illiterate Recruits.*

Years.	Number of Recruits.	Unable to Read or Write.	
		Total.	Per 1000 Recruits.
1875–76	139,855	3311	23·7
1880–81	151,180	2406	15·9
1885–86	152,933	1657	10·8
1890–91	193,318	1035	5·4
1895–96	250,287	374	1·5
1898–99	252,382	173	0·7

Of the 173 illiterates in 1898–99, 64 were in East and West Prussia, 46 in Posen and Silesia, and 12 in Bavaria. Since 1875 many municipalities have founded schools of a somewhat higher rank for the lower classes, called *Fortbildungsschulen*, or Continuation schools.

The four different classes of schools for higher education have been augmented since 1880. Exact and uniform statistics of the secondary schools for the whole empire do not as yet exist. In 1879 there were 878 schools with the privilege of furnishing pass certificates for the one-year volunteers; in 1900 there were 1286. There were included in this number 170 public seminaries for training teachers in 1879, and 184 in 1900. The number of other secondary schools in 1900 was as follows :—

TABLE XX.—*Number of Schools.*

Gymnasia (classical)	451
Progymnasia (classical)	90
Realgymnasia	121
Oberrealschulen (without Latin)	53
Realschulen	272
Höhere Bürgerschulen	2
Other Public Schools	33
Private Schools	54
Total	1076

The gymnasia, of which the constitution dates back to very remote times, have in Prussia the privilege of giving preparatory training for the universities. Pupils of the realschulen are only allowed to visit the universities for the study of mathematics, natural science, and modern languages. In the southern states the privileges of the upper realschulen are greater. There is now a movement in Germany for extending the privileges of the gymnasia to the other nine-years schools, that is to say, the realgymnasia and the oberrealschulen. The total number of teachers and pupils in the German higher schools is not known, but in 1897 the 578 Prussian schools contained 7683 teachers and about 148,500 scholars.

Universities and Higher Technical Schools.—The attendance of the German youth at the higher schools and the universities has greatly increased since 1880. The number of students at the twenty-one German universities (without taking account of the little academy at Braunsberg) was 16,000 in 1872, the year in which Strassburg university was founded, and 33,500 in 1898–99. At the same time the total population has only increased from 41,000,000 (1871) to 55,000,000, or 34 per cent. For some years women have been allowed to attend, and in 1899 there were from 450 to 500 women at the various universities.

TABLE XXI.—*The German Universities,* 1878 *and* 1899.

Universities.	Professors and Teachers.		Students.		Non-Matriculated Attendants.
	1876.	1900.	1876.	1898–99.	1898–99.
1. Berlin (Pr.)	193	419	1977	6478	4843
2. Munich (Bav.)	114	199	1136	4049	279
3. Leipzig (Sax.)	155	224	2730	3481	368
4. Bonn (Pr.)	100	154	751	1886	143
5. Halle (Pr.)	96	154	882	1636	181
6. Breslau (Pr.)	108	170	1107	1618	131
7. Tübingen (Wurt.)	86	102	1019	1361	30
8. Heidelberg (Bad.)	110	154	735	1250	119
9. Göttingen (Pr.)	119	127	1040	1238	87
10. Freiburg (Bad.)	54	118	272	1235	66
11. Wurzburg (Bav.)	66	88	954	1215	23
12. Strassburg (Als.)	94	132	674	1105	64
13. Marburg (Pr.)	69	97	440	1040	74
14. Erlangen (Bav.)	55	71	422	974	20
15. Königsberg (Pr.)	82	121	610	840	44
16. Giessen (Hesse)	59	75	333	802	71
17. Greifswald (Pr.)	60	96	498	759	15
18. Kiel (Pr.)	65	101	212	757	54
19. Jena (Thür.)	77	99	483	655	54
20. Münster (Pr.)	29	49	409	620	12
21. Rostock (Meckl.)	36	52	141	464	19
Total	1827	2802	16,825	33,463	6697

The number of foreign students is said to have been only 750 in 1860, but in 1899 it was 2092, of whom 126 were from England, 305 from America, and 81 from Asia. In 1898–99 the students were distributed among the different faculties as follows :—

TABLE XXII.—*Number of Students in the different Faculties.*

	1876.	1899.
1. Protestant Theology (17 faculties)	1,595	2,473
2. Catholic Theology (7 faculties)	686	1,548
3. Laws, Politics, and Forestry (20 faculties)	4,862	9,814
4. Medicine, Surgery, Pharmacy (20 faculties)	3,529	8,104
5. Philosophy, Philology, History, Geography, Mathematics, and Natural Science	6,153	11,524
Total	16,825	33,463

The teaching staff was classified in 1899 as follows :—ordinary professors, 1089 (1876, 931); extraordinary professors, 619 (1876, 371); honorary professors, non-salaried, 92 (1876, 45); private teachers (*privatdocenten*), 841 (1876, 431); teachers of languages, 161 (1876, 90). The expenses of all the universities (Braunsberg included) in 1891–92 were 19,912,000 marks, of which 4,872,000 marks were covered by their own revenues, and 15,040,000 marks by state or provincial funds.

The *Technical High Schools* have greatly increased, following on the industrial development of Germany in the last third of the 19th century. The attendance for the winter of 1898–99 is shown in the following table :—

TABLE XXIII.—*The Technical High Schools.*

Technical High School.	Students.	Attendants.
Berlin	2425	1003
Munich	1839	282
Darmstadt	1302	141
Karlsruhe	884	196
Hanover	858	339
Stuttgart	767	171
Dresden	689	134
Aachen	340	141
Brunswick	276	129
Total	9380	2536

The number of foreign students was about 1600.

Among the remaining higher technical schools may be mentioned the three mining academies, with 645 students in Berlin, Clausthal in the Harz, and Freiberg in Saxony; the eight academies of forestry, and the high schools of agriculture, most of them affiliated to the universities, have been named in the earlier article (*Ency. Brit.*, vol. x. p. 472).

Finance.—The most important expenses, in addition to those already mentioned, which the budget of the empire has annually to meet, are the interest on the increasing imperial debt, the charges for the colonies, the subventions for steamer lines, and the charges for workmen's insurance against old age and infirmity. When the revenue is insufficient, assessments are made upon the various states. These *Matrikular Beiträge* pressed so heavily upon the minor states that, after the reorganization of the customs and excise duties in 1887, certain assignments (*Überweisungen*) or repayments to the various states were introduced of the surplus revenue from customs, tobacco, stamps, and spirits above 130,000,000 marks.

The following tables show the increasing requirements of the empire and the respective receipts (in millions of marks). The figures are to be understood as net, as the gross amount of the receipts from the posts and telegraphs, printing office, and imperial railways is not shown. For the same rcason the assignments are deducted for the ordinary expenses and also for the contributions :—

TABLE XXIV.—*Development of the Imperial Finances.*

Years.	Expenditure.			Revenue.			
	Ordinary.	Extraordinary.	Total.	Ordinary (Proper).	Matric. Contributions.	Extraordinary.	Total.
1875	395·8	238·7	634·5	316·7	69·0	185·8	571·5
1880–81	425·0	86·8	511·8	374·1	43·5	74·6	492·2
1885–86	458·7	63·2	521·9	453·7	6·6	39·3	499·6
1890–91	578·5	396·2	974·7	687·6	...	186·7	874·3
1895–96	747·0	160·1	907·1	829·8	...	64·2	894·0
1900–1	862·7	274·4	1137·1	1016·1	12·8	75·7	1104·6

The imperial budget is voted every year by the Reichstag. The ordinary and extraordinary expenses for the financial year ending 31st March 1901 were distributed as follows :—

TABLE XXV.—*Expenditure*, 1900–1901 (*in thousand Marks*).

	Ordinary.	Extraordinary.
1. Reichstag	699	...
2. Chancellery	233	...
3. Foreign Office—		
(*a*) Foreign Service	11,986	530
(*b*) Colonial Office	548	19,636
4. Home Office—		
(*a*) General Service	9,705	3,396
(*b*) Subventions (Steamer Lines)	7,500	...
(*c*) Insurance (Old Age and Infirm)	31,573	...
5. Army	541,758	124,093
6. Navy	73,939	88,269
7. Ministry of Justice	2,119	...
8. Imperial Treasury—		
(*a*) General Service	5,355	25
(*b*) Assignments	514,940	...
9. Imperial Railway Office	392	2
10. Debt of the Empire	77,701	...
11. Audit Office	856	...
12. General Pension Fund	68,164	...
13. Invalid Fund (from 1870 to 1871)	30,076	...
14. Posts and Telegraphs	342,495	13,415
15. Imperial Printing Office	5,305	2,256
16. Imperial Railways (Alsace-Lorraine)	58,435	21,096
Total	1,783,779	272,718
Grand Total	2,056,497	

TABLE XXVI.—*Revenue*, 1900–1901 (*Budget*).

		1000 Marks.
1. Customs and Excise (net)—		
Customs		473,220
Common Duties (net) — Beetroot Sugar		102,009
Common Duties (net) — Tobacco		12,143
Common Duties (net) — Salt		47,810
Common Duties (net) — Spirits		124,301
Special Duties—Malt and Brewing		30,165
Contributions by Territories outside the *Zollverein*		78
2. Stamps		66,483
Playing-Cards	1,471	
Exchanges	10,367	
Effects, &c.	53,708	
Statistical Tax	937	
3. Posts and Telegraphs (Gross Revenue)		393,210
4. Imperial Printing Office (Gross Revenue)		7,516
5. Imperial Railways (Gross Revenue)		86,175
6. Imperial Bank (Share of Profits)		14,854
7. Various Revenues		18,762
8. From the Imperial Invalid Fund		30,076
9. Balance of Non-Common Revenue		15,586
10. Federal Contributions		527,662
11. Extraordinary Supply (Loans, &c.)		75,620
Total		2,025,670

The chief branches of imperial expenditure, ordinary and extraordinary, have increased as follows (in millions of marks):—

TABLE XXVII.—*Imperial Expenditure.*

Years.	Army.	Navy.	Per Head (Marks). Army.	Per Head (Marks). Navy.	Insurance.	Debt.
1875	364·9	48·6	8·5	1·1	...	...
1885–86	371·6	52·0	7·9	1·1	...	17·4
1895–96	562·7	85·9	10·8	1·6	15·3	71·7
1899–1900	642·9	133·7	11·7	2·4	28·9	75·6
1901–2	673·1	207·5	11·9	3·7	30·4	89·0

Customs Revenue.—The *Zollverein* or German Customs Union, founded in 1828 between Prussia and Hesse, and with progressive territorial extensions during the succeeding fifty years (for details see the earlier article, *Ency. Brit.*, x. 454), had an area of about 209,281 English square miles, with a population of 40,678,000 inhabitants in 1871, when the German Empire was created. The last important addition was in October 1888, when Hamburg and Bremen were incorporated. Outside the *Zollverein* there are now only the two little free-port territories at Hamburg and Bremen, and some districts on the frontier between Baden and Switzerland. These had in 1895 an area of 26·3 square miles, and 13,061 inhabitants. The Grand Duchy of Luxemburg is included in the *Zollverein*, although it is not a part of the German Empire. After having been in general a free-trade country from about 1860 (transit-duties abolished 1861), a more protective system was introduced by the tariff of 15th July 1879, modified to a certain extent by the commercial treaties of 1892. No export duties have been imposed since 1865; but in 1879 raw materials were taxed, and in 1885 the duties on cereals and other foods were raised. The gross amount of customs revenue was as follows (in millions of marks):—

TABLE XXVIII.—*Growth of the Customs Revenue.*

Years.	Total.	Per Head (Marks).	Years.	Total.	Per Head (Marks).
1878	114·7	2·62	1895	415·4	7·94
1880	182·2	4·08	1897	472·0	8·75
1885	235·0	5·08	1899	494·1	8·89
1890	389·4	7·85			

The customs revenue in proportion to the value of the imported taxed merchandise has been calculated as follows (in millions of marks) for 1898:—

TABLE XXIX.—*Ratio of Customs Duties to Imports.*

Articles.	Imports (Value).	Customs Duties.	Per Cent. of the Supposed Value.
Raw Materials for Industry	513·2	34·1	6·6
Manufactures	790·2	116·2	14·7
Articles for Consumption (Animals)	1594·2	355·8	22·3

The principal articles from which duties were received in 1898 were the following: Colonial products, 201·4 million of marks; cereals or agricultural products, 153·7; petroleum, 67·8; timber, &c., 20·7; oils and fats, 20·4; iron and iron manufactures, 9·7; cotton and cotton goods, 9·0.

The following table gives the net amount of the four licensed articles of consumption (totals in millions and per head in marks):—

TABLE XXX.—*Licensed Articles.*

	Spirits. Total.	Spirits. Per Head.	Beer. Total.	Beer. Per Head.	Tobacco. Total.	Tobacco. Per Head.	Salt. Total.	Salt. Per Head.
1875–76	44·3	1·38	...	...	14·5	0·35	...	...
1885–86	50·1	1·35	65·0	1·42	38·5	0·84	...	...
1895–96	149·1	2·84	87·2	1·66	59·9	1·14	48·8	0·93
1898–99	162·1	2·95	94·5	1·73	65·7	1·20	50·4	0·92

There is a great difference between the German beer duty and that of the southern states, where the taxation is much higher. The duty rose in Bavaria to 6·02 marks per head in 1898, in Baden to 4·35, in Würtemberg to 4·27, and in Alsace-Lorraine to 2·05, whereas in the common territory it was only 0·88 mark.

Funds of the Empire.—The Invalid Fund for paying the pensions of the men invalided in the Franco-German war, which amounted originally to 561,000,000 marks, stood at 383,106,600 on 31st March 1900. The imperial war reserve or *Reichskriegsschatz* in coined gold and bullion in Spandau still amounts to 120,000,000 marks. The imperial debt, mainly incurred for military expenses, rose from 2,000,000 marks in 1873 to 2,418,518,000 marks on

31st March 1900. Of this amount 1,240,000,000 marks was at the rate of $3\frac{1}{2}$ per cent., 1,059,000,000 marks at 3 per cent., and 120,000,000 marks in shares (*Reichskassenscheine*) paying no interest.

Defence (see also articles ARMIES and NAVIES).—The strength of the army on a peace footing (*Friedensfuss*) was fixed by the Army Bill of 1874 at 401,659 men (or say 1 per cent. of the population at the census of 1871) for a term of seven years ending 31st December 1881. Other Bills, of 6th May 1880, 11th March 1887, 15th June 1890, and 3rd August 1893, raised the peace footing to 479,229, and the Bill of 25th March 1899 fixed the number at 502,506 men in 1902. Since 1st April 1900 the imperial army has consisted of twenty-three army corps—namely, the Prussian guards corps, sixteen Prussian corps (including the troops of the minor states in military convention with Prussia), three Bavarian corps, two Saxon corps, and one Würtemberg corps. There are now five "army inspections," each comprising from three to five corps. Generally, an army corps consists of two divisions, composed of infantry, cavalry, and artillery, but two corps have three divisions. The guards corps contains two divisions of infantry and one division of cavalry. The army, therefore, has forty-eight mixed divisions and one cavalry division. In 1902 the army consisted of 625 battalions of infantry, 482 squadrons of cavalry, 574 batteries of field artillery, thirty-eight battalions of foot artillery, twenty-six battalions of pioneers, eleven battalions of communication troops (railway and balloon), and twenty-three transport battalions.

The following table shows the strength and the organization of the imperial army on the peace footing according to the budget estimates for 1900 :—

TABLE XXXI.—*The German Army.*

Peace Footing.	Officers.	Rank and File.	Special Service.	Horses.
1. Staff, Non-Regimental Officers	2,604	169	212	...
2. Infantry, 216 regiments	12,056	367,274	2473	...
Rifles (Jäger), 18 battalions	388	11,274	72	...
Bezirkskommandos (293) (Depôts of Landwehr)	870	5,757	15	...
3. Cavalry, 93 regiments	2,406	66.229	817	65,135
4. Field Artillery, 88 regiments	2,980	64,316	962	32,879
Foot Artillery, 17 regiments, 1 battalion	872	23,207	134	43
5. Pioneers, 25 battalions	571	14,814	99	...
6. Communication Troops (Railways, 3 regiments, 1 battalion; Balloon, 2 divisions; Telegraphs, 3 battalions)	237	6,074	47	...
7. Transport, 23 battalions	322	7,963	76	4,872
8. Special Formations	544	4,615	67	...
Total	23,850	571,692	4974	102,929
Grand Total		600,516		

The special service formation includes 2165 military surgeons, 1044 paymasters, 671 veterinary surgeons, and 1094 gunsmiths.

No official returns of the war strength of the army based upon the new formation are published, but no doubt Germany would be able to call up in the last extremity from 2,800,000 to 3,000,000 trained men.

The length of the frontier lines has been already mentioned. Germany has not good natural frontiers on the east or on the west, but the great rivers crossing the country from south to north constitute good lines of defence. These are strengthened by a system of fortresses. There are at present in Germany, which is divided into ten fortress districts, six fortresses of the first class, serving as camps (marked *). In the east we find *Königsberg, with Pillau and Boyen between the lakes in East Prussia; then along the Vistula, Danzig (Weichselmünde), Graudenz, and *Thorn; and farther south, *Posen, Glogau, and Glatz. In the centre, near Berlin, are situated Küstrin, Spandau, and Magdeburg; and along the Donau, Ingolstadt and Ulm. The Franco-German frontier is guarded by Neu-Breisach, *Strassburg, *Metz, and Diedenhofen; and behind by Germersheim, Mainz, Ehrenbreitstein, near Coblenz, *Cologne, and Wesel. Along the coast, besides the great naval ports of *Wilhelmshaven on the North Sea and *Kiel on the Baltic, many points are fortified.

The development of the navy has not until recently kept pace with that of the empire's commercial interests beyond the sea. The navy has also remained behind the marine forces of the other Great Powers. The following table gives the number of ships on 1st April 1901 :—

TABLE XXXII.—*The German Navy.*

	Number.	Displacement.	Indicated Horse-Power.
First-class battleships (*Linienschiffe*)	15	142,503	142,900
Defence armour-clads	8	28,102	38,400
Gunboats, armour-clad	13	13,886	10,700
Large cruisers	11	79,470	114,500
Cruisers	29	59,895	139,250
Gunboats	5	4,441	5,800
School ships	15	29,688	26,000
Vessels for other purposes	8	11,239	17,020
Total	104	369,224	494 750

The *personnel* for 1901 consisted of 1567 officers and surgeons, 526 aspirants, and 29,078 men.

The Navy Bill (*Flottengesetz*) of 14th June 1900 provides for (*a*) a battle-fleet of 2 flag-ships and 4 squadrons, each consisting of 8 first-class battleships, 8 large cruisers, and 24 small cruisers; (*b*) an *Auslands-Flotte* of 3 large cruisers and 10 small cruisers; (*c*) a reserve of 4 battleships, 3 large cruisers, and 4 small cruisers. The total is 38 battleships, 38 large cruisers, and 110 small cruisers. During the seven years ending 1907, 17 battleships, 10 large cruisers, and 29 small cruisers were to be laid down.

The Kaiser Wilhelm Canal, which crosses Schleswig-Holstein, and was opened in 1895, facilitates the transfer of naval forces from one sea to the other.

Agriculture.—In the last quarter of the 19th century there were three official inquiries into the agricultural improvement of the soil—namely, in 1878, 1883, and 1893. The last one gave the area of the different forms of cultivation as follows (in hectares, 000 omitted): —

TABLE XXXIII.—*Area of Different Forms of Cultivation.*

	1000 Hectares.	Per Cent.
(*A*) Cultivable area—		
1. Arable lands (including gardens)	26,243	48·6
Vineyards	133	0·3
2. Meadows	5,916	10·9
Pasture grounds	2,873	5·3
3. Woods and forests	13,957	25·8
Total	49,122	90·9
(*B*) Uncultivable Area—		
1. Houses and courtyards	484	0·9
2. Uncultivable land	2,061	3·8
3. Roads and waters (streams, lakes)	2,382	4·4
Total	4,927	9·1
Grand total	54,049	100

Since 1878 the woodland area has increased by about 20,000 acres. The state forests alone occupy 17,900 square miles, or 33·3 per cent., and are increasing. About 15·6 per cent. of the area belongs to towns or villages, and one-half is in private possession. The greatest attention is paid throughout the empire to forest culture. But the supply of native timber is not sufficient, and much has to be imported. On 14th June 1895 the total number of agricultural and forest holdings was 5,580,358, with an area of 49,627,751 hectares—namely, 22,041 exclusively forest holdings, with 6,343,000 hectares, and 5,558,317 combined holdings, including orchards and vineyards, with an area of 43,284,751 hectares.

The mean growth of the several agricultural holdings—each cultivated by one household—is given in the following table (holdings and hectares in thousands) :—

Table XXXIV.—*Extension of Agricultural Holdings.*

	Holdings.		Area.	
	Total.	Per Cent.	Total.	Per Cent.
1. Holdings (under 2 hectares)	3,236	58·2	1,808	5·6
2. Small farms (from 2 to 5 hectares)	1,016	18·3	3,286	10·1
3. Middle-sized farms (from 5 to 20 hectares)	999	18·0	9,722	29·9
4. Large farms (from 20 to 100 hectares)	282	5·1	9,870	30·3
5. Large properties (100 hectares and more)	25	0·4	7,832	24·1
Total 1895	5,558	100	32,518	100
,, 1882	5,276	...	31,869	...

This table shows that in Germany the farmers (Nos. 2, 3, 4), who held in 1895 70·3 per cent. of the total agricultural area, are still of great importance. There are, besides, many landowners of large estate, but the 4180 holdings of more than 500 hectares each did not cover together more than 4,461,000 hectares, of which there were 572 with more than 1000 hectares (or 2470 acres), holding together 1,169,000 hectares. It appears from the census that 37,270,000 hectares (or 86 per cent. of a total of 43,245,000 hectares) belonged to the holder, and only 14 per cent. was held by tenants. These farms supported in 1895 18,069,000 persons, of whom 8,156,000 were actually working upon the land. If we take the mean of the five years 1895–99, the areas under the principal crops, and the yield of their products, were as follows (in thousands of hectares and thousand metric tons, 1 metric ton or 1000 kilogrammes = 2200 ℔ or ·984 of an English ton).

Table XXXV.—*Acreage under Crops, and Yield per Hectare.*

Crops, 1895–99 (Mean).	Area under Crops. 1000 Hectares.	Yield.	
		1000 Tons.	Tons Per Hectare.
Rye	5,932	8,427	14·0
Wheat	1,953	3,502	17·7
Winter Spelt (Bavaria, Würtemberg, Baden)	328	470	14·3
Oats	4,001	6,314	15·8
Barley	1,647	2,780	16·9
Potatoes	3,076	35,820	116·4
Hay	5,908	23,982	40·7

Though the crops have increased, the yield is not sufficient for the supply of the rapidly increasing population. Nearly all kinds of cereals have to be imported. There were in recent years about 150,000 tobacco planters in Germany, the mean area under plantation being 20,000 hectares in 1894–98, and the mean yield 42,200 tons. The culture of hops is important only in Bavaria, Würtemberg, Baden, and Alsace. The 40,600 hectares planted on an average in 1894–98 with hops gave 27,000 tons, of which 6500 tons were available for export. The culture of the vine is concentrated in the valleys of the Rhine and its confluents (Neckar, Main, and Mosel). The mean area of the cultivated vineyards was 117,000 hectares in 1894–98. The yield has fluctuated enormously in recent years, from 6·3 hectolitres per hectare in 1891 to 43·4 in 1896; the mean from 1888 to 1897 was 21·1. The total yield in 1891 was 748,000, and in 1896, 5,051,000 hectolitres. The mean yield from 1889 to 1891 was 5,200,000 hectolitres.

The Prussian provinces east of the Elbe, including the province of Saxony and Mecklenburg, with a population of about 19,000,000, produced from potatoes in 1898–99 2,800,000 hectolitres of pure spirits, there being 3369 distilleries. The rest of Germany, with a population of 36,000,000, produced only about 1,000,000 hectolitres from 63,500 distilleries, mostly of small size. The mean total annual product of spirits in the twelve years since Bavaria, Würtemberg, and Baden were introduced into the German area of common spirit duty in 1887 was 3,125,000 hectolitres. The number of breweries decreased from 14,000 in 1872 to 7312 in 1898, but they are at present of much larger dimensions. The quantity of beer produced, calculated per head of the population, was enormous in Bavaria and Würtemberg in proportion to the other German states; it has increased also in the latter, but not at all in the same degree as in Northern Germany (German Brewery Union) and Baden.

Table XXXVI.—*Progress of the Production of Beer.*

Year.	Millions of Hectolitres.				Per Head (Hectolitres).		
	Bavaria.	Würtemberg.	German Union.	Empire.[1]	Bavaria.	Würtemberg.	Union.
1872	10·9	4·2	16·1	32·9	256	229	52
1882	12·3	3·2	21·3	38·9	232	165	62
1892	15·1	3·7	33·2	53·6	267	183	84
1899	17·7	4·1	43·2	69·5	292	193	99

The centres of beetroot sugar production are Silesia and Posen, the province of Saxony and Hanover, with Brunswick and Anhalt. But beet is also largely grown in West Prussia, Pomerania, and Mecklenburg.

Table XXXVII.—*Progress of the Production of Beetroot Sugar.*

Year.	Manufactories.	Beetroot consumed.	Sugar (Raw).	Molasses.
		1000 Tons.	1000 Tons.	1000 Tons.
1876–77	328	3,550	289	...
1886–87	401	8,307	986	216
1896–97	399	13,721	1,739	342
1897–98	402	13,698	1,755	344
1898–99	402	12,117	1,627	306

Live Stock.—Since 1873 the number of horses and cattle has increased nearly in the same proportion as the population. But sheep-breeding has declined enormously, as in almost all European countries (from 25 to 10 millions). On the contrary, pig-breeding has spread much in recent years, and the number has doubled since 1873. Germany is still absolutely dependent on foreign countries for live stock.

[1] Including Baden (1872, 927,000 hectolitres; 1898, 2,947,000) and Alsace-Lorraine.

TABLE XXXVIII.—*Live Stock.*

Year.	Live Stock (in Millions).				Per 100 Inhabitants.			
	Horses.	Cattle.	Sheep.	Pigs.	Horses.	Cattle.	Sheep.	Pigs.
1873	3·35	15·78	25·00	7·12	8·2	38·4	60·9	17·4
1883	3·52	15·79	19·19	9·21	7·7	34·5	42·0	20·1
1892	3·84	17·56	13·59	12·17	7·8	35·5	27·5	24·6
1900	4·18	19·00	9·67	16·76	7·3	34·0	17·3	30·0

The number of goats was 3,091,000 in 1892, and 2,320,000 in 1873. Not unimportant is the rearing of bees; there were in 1892 2,034,000 bee-hives.

Fisheries.—The occupation census of 1895 showed that 42,000 persons (members of families included) were occupied in fisheries on lakes, and 34,500 on shore and on the open sea.

Minerals and Mining.—The extraordinary industrial development of the country since 1870 was largely based on its mineral wealth. Having left France much behind in mineral production, Germany now rivals Great Britain and the United States.

Coal.—The six large coalfields rank according to production nearly in the same order as in 1878.

TABLE XXXIX.—*Number and Production of Collieries in* 1900.

Coalfields.	Collieries.	Quantities.	Average No. of Hands.	Value.
		Mill. Tons.		Mill. Marks.
Ruhr	170	60·2	229,000	514·8
Upper Silesia	57	24·8	70,000	184·5
Saar	25	11·1	51,000	129·0
Zwickau, Saxony	31	4·8	23,500	60·3
Lower Silesia	18	4·8	23,000	43·8
Aachen	13	1·8	8,000	16·7
Minor fields	24	1·8	9,500	17·0
Total	338	109·2	414,000	966·1

The following table shows the rapidly increasing development of the coal production. That of lignite is added, the provinces of Saxony and Brandenburg being rich in this product:—

TABLE XL.—*Production of Coal and Lignite.*

Year.	Coal.			Lignite.		
	Quantities.	Value.	Hands.	Quantities.	Value.	Hands.
	Mill. Tons.	Mill. Mks.		Mill. Tons.	Mill. Mks.	
1871	29·4	218·4	...	8·5	26·2	...
1881	48·7	252·3	186,000	12·8	38·1	25,600
1891	73·7	589·5	283,000	20·5	54·2	35,700
1899	101·6	789·6	379,000	34·2	78·4	44,700
1900	109·3	966·1	414,000	40·5	98·5	50,900

This production permits a considerable export of coal to the west and south of the empire (1900, 15,300,000 tons), but the distance from the coalfields to the German coast is such that the import of British coal cannot yet be dispensed with (1900, nearly 6,000,000 tons). Besides this from 7,000,000 to 8,000,000 tons of lignite come annually from Bohemia.

Iron.—The production of iron ores, mostly in Lorraine and Luxemburg, though three times greater than in 1871, does not satisfy the increasing demand. Some fine sorts have to be imported from Sweden and Spain. The following is the production of pig iron. The figures in (*a*) relate to the production exclusive of that of Luxemburg, the figures in (*b*) include this:—

TABLE XLI.—*Production of Iron Ores and Pig Iron.*

Year.	Iron Ores.				Pig Iron.			
	Quantities.		Value.		Quantities.		Value.	
	(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)
	Mill. Tons.	Mill. Tons.	Mill. Marks.	Mill. Marks.	Mill. Tons.	Mill. Tons.	Mill. Marks.	Mill. Marks.
1872	4·72	5·90	38·9	42·4	1·82	1·99	211·7	222·3
1881	5·41	7·57	31·1	36·1	2·62	2·91	152·7	164·0
1891	7·55	10·66	33·4	39·4	4·10	4·64	210·1	232·4
1899	11·98	17·99	57·2	70·2	7·15	8·13	410·1	454·7
1900	12·79	18·96	63·8	77·6	7·55	8·52	491·8	551·1

The following table shows the quantities of coal (lignite included) and pig iron which have been produced by the four most important industrial countries of the world (in millions of tons):—

TABLE XLII.—*Production of Coal and Pig Iron.*

States.	Coal.		Pig Iron.	
	1871.	1897.	1871.	1897
	Mill. Tons.	Mill. Tons.	Mill. Tons.	Mill. Tons.
Great Britain	125 5	205·4	6·7	8·9
United States	41·5	181·6	1·9	9·7
Germany	42·3	120·4	1·7	6·9
France	15·9	30·7	1·2	2·5

The production of other important minerals or metals is combined in a single table, showing similar progress to that of coal and iron (in thousands of tons and millions of marks):—

TABLE XLIII.—*Production of other Minerals and Metals.*

	1871.		1899.	
	Quantity.	Value.	Quantity.	Value.
	Mill. Tons.	Mill. Mks.	Mill. Tons.	Mill. Mks.
Zinc ore	335	5·4	665	35·4
Lead ore	97	14·4	144	14·1
Copper ore	217	5·5	774	20·9
Silver and gold ore	27·4	5·3	13·5	1·9
Iron pyrites	140	1·5	145	1·0
Rock salt	140	1·1	861	3·8
Potassic salt	375	3·3	2500	32·2

The total product of the mines, including coal and lignite and iron, and some minor ores, was of the value of 314,000,000 marks in 1871, and of 1,263,000,000 marks in 1900.

Manufactures.—The general census of industries, taken on 14th June 1895, gives the following table, showing the number of the different trades and industries and of the persons engaged in them. The census gives twenty-one groups of manufactures combined in three divisions:—

TABLE XLIV.—*Industries*, 1895.

Groups.	Establishments	Persons Engaged.
1. Horticulturists	24,768	74,991
2. Fishermen, &c.	17,553	28,137
Total *A*	42,321	103,128
3. Miners	4,003	536,289
4. Workers in stone, clay, and glass	48,229	558,286
5. Workers in metal	158,618	639,755
6. Workers in machines, instruments, &c.	87,879	582,672
7. Chemical industry	10,385	115,231
8. Workers in lighting materials, soap, fats, oils, &c.	6,191	57,909
9. Textile industry	205,292	993,257
10. Workers in paper	17,631	152,909
11. Workers in leather	47,325	160,343
12. Workers in wood	219,914	598,496
13. Workers in foods and drinks	269,971	1,021,490
14. Workers in dress and washing	848,845	1,390,604
15. Workers in building	198,985	1,045,576
16. Polygraphic industry	14,193	127,867
17. Artistic industry	9,511	19,879
Total *B*—Industry, including mining and building	2,146,972	8,000,563
18. Persons in mercantile business	635,209	1,332,993
19. Persons in assurance business	7,342	22,256
20. Persons engaged in conveyance	78,696	230 431
21. Lodging and boarding	234,437	579,958
Total *C*—Commerce, innkeeping, &c.	955,684	2,165,638
All industries, incl. commerce, 1895	3,144,977	10,269,329
,, ,, ,, 1882	3,005,457	7,340,789

The rate of increase of persons engaged in industries was 40 per cent. from 1882 to 1895. The following table shows the extent of the several establishments (000 omitted):—

TABLE XLV.—*Extent of Industries.*

Year.	Small Establishments. (1 to 5 Persons.)		Middle-Sized Establishments. (6 to 50 Persons.)		Large Establishments. (more than 50.)	
	Establs.	Persons.	Establs.	Persons.	Establs.	Persons.
Total in 1895 .	2,935	4,771	191	2,454	19	3,044
Total in 1882 .	2,883	4,336	113	1 392	10	1,613
Increase per cent.	1·8	10·10	69·7	76·3	90·0	88·7

The number of establishments employing persons in domestic industry was 22,307 in 1895, with 490,711 persons engaged; 151,695 establishments or factories used steam or water, the horse-power produced amounting to 3,300,000.

Commerce.—It has been stated that the *Zollverein* or German Customs Union does not completely coincide with the frontiers of the empire. Included within it are the Grand Duchy of Luxemburg and some small Austrian communes. The following table shows the special trade. It should be remembered that Hamburg and Bremen were included in the *Zollverein* in 1888:—

TABLE XLVI.—*Special Trade* (*in millions of marks*).

Year.	Imports.	Exports.	Year.	Imports.	Exports.
1880	2859·9	2946·2	1897	4864·6	3786·2
1885	2989·9	2915·3	1898	5439·7	4010·6
1890	4272·9	3409·6	1899	5783·6	4368·4
1895	4246·1	3424·1	1900	6043·0	4752·6

The three principal groups of articles which the official returns distinguish were as follows in 1890 and 1899 (in millions of marks):—

TABLE XLVII.—*Specification of the Special Trade,* 1890 *and* 1900.

Articles.	1890.		1899.	
	Imports.	Exports.	Imports.	Exports.
Raw materials for industry	1767·4	708·3	2803·1	1111·4
Manufactures . . .	981·1	2147·5	1199·7	2982·4
Articles of consumption .	1397·0	470·7	1762·8	517·6

The following table gives further details of the special trade in 1899 (in millions of marks). The official returns distinguish the raw materials from the manufactured articles in respect of certain classes of imports and exports:—

TABLE XLVIII.—*Classes of Imports and Exports,* 1899.

	Imports.		Exports.	
Living and other Animals	186·4		19·7	
Animal Products . .	191·2		40·6	
Seeds and Plants . .	68·6		42·6	
Fuel	160·7		235·6	
Railway Waggons, Ships, &c.	12·9		19·1	
Machinery, Instruments .	109·3		291·0	
Hardware, Toys, Jewels .	26·7		122·3	
Literature, Art, &c. .	45·0		140·3	
Various	...		2·8	
Raw and Manufactured Materials:—	Raw.	Manufactured.	Raw.	Manufactured.
Articles of consumption	1273·9	268·1	109·0	350·1
Fats and Oils . .	165·7	140·5	14·7	20·0
Chemicals, Drugs .	207·5	108·8	44·4	365·4
Stone, Clay, Glass .	54·3	23·6	51·9	117·6
Metals, Metallic Manufactures . .	350·2	62·3	97·2	487·0
Wood, Wooden Wares	152·7	231·9	43·0	105·6
Paper goods . .	17·8	9·5	22·9	81·6
Leather, Furs . .	144·4	106·7	66·2	204·6
Textiles . . .	802·7	470·5	154·2	880·4
Indiarubber, &c. . .	76·7	14·5	24·3	54·1
Total . .	5483·3		4207·0	
Gold and Silver . .	300·3		161·4	

The principal imports and exports under the above heads were, in millions of marks, as follows. The figures are to be considered as net, the exports being deducted from the imports, and *vice versâ*:—

TABLE XLIX.—*Imports* (*excess over Exports*) *in* 1899.

Articles.	Quantity. 1000 Tons.	Value.	Articles.	Quantity. 1000 Tons.	Value.
Cereals:—			Raw Materials:—		
Wheat . .	1371	180·4	Lignite . .	8596	60·2
Maize . .	1626	135·2	Copper . .	63	93·6
Barley . .	1104	127·9	Tin . .	11	27·5
Rye . . .	561	64·9	Iron Ores . .	1045	59·6
Rice . . .	257	35·1	Pig Iron . .	430	27·8
Oats . . .	259	28·9	Petroleum . .	909	78·3
Malt . . .	92	20·9	Other Mineral Oils .	104	17·2
Fruits . . .	382	99·5	Oil, Oilseed, &c.	530	94·4
Wine . . .	89	30·3	Linseed, Rape	353	72·3
Coffee . . .	156	128·0	Various Fodder	678	56·8
Cocoa . . .	18	24·9	Clover Seed, &c.	20	17·9
Tea . . .	2·5	4·5	Saltpetre .	500	70·6
Tobacco . .	56	88·1			
Animals:—	Number.		Raw Materials for Textile Industry:—		
Horses . .	119,000	88·8	Wool . . .	176	346·7
Cattle . .	179,000	55·9	Cotton . .	316	212·1
Swine . .	70,000	4·9	Hemp and Flax	86	42·2
Animal Products:	1000 Tons.		Jute . . .	81	22·1
Meat . .	71	66·0	Silk . . .	47	128·4
Lard and Tallow	153	91·0	Yarn, all sorts	42	105·5
Butter . .	10	14·4	Wood and Timber	4579	272·3
Cheese . .	14	17·9	Indiarubber . .	8	51·8
Poultry . .	35	37·8	Hides . . .	69	88·4
Eggs . . .	112	95·8			
Fish (including Herrings)	..	60·8			

TABLE L.—*Exports* (*excess over Imports*) *in* 1899.

Articles.	Quantity. 1000 Tons.	Value.	Articles.	Quantity. 1000 Tons.	Value.
Articles of Consumption:—			Instruments, Pianofortes	16	42·3
Sugar . .	938	203·2			
Flour . .	141	18·7	Furniture, &c. .	11	23·3
Hops . .	4	8·4	Paper . . .	75	65·8
Beer . . .	21	10·1	Chemicals . .	42	93·4
Coal and Coke .	5889	130·2	Textile manufactures:—		
Cement . .	517	19·5			
Iron:—			Woollen . .	23	197·8
Angle Iron, &c.	377	48·6	Cotton . .	31	173·4
Manufactures .	711	263·0	Silk . . .	5	104·7
Telegraph Wire, &c.	12	22·2	Cloths, &c. .	9	123·9
Machinery .	137	121·0	Leather, &c. . .	10	107·6
Ships . .	12	4·2	Indiarubber Manufactures	3	37·2
Copper, manufactured	19	5·2	Gold and Silver Wares . .	73	45·2
Zinc, raw and manufactured	51	31·6	Toys . . .	28	42·6
			Books, printed .	8	48·6
Earthen and China Wares	33	43·1	Impressions in Colour, Lithographs, &c.	5	51·8
Glass . . .	102	20·3			

Countries.—The special commerce of the German *Zollverein* was divided as follows in 1899, according to countries:—

TABLE LI.—*Imports from Different Countries, and Exports to them,* 1899 (*in millions of marks*).

Countries.	Imports.	Exports.
Great Britain . . .	777·1	851·6
Austria-Hungary . .	730·4	466·0
Russia	715·9	437·3
France	303·1	216·7
Netherlands . . .	203·3	327·7
Belgium	246·1	207·1
Switzerland	176·3	284·7
Sweden	104·2	136·1
Denmark	77·5	125·8
Norway	24·8	77·0
Italy	197·0	116·0
Spain	69·5	44·0
Portugal	15·9	18·9
Rumania	27·1	36·8
Turkey	28·9	32·6
Hamburg (free port) .	19·3	70·8
United States . . .	907·2	377·6
British North America .	4·7	23·7
Mexico	11·8	22·3
West Indies . . .	30·1	11·0
Central America . . .	29·6	4·1
Argentine Republic . .	194·5	52·3
Brazil	91·0	46·5
Chile	93·4	28·1
Ecuador, Peru, Bolivia .	19·7	14·0
Colombia, Venezuela . .	17·7	9·0
Uruguay	13·1	10·4
Carry forward . .	5129·2	4048·1

TABLE LI.—*continued.*

Countries.	Imports.	Exports.
Brought forward .	5129·2	4048·1
British India . . .	230·5	65·3
Australasia	121·1	37·8
Dutch East Indies . .	62·4	19·5
China	29·0	50·6
Japan	16·5	40·9
Egypt	31·9	9·7
Transvaal [1]	39·3	11·3
British South Africa . .	30·0	11·3
West Africa	40·7	19·5
Other Countries . . .	53·4	54·4
Total . . .	5784·0	4368·4

[1] Including gold to the value of 38·4 millions of marks.

Shipping and Navigation.—As with all sea-faring nations, the number of sailing vessels in the German merchant service has decreased, but the number and tonnage of steamers have greatly increased. The official returns do not include ships of less than 17⅗ gross tons. Since 1897 a statement of the gross tonnage has taken the place of the net tonnage returns. The following table shows the rapid increase in the number of steamships since 1871:—

TABLE LII.—*The Mercantile Marine of Germany.*

Year. January 1.	Sailing Vessels.		Steamers.		Total.	
	Number.	Tonnage.	Number.	Tonnage.	Number.	Tonnage.
		Net Tonnage.		Net Tonnage.		Net Tonnage.
1871 .	4372	900,000	147	82,000	4519	982,000
1881 .	4246	966,000	414	216,000	4660	1,181,000
1891 .	2757	710,000	896	723,000	3653	1,433,000
1897	2552	598,000	1126	890,000	3678	1,488,000
		Gross Tonnage.		Gross Tonnage.		Gross Tonnage.
1897	2552	632,000	1126	1,428,000	3678	2,060,000
1900	2466	632,000	1293	1,864,000	3759	2,495,000

The total number of sailors required for manning the ships of the mercantile marine in 1899 was 42,661, of whom 29,111 were on steamers. Of the total number of vessels almost half the tonnage belonged to Hamburg.

TABLE LIII.—*Ships according to States.*

	Total.		Steamers only.	
	Number.	Gross Tonnage.	Number.	Gross Tonnage.
Hamburg . . .	846	1,229,500	435	993,700
Bremen . . .	520	723,000	273	510,000
Prussian Ports . .	2074	407,500	525	314,600
Mecklenburg-Schwerin	65	39,300	32	20,200
Oldenburg . .	228	81,900	14	10,900
Lübeck . . .	26	14,100	14	14,100
Total . .	3759	2,495,300	1293	1,863,500

Much progress has been made in shipbuilding since 1890. The numbers and gross tonnage of ships built in German yards in 1899 were as follows:—

TABLE LIV.—*Ships built in* 1899.

	Total.		Steamers only.	
	Number.	Gross Tonnage	Number.	Gross Tonnage.
A—Ships Building.				
Men of War—				
For H.M. Navy . .	24	65,470	24	65,470
For Foreigners . .	23	26,143	23	26,143
Merchant Vessels—				
For Home Merchant Marine . .	418	415,855	283	389,245
For Foreigners . .	69	54,812	58	52,892
River Ships—				
For Home Rivers .	166	28,687	46	5,404
For Foreigners . .	33	2,118	25	1,767
B—Ships built in 1899.				
Men of War . . .	9	3,090	9	3,090
Merchant Vessels . .	307	209,901	222	196,738
River Ships . . .	150	22,633	33	2,852

The number and tonnage of registered sailing and steam vessels of the German Empire engaged in home and foreign trade during 1898 are given in the following table, the net tonnage being in millions of tons:—

TABLE LV.—*Trade Voyages.*

	With Cargoes.		In Ballast.	
	Number.	Tonnage.	Number.	Tonnage.
Voyages between German Ports	42,100	3·0	9,086	0·6
Voyages between German and Foreign Ports . .	18,541	10·2	3,398	1·5
Voyages between Foreign Ports	18,564	26·4	3,420	2·1
Total . . .	79,205	39·6	15,904	4·2

The maritime development of the German ports may be seen from the following table, giving the tonnage of the vessels cleared and entered (in millions of net register tons):—

TABLE LVI.—*Clearances and Entries of Ships.*

Years.	Entered.			Cleared.		
	German.	Foreign	Total.	German.	Foreign.	Total.
1873–75	2·97	3·46	6·43	2·94	3·38	6·32
1880–85	4·50	4 67	9·17	4·53	4·69	9·22
1895	7·91	7 28	15·19	8·03	7·25	15·28
1899	10·25	7·74	17·99	10·31	7·72	18·03

The tonnage of the vessels entered in 1899 under the British flag was 4,353,000 tons. Other countries were as follows: Sweden 958,000 tons, Denmark 925,000, Norway 711,000, Netherlands 285,000, Russia 237,000, France 90,700.

The principal ports of the German Empire ranked as follows in 1899 as to the tonnage of ships entered and cleared (in millions of tons):—

TABLE LVII.—*Number of Ships Entered and Cleared in the most important Ports.*

Ports.	Entered.		Cleared.	
	With Cargoes.	In Ballast.	With Cargoes.	In Ballast.
Hamburg . . .	7·17	0·43	5·36	2·36
Stettin	1·43	0·04	0·90	0·55
Bremerhaven . . .	1·15	0·08	1·04	0·24
Bremen	0·80	0·03	0·64	0·20
Danzig	0·54	0·11	0·50	0·16
Lübeck	0·53	0·01	0·38	0·16
Kiel	0·50	0·02	0·36	0·14
Königsberg . . .	0·33	0·01	0·37	0·03

Railways.—The German railway system nearly doubled from 1865 to 1875. Since that time Prussia has followed the southern states, where the building of railways has from the outset been regarded as a Government duty. To-day the great majority of German railways are owned by the state governments.

TABLE LVIII.—*Development of the Railway System.*

Year. January 1.	Length in Miles.		Total. English Miles.
	Government Lines. English Miles.	Lines belonging to Private Companies. English Miles.	
1875	7,493	10,019	17,522
1885	19,823	3,286	23,109
1895	25,811	2,277	28,088
1900	28,087	2,510	30,597

Of the total in 1900, 21,050 miles were trunk-lines and 9547 branch lines. Germany possesses the most extensive network of railways of any country except the United States. The United Kingdom has about 22,000 miles. As regards proportion to the area, Germany had in 1899 144 miles for every 1000 English square miles, but in Great Britain and Ireland the proportion is about 180 per 1000 square miles. Narrow-gauge lines, not comprised in the above figures, measured 1075 miles in 1900. The financial condition of the railways shows, as to broad-gauge lines, that the total capital invested was 12,134 millions of marks at the end of the financial year 1898, or 405,503 marks per mile; the interest is estimated at 6·06 per cent., the excess of receipts (1898, 1840 millions) over the expenditure (111 millions) being 723 millions of marks. The number of men employed was 509,600, including 308,600 workmen. In 1897–98 320·8 millions of metric tons of goods were carried, and the number of passengers conveyed was 756 millions.

Internal Navigation.—The length of navigable rivers in Germany is 5779 miles, that of canalized rivers 1451 miles, and of canals proper 1551 miles. The construction of canals had almost ceased for a long time, but in recent years the Ruhr and the Ems (Dortmund-Ems Canal) and the Elbe and the Trave (near Lübeck) have been joined by canals. The number of vessels engaged in internal navigation was in 1897 22,000, with a tonnage of 3,370,000 tons. Not included in the above figures is the Kaiser-Wilhelm Canal, joining the Baltic and North Sea and traversing Holstein from Kiel Bay to the mouth of the Elbe. The canal was built between 1887 and 1895. The length is 61 miles, its breadth at the bottom is 72 feet, at the surface 213 feet, and the depth 29½ feet. The number of ships passing through the canal has steadily increased from 20,068 vessels of 1,751,000 tons in 1896 to 29,045 of 4,282,000 tons in 1900, men-of-war not included.

Posts and Telegraphs.—With the exception of Bavaria and Würtemberg, which have administrations of their own, all the German States belong to the Imperial Postal District (*Reichspostgebiet*). The following table shows the extension of the net of post offices for the whole empire, and also the estimated number of letters and packets delivered:—

TABLE LIX.—*Post Office Development.*

Year.	Post Offices.	Men Employed.	Letters Entered.	Packets Entered.	Letters. Per Head.
			Millions.	Millions.	
1872	7,518	...	501·2	62·7	12·1
1880	9,460	...	843·2	86·6	18·7
1890	24,952	128 687	1634·4	120·8	33·2
1899	36,388	206,945	2724·3	184·6	49·4

The number of post offices was 18 per 100 English square miles in 1899.

Telegraph statistics are given in the subjoined table:—

TABLE LX.—*Imperial Telegraphs.*

Year.	Telegraph Offices.	Length of Lines.	Length of Wire.	Number of Messages Entered.	
				Total.	Per Head.
		Miles.	Miles.	Millions.	
1872	2,359	23,425	78,022	9·7	0·24
1880	9,980	44,011	158,986	13·5	0·38
1890	17,200	64,194	226,663	21·8	0·45
1899	23,716	79,870	294,900	37·9	0·69

There were 188 places provided with telephone service in 1888, and 13,175 in 1899; the number of towns in telephonic communication with one another was 1964 in 1899. The number of receivers rose from 37,313 in 1888 to 229,391 in 1899, and that of telephonic messages from 155 millions in 1888 to 621 millions in 1899.

The amount of money circulated by means of the post has also much increased.

TABLE LXI.—*Money circulated through the Post.*

	1872.	1899.
	Millions of Marks.	
Value of charged Letters and Parcels .	14,096	17,235
Value of Payments through Post Office.	55	462
Value of Money Orders issued . .	530	8212

Banking and Credit.—The amount of money coined from the foundation of the empire (1871) to the end of March 1900 is shown in the following table (in millions of marks):—

TABLE LXII.—*Coinage.*

Gold	3631·5
Silver	543·4
Nickel	64·6
Copper	14·6
Total	4254·1
Withdrawn	59·6
Surplus	4194·5

The total value of thalers, which are still legal tender, was estimated in 1894 at about 400,000,000 marks.

There are eight note-issuing banks (*Notenbanken*), that is to say, the Imperial Bank (*Reichsbank*) in Berlin, the Frankfort Bank, the Bayrische Notenbank in Munich, the Sächsische Bank in Dresden, the Würtemberger Notenbank in Stuttgart, the Badische Bank in Karlsruhe, the Bank für Süddeutschland in Darmstadt, and the Braunschweiger Bank. The total mean amount of notes in circulation (100, 500, and 1000 marks) was 1322 millions of marks in 1899. *Reichskassenscheine*, or small paper notes for five, twenty, and fifty marks, have been in circulation of recent years to the amount of 120 millions of marks. The following table shows the average financial condition of the above-named eight note-issuing banks in 1899 (in millions of marks):—

TABLE LXIII.—*Note-Issuing Banks.*

	Liabilities.			Assets.	
	Total.	Reichsbank.		Total.	Reichsbank.
Capital . .	219·7	120·0	Coin and Bullion	911·5	825·5
Reserve Fund .	47·6	30·0	Notes (Empire and Banks)	50·8	35·1
Notes in Circulation .	1322·2	1141·7	Bills . . .	1049·4	817·1
Other Liabilities	649·2	554·9	Other Assets .	229·0	168·9
Total . .	2238·7	1846·6	Total . .	2240·7	1846·6

Life Assurance.—There were forty-six companies in 1900 for the insurance of life. The number of persons insured was 1,446,249 at the end of that year, the insurances amounting to 6397 millions of marks. Besides these are sixty-one companies—of which forty-six are comprised in the above life assurance companies—paying subsidies in case of death or of military service, endowments, &c. Some of these companies are industrial. The transactions of all these companies included in 1900 over 4,179,000 persons, and the amount of insurances was 1606 millions of marks.

Insurance for Working Classes.—The speech of the Emperor William I. from the throne on 17th November 1881 inaugurated a great system of public care for the working classes, such as is not to be found in any other great state. A series of Acts passed during the years 1883 to 1892 introduced obligatory insurance for all the working classes in case of sickness, accident, or incapacity, so that now only an insurance of the widows of workmen is required to complete this system. The insurance in case of sickness is carried out by 23,000 local sick funds, and included in 1898 over 9,223,000 workmen. These funds had receipts amounting to 165,800,000 marks in 1898, and possessed property of the value of 163,900,000 marks. The workmen contribute at the rate of two-thirds, the employers at the rate of one-third. The accident insurance embraces 18,246,000 persons, belonging to 5,110,000 establishments, with 522 professional co-operative associations. Contributions are made by employers only. The receipts were 83,380,000 marks in 1898, and the property was valued at 161,500,000 marks at the end of that year. The old age and invalid insurance is carried out by thirty-one large territorial offices, to which must be added nine special unions. The premiums are paid half by employers and half by workmen, but the empire contributes 50 marks to every annuity. The income of the forty establishments was 163,564,000 marks in 1898 (including 24,400,000 marks of imperial contributions). The capital collected was 671,900,000 marks. The number of annuitants—the old age annuities beginning at seventy years of age—was 512,000 in 1898, and the amount of annuities 68,940,000 marks.

Money, Weights, and Measures.—The variety of German coinage was replaced after the creation of the empire by a united one (Act of 4th December 1871, supplemented by that of 9th June 1873). The standard of value is gold. Silver is legal tender only up to 20 marks. One mark of 100 pfennige is equal to 100/279 grammes of fine gold, so that 1 livre gold (500 grammes) has a value of 1395 marks. The gold coins are 20- and 10-mark pieces, called *doppelkrone* and *krone*. The small 5-mark pieces in gold have been withdrawn. The 20-mark piece contains 7·16846 grammes of fine gold, the fineness being 900/1000. The pound sterling is of the value of 20·43 marks. The silver coins are 5-, 2-, and 1-mark pieces and 50-pfennig pieces. The nickel coins are 20-, 10-, and 5-pfennig pieces, and the bronze coins 2- and 1-pfennig pieces.

The metrical system of weights and measures came into force on 1st January 1872, and the people soon became familiarized with it.

AUTHORITIES. — **General.**—P. E. RICHTER. *Bibliotheca geographica Germaniae.* "Literatur des Landes- und Volkeskunde des Deutschen Reiches," Leipzig, 1896.—L. NEUMANN. *Berichte über die Fortschritte der wissenschaftl. Landeskunde Deutschlands* published in the Geographical Year-Book, Gotha, since 1894, every two years.—A. KIRCHHOFF. *Anleitung zur Deutschen Landes- und Volkskunde*, Stuttgart, 1889. **Maps.**—"Karte des Deutschen

Reiches" (scale 1 : 100,000), edited by the Topographical Bureaux of Prussia, Bavaria, Saxony, and Würtemberg since 1880 (not quite completed; there are wanting about 40 sheets of a total of 674 sheets).—"Topographische Spezialkarte von Mitteleuropa," edited by the Prussian Topographical Survey (Landesaufnahme) (1 : 200,000). Other good special maps: W. LIEBENOW, "Spezialkarte von Mitteleuropa" (1 : 300,000), Frankfurt; C. VOGEL'S "Karte des deutschen Reiches" (1 : 500,000), 27 sheets, Gotha, J. Perthes; R. LEPSIUS, "Geologische Karte des deutschen Reiches" (1 : 500,000), 27 sheets, Gotha, 1893. **Physical Geography.**—A. PENCK. *Das Deutsche Reich.* (Part i. of the Länderkunde des Erdteils Europa, edited by A. Kirchhoff), Leipzig and Vienna, 1887.—R. LEPSIUS. *Geologie von Deutschland* und den angrenzenden Gebieten. I. Das westliche und südliche Deutschland, Stuttgart, 1887–92.—O. DRUDE. *Deutschlands Pflanzengeographie*, i., Stuttgart, 1896. **Special Subjects.**—*Die Stromgebiete des Deutschen Reiches* (Statistik des Deutschen Reiches, Neue Folge, vol. xxxix., i. (1891), ii. (1900), Rhine and Danube yet wanting). **Political Geography and Statistics.**—DANIEL. *Deutschland nach seinen physischen und politischen Verhältnissen geschildert*, ii. Political Geography, 1863, 7th edition, revised by Volz, Leipzig, 1893–94.—PESCHEL and ANDREE, *Physikalisch-statistischer Atlas des Deutschen Reiches*, 1876–78. *Statistisches Jahrbuch des Deutschen Reiches*, annual official publication since 1880, Berlin, containing every year an index covering the whole suite of the *Statistik des Deutschen Reiches*, published by the Imperial Statistical Office since 1873, partly periodically as "Monatshefte" and (since 1892) as "Vierteljahrshefte."—R. BOECK. *Der Deutschen Volkszahl und Sprachgebiet*, Berlin, 1869.—NABERT. *Karte der Verbreitung der Deutschen in Europa*, 12 sheets (scale 1 : 925,000), Glogau, 1891, and since.—H. MEYER. *Das deutsche Volkstum*, Leipzig, 1899.—P. LANGHANS. *Alldeutscher Atlas*, Gotha, 1900.—Census Works: *Volkszahlung of* 1890; Statistik des Deutschen Reiches, N.F., vol. lxviii. (1894); for that of 1895 Vierteljahrshefte 1897, for that of 1900 Vierteljahrshefte 1901.—*Die Berufs- und Gewerbezählung vom 14. Juni* 1895 (Statistik des Deutschen Reiches, N.F., vols. cii.-cxix., particularly vols. cxi. (with 19 maps), cxix. (with 14 maps), and cxii., die Landwirtschaft im Deutschen Reiche (with 8 maps). *Atlas der Bodenkultur des Deutschen Reiches* (15 maps), Berlin, 1881. Annual publications of the Reichsstatistik deal with external commerce, internal shipping, navigation on sea, criminal justice, insurance in case of sickness. **Topography.**—NEUMANN. *Ortslexikon des Deutschen Reiches*, 3rd edition, by Keil, Leipzig, 1894.—H. RUDOLPH. *Vollständigstes geogr.-topogr.-statist. Ortslexikon von Deutschland*, 2 vols., Weimar, 1870; though its figures are out of date, it is useful, and not yet replaced in respect of completeness.—BRUNKOW. *Die Wohnplätze des Deutschen Reiches*, 3 vols., Berlin, 1889.—Useful, but not yet complete, is KÜRSCHNER-PEIP'S *Deutsches Kartenwerk*, 690 sheets (scale 1 : 200,000), with 158-sheet gazetteer for every four neighbouring sheets, Berlin, Eisenach, Leipzig since 1897. (H. WA.)

II.—HISTORY, 1870–1900.

The new empire.

The foundation of the empire in 1871 begins a new era in the history of Germany. The rivalry of the dynasties to which for so long the interests of the nation had been sacrificed now ceased. By the treaties of Versailles the kingdoms of Bavaria and Würtemberg, and the grand duchy of Baden, as well as the southern provinces of the grand duchy of Hesse, were added to the North German confederation. Henceforward all the German states that had survived the struggle of 1866, with the exception of the empire of Austria, the grand duchy of Luxemburg, and the principality of Liechtenstein, were incorporated in a permanent federal state under the leadership of Prussia. No important alterations were made in the constitution of 1867. The states retained their autonomy except in those matters which were expressly transferred to the imperial authorities; the princes retained their sovereignty; the king of Prussia, though he now took the title of German Emperor, was only *primus inter pares;* he was president of the confederation, but had no suzerainty over the other princes. None the less, from this time the acts of the State Governments and Parliaments have ceased to have more than a local importance; the history of the nation is centred in Berlin, in the *Bundesrath* or Federal Council, in which the interests of the individual states are represented; in the Reichstag, in which the feelings and wishes of the nation are expressed; and above all, in the Prussian Government and imperial executive.

The constitution of the empire.

The constitution, as established in 1867 and revised in 1871, derives its authority from a double source:—the treaties between the sovereign states of which the confederation is composed, and the vote of the constituent assembly of 1867. It created for federal purposes a *Bundesrath* or Council, in which Prussia had 17 votes; Saxony, 4; Mecklenburg-Schwerin and Brunswick, 2 each; all the other states, 1. In 1871 Bavaria received 6 votes; Würtemberg, 4; Baden, 3; and Hesse, 2 additional votes. The Council, the meetings of which are private, exercises a general control over the administration, and all laws require its sanction. In legislation it is assisted by the Reichstag, which is elected by universal suffrage. The Federal Budget has to be passed each year in the form of a law. The office of president of the confederation, to which in 1871 the title of German Emperor was attached, is permanently vested in the king of Prussia. The emperor commands the army and navy; appoints all federal officials; summons the Council and Reichstag; publishes the laws and administers them. All his acts (except orders as commander of the army and navy) must be countersigned by the chancellor, who is the only responsible imperial minister, and is also president of the Council. The federation formed a customs union (except for the free cities of Hamburg and Bremen), and all legislation on customs, as well as excise on salt, tobacco, beer, brandy, and sugar, belongs to the federal authorities. Post-office, navy, and consular service are also federal. The states retain the right of diplomatic representation, but there is also a common diplomatic representation appointed by the president. The subjects on which the imperial authorities were qualified to legislate were, besides naval and military matters and customs, the law of domicile, trade, banking, money, weights and measures, patents and copyright, mercantile marine, railways, rivers and canals, posts and telegraphs, the press, the law of association, medical law, criminal law, legal procedure, and commercial law.

The southern states when they joined the confederation reserved certain privileges: the king of Bavaria kept the command of his army in time of peace, and military jurisdiction; he, as well as the king of Würtemberg, retains the right of appointing officers. Excise duties on beer and brandy in both kingdoms and in Baden were reserved. Both kingdoms retained the separate administration of their own posts and telegraphs. Bavarian railways were exempt from imperial supervision except for military purposes, and Bavaria kept the right to have its own laws on marriage and domicile.

The empire and the states.

The constitution has stood the test. No serious changes have been made, no serious constitutional questions have arisen. The number of states of which the empire consists has remained unaltered;[1] occasional disputes have been settled harmoniously in a legal manner. The special rights reserved to Bavaria and Würtemberg have not proved, as was feared, a danger to the stability of the empire. Much apprehension had been caused by the establishment of a permanent committee for foreign affairs in the Council, over which the Bavarian representative was to preside; but the clause remained a dead letter. There is no record that the committee ever met until July 1900, when it was summoned to consider the situation in China; and on that occasion it probably formed a useful support to the Government, and helped to still apprehension lest a too adventurous policy should be pursued. Another clause determined that in a division in the Reichstag on any law which did not concern the whole empire, the representatives of those states which were not concerned should not vote. This, had it been retained, would have destroyed the coherence of the Reichstag as representative of the whole nation. It was repealed in 1873. The permission to maintain diplomatic missions has been equally harmless: most of the states have recalled all their diplomatic representatives; Saxony, Bavaria, and Würtemberg have maintained only those at Vienna, the Vatican,

[1] The only formal change is that the duchy of Lauenburg, which since 1865 had been governed by the king of Prussia as a separate principality (but without a vote in the *Bundesrath*) was in 1876 incorporated in the Prussian province of Schleswig-Holstein.

and at St Petersburg. Bavaria has even voluntarily adopted many imperial laws from which it was legally exempted; for instance, the laws of settlement.

If the states have been loyal to the empire, the imperial Government has also respected the constitutional privileges of the states. The harmonious working of the constitution depends on the union of policy between the empire and Prussia, for it is the power of Prussia which gives strength to the empire. This was practically secured by the fact that the emperor, who is king of Prussia, appoints the chancellor, and the chancellor is generally president of the Prussian ministry as well as minister of foreign affairs—in his person the Government of the two is identified. For twenty years the double office was held by Bismarck, who, supported as he was by the absolute confidence of the emperor, and also of the allied princes, held a position greater than that ever attained by any subject in modern Europe since the time of Richelieu. For ten months in 1873 he, indeed, resigned the office of minister president to Roon; and in the same way Caprivi, during the years 1893–94, held the chancellorship alone; but in neither case was the experiment successful, and Hohenlohe and Bülow adhered to the older plan. So important is the practical co-operation of the imperial administration and the Prussian Government, that it has become customary to appoint to seats in the Prussian ministry the more important of the secretaries of state who administer imperial affairs under the chancellor. Delbrück, head of the imperial chancery, had held this position since 1868; in 1877 Bülow, secretary of state for foreign affairs, was appointed Prussian minister, and in recent years this has become the ordinary practice. One result of this is to diminish the control which the Prussian parliament is able to maintain over the Prussian ministry.

Prussia and the empire.

In the federal council Prussian policy nearly always prevails, for though Prussia has only seventeen votes out of fifty-eight, the smaller states of the North nearly always support her; practically she controls the vote of Waldeck, and since 1885 those of Brunswick. A definite defeat of Prussia on an important question of policy must bring about a serious crisis; it is generally avoided because, as the meetings are secret, an arrangement or compromise can be made. Bismarck, knowing that nothing would more impede the consolidation of the empire than an outbreak of local patriotism, always so jealous of its rights, generally used his influence to avoid constitutional disputes, and discouraged the discussion of questions which would require an authoritative interpretation of the constitution. It was, however, opposition in the Bundesrath which obliged him to abandon his scheme for imperial railways, and when, in 1877, it was necessary to determine the seat of the new supreme court of justice, the proposal of the Government that Berlin should be chosen was outvoted by thirty to twenty-eight in favour of Leipzig. On this occasion Bismarck accepted the decision, but when important interests were at stake he showed himself as ready to crush opposition as in the older days, as in the case of Hamburg and Bremen (see below).

The great personal qualities of the reigning emperors and the widely-extended family connexions of the house of Hohenzollern have enabled them to hold with ease their position as leaders among the ruling families. So far as is known, with one or two unimportant exceptions, the other princes have loyally accepted their new position. It is only as regards the house of Brunswick that the older dynastic questions still have some political importance.

The other princes who were dispossessed in 1866 have all been reconciled to Prussia. The elector of Hesse and the duke of Nassau have formally relinquished their claims. In 1883 the daughter of the duke of Augustenburg, the former claimant to the duchies of Schleswig and Holstein, married the heir to the Prussian throne, who became Wilhelm II. On the other hand, the royal family of Hanover has never ceased to protest against the acts by which they were deprived of their dominions. King George (*q.v.*) to the end of his days, whether in Austria or in France, still regarded himself as in a state of war with Prussia. As he had used his large personal property to organize a regiment in order to regain his possessions, the Prussian Government had sequestrated that part of his income, amounting to some £50,000, over which they had control, and used it as secret service money chiefly for controlling the press; to this fund the name "Welfen-Fond" was commonly given. After 1870 the Hanoverian regiment was disbanded, but the sequestration continued. The death of the old king in 1878 made no difference, for his son in a letter to the king of Prussia announced that he assumed and maintained all his father's rights, and that he did not recognize the legal validity of the acts by which he was, as a matter of fact, prevented from enjoying them. His protest was supported by a considerable number of his former subjects, who formed a party in the Reichstag. The marriage of the duke of Cumberland (the title by which the king called himself till he could come into his possessions) with Princess Thyra of Denmark in the same year was made the occasion of a great demonstration, at which a deputation of the Hanoverian nobility assured the duke of their continued attachment to his house.

Hanover.

After Bismarck's retirement, the emperor attempted to bring about a reconciliation with the duke and the Hanoverians. His attention had been drawn to the bad moral effect of the use to which the Welfen-Fond was applied, and on the duke of Cumberland writing him a letter, in which, while maintaining his claims to the throne of Hanover, he recognized the empire and undertook not to support any enterprise against the empire or Prussia, with the consent of the Prussian parliament the sequestration of his property was removed. The attitude of passive resistance is, however, still maintained, and has affected the position of the duchy of Brunswick.

In 1884 William, duke of Brunswick, died after a reign of fifty-four years. The younger son of the duke who fell at Quatre Bras, he had been called to the throne in 1831 to take the place of his elder brother Charles, who had been deposed. Duke Charles had died at Geneva in 1873, and as both brothers were childless, the succession went to the duke of Cumberland as head of the younger branch of the house of Brunswick-Lüneburg. Duke William before his death had arranged that the government should be carried on by a council of regency so long as the heir was prevented from actually assuming the government; at the end of a year a regent was to be chosen from among the non-reigning German princes. He hoped in this way to save his duchy, the last remnant of the dominions of his house, from being annexed by Prussia. As soon as he died the town was occupied by the Prussian troops already stationed therein; the duke of Cumberland published a patent proclaiming his succession; the council of state, however, declared, in agreement with the Bundesrath, that the relations in which he stood to the kingdom of Prussia were inconsistent with the alliances on which the empire was based, and that therefore he could not assume the government. The claim of the duke of Cambridge as the only male heir of full age was referred to the Bundesrath, but the duke refused to bring it before that body, and after a year the Brunswick Government elected as regent Prince Albert of Hohenzollern, to hold office so long as the true heir was prevented from entering on his rights.

Duchy of Brunswick.

By this arrangement Brunswick, which hitherto had steadily opposed all attempts to assimilate and subordinate its institutions to those of Prussia, though it retains formal independence, has been brought into very close dependence upon Prussia, as is the case with all the other northern states. In them the armies are incorporated in the Prussian army; the railways are generally merged in the Prussian system; indirect taxation, post-office, and nearly the whole of the judicial arrangements are imperial. None, however, has yet imitated the prince of Waldeck, who in 1867, at the wish of his own subjects, transferred the administration of his principality to Prussia. The local estates still meet, and the principality still forms a separate administrative district, but it is managed by a director appointed by Prussia. The chief reason for this act was that the state could not meet the obligations laid upon it under the new system, and the responsibility for any deficit now rests with Prussia.

Waldeck.

A curious difficulty, a relic of an older state of society, recently arose in the principality of Lippe. On the death of Prince Waldemar in 1895 (his brother and heir the reigning prince Alexander being childless and insane) a dispute as to the succession arose. The nearest agnate was a count of Biesterfeld, but Prince Adolf of Schaumburg-Lippe, the representative of a younger line, claimed the succession on the ground that the marriage of Count Biesterfeld's grandfather with Fraülein von Unruh was not valid for the purposes of transmitting rights of succession. Under the old empire this would have been decided by the imperial courts, for the answer depended on very old-established principles concerning the different grades of nobility. Under the new empire there is no tribunal qualified to give a decision. The estates of Lippe wished to refer it to the Bundesrath, but the council refused to take the responsibility; at last the two claimants agreed to abide by the arbitration of the king of Saxony. The jurists appointed by him decided in favour of the count, who therefore, as next heir, now acts as regent. Some political importance attaches to the case, for it is not impossible that similar difficulties may occur elsewhere, and the open support given by the emperor to the prince of Schaumburg, who had married his sister, caused apprehension of Prussian aggression. It is probable, in fact, that on the death of the present regent the claims of the prince will again be revived, for the validity of the regent's marriage, and therefore the claim of his children to succeed, is also contested.

Lippe.

A much more serious question of principle arose from the peculiar circumstances of Mecklenburg. The grand duchies, which, though divided between two lines of the ducal house, have a common constitution, are the only state in Germany in which the parliament still takes the form of a meeting of the estates—the nobility and the cities—and has not been altered by a written constitution. Repeated attempts of the grand dukes to bring about a reform were stopped by the opposition of the Ritterschaft. Büffing, one of the Mecklenburg representatives in the Reichstag, therefore proposed to add to the imperial constitution a clause that in every state of the confederation there should be a parliamentary assembly. This was supported by all the Liberal party, and carried repeatedly; of course it was rejected by the Bundesrath, for it would have established the principle that the constitution of each state could be revised by the imperial authorities, which would have completely destroyed their independence. It is noticeable that on the last occasion, in 1894, when this motion was introduced it was lost; a striking instance of the decay of Liberalism.

The Mecklenburg constitution.

The public political history naturally centres around the debates in the Reichstag, and also those in the Prussian parliament. The table on page 681 above shows the position of parties in the German Reichstag. In the Prussian parliament are discussed questions of education, local government, religion, and direct taxation, and though of course it is only concerned with Prussian affairs, Prussia is so large a part of Germany that its decisions have a national importance. The two parliaments sit in Berlin at the same time, an inconvenient arrangement which made Bismarck propose the introduction of biennial budgets, a custom which exists in Bavaria and other states. The constitution is very different, for while the Reichstag, which consists of only one House, is elected by universal suffrage, the Prussian parliament (Landtag) consists of two Houses, and the Lower House is chosen by indirect election on a complicated system which gives great influence to wealth. One result of this was that the Socialists, so powerful in the Reichstag, until the year 1900 refused even to contest seats in the Prussian parliament. In the Prussian parliament the members receive payment, but the members of the Reichstag do not. A very large number of the members sit in both, and the parties in the two are nearly identical. In fact, the political parties in the Reichstag are generally directly descended from the older Prussian parties.

Public affairs: Political parties.

The first place belongs to the Conservatives, who for twenty years had been the support of the Prussian Government. The party of the feudal aristocracy in North Germany, they were strongest in the agricultural districts east of the Elbe; predominantly Prussian in origin and in feeling, they had great influence at court and in the army, and desired to maintain the influence of the orthodox Lutheran Church. To them Bismarck had originally belonged, but the estrangement begun in 1866 constantly increased for the next ten years. A considerable number of the party had, however, seceded in 1867 and formed a new union, to which was given the name of the *Deutsche Reichspartei* (in the Prussian House they were called the *Frei Conservativen*). These did not include any prominent parliamentary leaders, but many of the most important ministers and officials, including Moltke and some of the great nobles. They were essentially a Government party, and took no part in the attacks on Bismarck which came from the more extreme Conservatives, the party of the *Kreuzzeitung*.

Conservatives.

The events of 1866 had brought about a similar division among the Progressives. A large section, including the most important leaders, determined to support Bismarck in his national policy and to subordinate to this, though not to surrender, the struggle after Constitutional development. Under the name of *National-liberal-partei* they became in numbers as in ability the strongest party both in Prussia and the empire. Essentially a German, not a Prussian, party, they were joined by the Nationalists from the annexed provinces of Hanover and Hesse; in 1871 they were greatly strengthened by the addition of the National representatives from the southern states; out of fourteen representatives from Baden twelve belonged to them, seventeen out of eighteen Würtemberger, and a large majority of the Bavarians. It was on their support that Bismarck depended in building up the institutions of the empire. The remainder of the Progressives, the *Fortschrittspartei*, maintained their protest against the military and monarchical elements in the state; they voted against the Constitution in 1867 on the ground that it did not provide sufficient guarantees for popular liberty, and in

National Liberals.

1871 against the treaty with Bavaria because it left too much independence to that state. Their influence was strongest in Berlin, and in the towns of East Prussia; they have always remained characteristically Prussian.

These great parties were spread over the whole of Germany, and represented the great divisions of political thought. To them must be added others which were more local, as the *Volkspartei* or People's party in Würtemberg, which kept alive the extreme democratic principles of 1848, but was opposed to Socialism. They had been opposed to Prussian supremacy, and in 1870 for the time completely lost their influence, though they were to regain it in later years.

Of great importance was the new party of the Centre. Till the year 1863 there had been a small party of Catholics in the Prussian parliament who received the name of the *Centrum*, from the part of the House in which they sat. They had diminished during the years of conflict, and disappeared in 1866. In December 1870 it was determined to found a new party which, while not avowedly Catholic, practically consisted entirely of Catholics. The programme required the support of a Christian-Conservative tendency; it was to defend positive and historical law against Liberalism, and the rights of the individual states against the central power. They were especially to maintain the Christian character of the schools. Fifty-four members of the Prussian parliament at once joined the new party, and in the elections for the Reichstag in 1871 they won sixty seats. Their strength lay in Westphalia and on the Rhine, in Bavaria and the Polish provinces of Prussia. The close connexion with the Poles, the principle of federalism which they maintained, the support given to them by the Bavarian "patriots," their protest against the "revolution from above" as represented equally by the annexation of Hanover and the abolition of the Papal temporal power, threw them into strong opposition to the prevailing opinion, an opposition which received its expression when Mallincrodt declared that "justice was not present at the birth of the empire." For this reason they were generally spoken of by the Nationalist parties as *Reichsfeindlich.*

The Centre.

This term may be more properly applied to those who still refuse to recognize the legality of the acts by which the empire was founded. First among these are the Guelphs, or, as they call themselves, *Hannoverische Rechtspartei*, members of the old Hanoverian nobility who represent the rural districts of Hanover and still regard the duke of Cumberland as their lawful ruler. They make no attempt at conspiracy or rebellion; that would indeed be useless, but they maintain a protest against what is still felt to have been an act of injustice. Neither the lapse of time nor the death of King George has seriously affected their numbers. They have repeatedly demonstrated their attachment to the exiled house, and it is noteworthy that in the elections of 1898 nine members of the Guelph party were returned. The attachment of the nobility to the exiled house is a quality which neither the present emperor nor his predecessors could afford to look on with disfavour, for it is at least evidence of that strong monarchical sentiment which they value so highly. A pleasant concession to Hanoverian feeling was made in 1899, when the emperor ordered that the Hanoverian regiments in the Prussian army should be allowed to assume the names and so continue the traditions of the Hanoverian army which was disbanded in 1866.

Guelphs.

The Government has also not succeeded in reconciling to the empire the alien races which have been incorporated in the kingdom of Prussia.

From the Polish districts of West Prussia, Posen, and Silesia a number of representatives are sent to Berlin to protest against their incorporation in the empire. Bismarck, influenced by the older Prussian traditions, always adopted towards them an attitude of uncompromising opposition. The growth of the Polish population has caused much anxiety; supported by the Roman Catholic Church, the Polish language has advanced, especially in Silesia, and this is only part of the general tendency, so marked throughout Central Europe, for the Sclavonians to gain ground upon the Teutons. The Prussian Government has attempted to prevent this by special legislation and severe administrative measures. In 1885 and 1886 large numbers of Austrian and Russian Poles who had settled in these provinces were expelled. Windthorst thereupon raised the question in the Reichstag, but the Prussian Government refused to take any notice of the interpolation on the ground that there was no right in the constitution for the imperial authority to take cognizance of acts of the Prussian Government. In the Prussian parliament Bismarck introduced a law taking out of the hands of the local authorities the whole administration of the schools and giving them to the central authority, so as to prevent instruction being given in Polish. A further law authorized the Prussian Government to spend £5,000,000 in purchasing estates from Polish families and settling German colonists on the land. The commission, which was appointed for the purpose, during the next ten years bought land to the amount of about 200,000 acres, and on it settled more than 2000 German peasants. It appears doubtful whether this will have any appreciable effect, for the Poles have founded a society to protect their own interests, and have often managed to profit by the artificial value given to their property. It has, however, caused great bitterness among the Polish peasants, and the effect on the population is also counteracted by the fact that the large proprietors in purely German districts continue to import Polish labourers to work on their estates.

Poles.

In the general change of policy that followed after the retirement of Bismarck an attempt was made by the emperor to conciliate the Poles. Concessions were made to them in the matter of schools, and in 1891 a Pole, Stabelewski, who had taken a prominent part in the Kulturkampf, was accepted by the Prussian Government as Archbishop of Posen. A moderate party arose among the Poles which accepted their position as Prussian subjects, gave up all hopes of an immediate restoration of Polish independence, and limited their demands to that free exercise of the religion and language of their country which was enjoyed by the Poles in Austria. They supported Government Bills in the Reichstag, and won the commendation of the emperor. Unfortunately, for reasons which are not apparent, the Prussian Government did not continue a course of conciliation; administrative edicts still further limited the use of the Polish language, even religious instruction was to be given in German, and an old royal ordinance of 1817 was made the pretext for forbidding private instruction in Polish. A further sum of £5,000,000 was voted for the settlement of German colonists, and the whole influence of the law, of education, and of the army is used to compel the Poles to forget their mother-tongue and the traditions of their country. Further measures are promised to meet the danger to German nationality which is anticipated from the fact that numerous Poles have migrated to the more prosperous districts in the west.

Compared with the Polish question, that of the Danes in North Schleswig is of minor importance; they number less than 150,000, and there is not among them, as among the Poles, the constant encroachment along an extended line of frontier; there is also no religious question involved. These Danish subjects have elected one member to the Reichstag, whose duty is to demand that they should be handed over to Denmark. Up to the year 1878 they could appeal to the Treaty of Prague; one clause in it determined that the inhabitants of selected districts should be allowed to vote whether they should be Danish or German. This was inserted merely to please Napoleon; after his fall there was no one to demand its execution. In 1878, when the Triple Alliance was concluded, Bismarck, in answer to the Guelphic demonstration at Copenhagen, arranged with Austria, the other party to the Treaty of Prague, that the clause should lapse. Since then the Prussian Government, by prohibiting the use of Danish in the schools and public offices, and by the expulsion from Schleswig of residents of Danish nationality, has used the customary means for compelling all subjects of the king to become German in language and feeling.

Danes.

The attempt to reconcile the inhabitants of Elsass-Lothringen to their condition has been equally unsuccessful. The provinces had been placed under the immediate rule of the emperor and the chancellor, who was minister for them; laws were to be passed by the Reichstag. In accordance with the Treaty of Frankfort, the inhabitants were permitted to choose between French and German nationality, but all who chose the former had to leave the country; before 1st October 1872, the final day, some 50,000 had done so. In 1874, for the first time, the provinces were enabled to elect members for the Reichstag; they used the privilege to send fifteen *Elsasser*, who, after delivering a formal protest against the annexation, retired from the House; they joined no party, and took little part in the proceedings except on important occasions to vote against the Government. The same spirit was shown in the elections for local purposes. It seemed to be the sign of a change when a new party, the *Autonomisten*, arose, who demanded as a practical concession that the dictatorship of the chancellor should cease and local self-government be granted. To some extent this was done in 1879; a resident governor or *statthalter* was appointed, and a local representative assembly, which was consulted as to new laws. All the efforts of Manteuffel, the first governor, to win the confidence of the people failed; the anti-German feeling increased; the party of protestors continued in full numbers. The next governor, Prince Hohenlohe, had to use more stringent measures, and in 1888, to prevent the agitation of French agents, an imperial decree forbade any one to cross the frontier without a passport. Since 1890 there has been, especially in the neighbourhood of Strasburg, evidence of a spread of national German feeling, probably to a great extent due to the settlement of Germans from across the Rhine.

Elsass-Lothringen.

The persistence of opposition in these districts is remarkable. In all cases the inhabitants have shared in the great growth of material prosperity; the Reichsland has been treated with great generosity; the taxes are very low. Strasburg has grown rapidly in wealth and numbers. The foundation of a new university, and the great impulse given to trade by the opening up of new railway and water communications, have added greatly to its prosperity. But the national feeling in Germany is so imperious and so intolerant of opposition, it is so constantly put forward as the only legitimate basis for the existence of the state, as naturally to arouse opposition among those who do not share it. The presence of these parties, amounting often to one-tenth of the whole, has added greatly to the parliamentary difficulties of the Government.

The great work since 1870 has been that of building up the institutions of the empire. For the first time in the history of Germany there has been a strong administration ordering, directing, and arranging the life of the whole nation. The work which in England was done by the Plantagenets, which in France was begun by the House of Bourbon and completed by the Revolution, is now proceeding, and the city of Berlin is rapidly acquiring a position similar to that held by London and Paris. The unification of Germany was not ended by the events of 1866 and 1871; it was only begun. The work has throughout been done by Prussia; it has been the extension of Prussian principles and Prussian administrative energy over the whole of Germany. It naturally falls into two periods; the first, which ends in 1878, is that in which Bismarck depended on the support of the National Liberals. They were the party of union and uniformity. The Conservatives were attached to the older local diversities, and Bismarck had therefore to turn for help to his old enemies, and for some years an alliance was maintained, always precarious but full of results.

The period 1870 to 1878.

The great achievement of the first period was legal reform. In nothing else was legislation so much needed. Forty-six districts have been enumerated, each of which enjoyed a separate legal system, and the boundaries of these districts seldom coincided with the frontiers of the states. Everywhere the original source of law was the old German common law, but in each district it had been wholly or partly superseded by codes, text-books, and statutes to a great extent founded on the principles of the Roman civil law. Owing to the political divisions, however, this legislation, which reached back to the 14th century, had always been carried out by local authorities. There had never been any effective legislation applicable to the whole nation. There was not a state, not the smallest principality, in which some authoritative but imperfect law or code had not been published. Every free city, even an imperial village, had its own "law," and these exist down to the present time. In Bremen the foundation of the civil code still were the statutes of 1433; in Munich, those of 1347. Most of the states by which these laws had been published had long ago ceased to exist; probably in every case their boundaries had changed, but the laws remained valid (except in those cases in which they had been expressly repealed) for the whole of the district for which they had been originally promulgated. Let us take a particular case. In 1591 a special code was published for the upper county of Katzellenbogen. More than a hundred years ago Katzellenbogen was divided between the neighbouring states. But till the end of the 19th century (which in Germany meant the end of 1899) this code still retained its validity for those villages in Hesse, and in the Prussian province of Hesse, which in old days had been parts of Katzellenbogen. The law, however, had to be interpreted so as to take into consideration later legislation by the kingdom of Westphalia, the electorate of Hesse, and any other state (and they are several) in which for a short time some of these villages might have been incorporated.

Legal reform.

In addition to these earlier imperfect laws, three great codes have been published, by which a complete system was applied to a large district: the Prussian Code of 1794, the Austrian Code of 1811, and the Code Napoléon, which applied to all Germany left of the Rhine; for neither Prussia, nor Bavaria, nor Hesse had ever ventured to interfere with the French law. In Prussia therefore the older provinces came under the Prussian Code, the Rhine provinces had French law, the newly annexed provinces had endless variety, and in part of Pomerania considerable elements of Swedish law still remained, a relic of the long Swedish occupation. On the other hand, some districts to which the Prussian Code applied no longer belonged to the kingdom of Prussia—for instance, Anspach and Bayreuth, which are now in Bavaria. In other parts of Bavaria in the same way Austrian law still ran, because they had been Austrian in 1811. In two states only was there a more or less uniform system: in Baden, which had adopted a German translation of the Code Napoléon; and in Saxony, which had its own code, published in 1865. In criminal law and procedure there was an equal variety. In one district was trial by jury in an open court; in another the old procedure by written pleadings before a judge. In many districts, especially in Mecklenburg and some of the Prussian provinces, the old feudal jurisdiction of the manorial courts survived.

The constant changes in the law made by current legislation in the different states really only added to the confusion, and though imperial laws on those points with which the central government was qualified to deal superseded the state laws, it is obvious that to pass occasional Acts on isolated points would have been only to introduce a further element of complication.

It was therefore convenient, so far as was possible, to allow the existing system to continue until a full and complete code dealing with the whole of one department of law could be agreed upon, and thus a uniform system (superseding all older legislation) be adopted. Legislation, therefore, has generally taken the form of a series of elaborate codes, each of which aims at scientific completeness, and further alterations have been made by amendments in the original code. The whole work has been similar in character to the codification of French law under Napoleon; in most matters the variety of the older system has ceased, and the law of the empire is now comprised in a limited number of codes.

A beginning had been made before the foundation of the empire; as early as 1861 a common code for trade, commerce, and banking had been agreed upon by the states included in the Germanic Confederation. It was adopted by the new confederation in 1869. In 1897 it was replaced by a new code. In 1869 the criminal law had been codified for the North German Confederation, and in 1870 there was passed the *Gewerbeordnung*, an elaborate code for the regulation of manufactures and the relations of masters to workmen. These were included in the law of the empire, and the work was vigorously continued.

In 1871 a commission was appointed to draw up regulations for civil and criminal procedure, and also to frame regulations for the organization of the law courts. The draft code of civil procedure, which was published in December 1872, introduced many important reforms, especially by substituting public and verbal procedure for the older German system, under which the proceedings were almost entirely carried on by written documents. It was very well received. The drafts for the other two laws were not so successful. Protests, especially in South Germany, were raised against the criminal procedure, for it was proposed to abolish trial by jury and substitute over the whole empire the Prussian system, and a sharp conflict arose as to the method of dealing with the press. After being discussed in the Reichstag, all three projects were referred to a special commission, which after a year reported to the diet, having completely remodelled the two latter laws. After further amendment they were eventually accepted, and became law in 1877. By these and other supplementary laws a uniform system of law courts was established throughout the whole empire; the position and pay of the judges, the regulations regarding the position of advocates, and costs, were uniform, and the procedure in every state was identical. To complete the work a supreme court of appeal was established at Leipzig, which was competent to hear appeals not only from imperial law, but also from that of the individual states.

By the original constitution, the imperial authorities were only qualified to deal with criminal and commercial law; the whole of the private law, in which the variety was greatest, was withdrawn from their cognizance. Lasker, to remedy this defect, proposed, therefore, an alteration in the constitution, which, after being twice carried against the opposition of the Centre, was at last accepted by the Bundesrath. A commission was then appointed to draw up a civil code. They completed the work by the end of 1887; the draft which they then published was severely criticized, and it was again submitted for revision to a fresh commission, which reported in 1895. In its amended form this draft was accepted by the Reichstag in 1896, and it entered into force on the 1st of January 1900. The new Civil Code deals with nearly all matters of law, but excludes those concerning or arising out of land tenure and all matters in which private law comes into connexion with public law; for instance, the position of Government officials, and the police: it excludes also the relations of master and servant, which in most points are left to the control of individual states. It was accompanied by a revision of the laws for trade and banking. This is far the most important measure which has hitherto been carried by the initiative of a private member of the Reichstag, and though Lasker himself was dead and his party broken up long before the new code became law, and though in many ways the contents of the code did not satisfy the expectations of those who had helped to carry it, it remains a lasting memorial of the reforming zeal and the national enthusiasm of the first years of the empire.

Equal in importance to the legal was the commercial reform, for this was the condition for building up the material prosperity of the country. Germany was a poor country, but the poverty was to a great extent the result of political causes. Communication, trade, manufactures, were impeded by the political divisions, and though the establishment of a customs union had preceded the foundation of the empire, the removal of other barriers required imperial legislation. A common system of weights and measures was introduced in 1868. The reform of the currency was the first task of the empire. In 1871 Germany still had seven different systems; the most important was the thaler and the groschen, which prevailed over most of North Germany, but even within this there were considerable local differences. Throughout the whole of the south of Germany and in some North German states the gulden and kreuzer prevailed. Then there were other systems in Hamburg and in Bremen. Everywhere, except in Bremen, the currency was on a silver basis. In addition to this each state had its own paper money, and there were over 100 banks with the right of issuing bank-notes according to regulations which varied in each state. In 1871 a common system for the whole empire was established, the unit being the mark, which was divided into a hundred pfennig: a gold currency was introduced; no more silver was to be coined, and silver was made a legal tender only up to the sum of twenty marks. The gold required for the introduction of the new coinage was provided from the indemnity paid by France. Great quantities of thalers, which hitherto had been the staple of the currency, were sold.

Commercial reform.

The right of coinage was, however, left to the individual states, and as a special concession it was determined that the rulers of the states should be permitted to have their head placed on the reverse of the coins. All paper currency, except that issued by the empire, ceased, and in 1873 the Prussian Bank was converted into the Imperial Bank.

The Bank. The Prussian (now the Imperial) Bank is a society of private capitalists, but the management is in the hands of the State. The extension of the privilege has always been supported by the Liberals, but in 1891 and again in 1900 unsuccessful attempts were made by the Conservatives, supported by the Agrarians and Anti-Semites, to prevent the renewal of the Bank Act.

Bimetallism. The introduction of a gold standard has not been completely carried through. In 1877, owing to the depreciation of silver, the sale of silver was suspended, and thalers to the value of about 400 million marks were reserved. About half of these are in circulation, and are full legal tender. The Conservative reaction which followed deprived of their influence the economists who were more strongly in favour of a gold standard, and the fall in prices caused in Germany, as in other countries, a demand for the adoption of a bimetallic standard, especially among agriculturists; of recent years bimetallism has become one of the chief points in the Agrarian and even in the Conservative programme. In 1895 a motion was carried in the Reichstag requesting the Governments to summon a conference for an international regulation of the currency. The Council, however, refused to do this, on the ground that there was no prospect that a discussion would lead to any practical result, unless the Indian Government would reopen the mints.

Banking laws. Closely connected with the reform of the currency and the codification of the commercial law was the reform of the banking laws. Here the tendency to substitute uniform imperial laws for state laws is clearly seen. Before 1870 there had been over 100 banks with the right of issue, and the conditions on which the privilege was granted varied in each state. By the Bank Act of 1875, which is the foundation of the existing system, the right of granting the privilege is transferred from the Governments of the states to the Bundesrath. The existing banks could not be deprived of the concessions they had received, but unless they submitted to the regulations of the new law their notes were not to be recognized outside the limits of the state by which the concession had been granted. All submitted to the conditions except the Brunswick Bank, which still holds a unique position. The experience of Germany in this matter has been different from that of England, for nearly all the private banks have since surrendered their privilege, and there now remain only six banks (of which only one, the Frankfurter Bank, is in Prussia) which still issue bank-notes. The other five are situated in Bavaria, Saxony, Würtemberg, Baden, and Hesse, and the continuance of their privilege is a natural accompaniment of the political importance which still belongs to these states.

The organization of the imperial post-office was carried out with great success by Herr v. Stephan (*q.v.*), who remained at the head of this department from its creation till his death in 1897. Proposals to Bavaria and Würtemberg to surrender their special rights have not been accepted.

Railways. The unification of the railways caused greater difficulties. Nearly every state had its own system; there was the greatest variety in the methods of working and in the tariffs, and the through traffic, so important for the commercial prosperity of the country, was very ineffective. In Baden, Würtemberg, and Hanover the railways were almost entirely the property of the State, but in all other parts public and private lines existed side by side, an arrangement which seemed to combine the disadvantages of both systems. In 1871 three-quarters of the railway lines belonged to private companies, and the existence of these powerful private corporations, while they were defended by many of the Liberals, was, according to the national type of thought, something of an anomaly. Bismarck always attached great importance to the improvement of the railway service, and he saw that uniformity of working and of tariffs was very desirable. In the constitution of the empire he had introduced several clauses dealing with it. The independent administration of its lines by each state was left, but the empire received the power of legislating on railway matters; it could build lines necessary for military purposes even against the wish of the state in whose territory they lay, and the states bound themselves to administer their lines as part of a common system.

In order to carry out these clauses a law was passed in 1873 creating an imperial railway office which should have a general control over all the railways. It does not appear, however, that this office has ever been able to acquire any real power or influence; it has drafted laws on railway management, but they have never been laid before the Reichstag. Bismarck desired to go farther, and acquire all the railways for the empire. He found, however, that it was impossible to carry any Bill enforcing this. He therefore determined to begin by transferring to the imperial authority the Prussian state railways; had he been able to carry this out the influence of the imperial railways would have been so great that they would gradually have absorbed those of the other states. The Bill was carried through the Prussian parliament, but the opposition aroused in the other states was so great that he did not venture even to introduce in the Bundesrath a law empowering the empire to acquire the Prussian railways. In many of the state parliaments resolutions were carried protesting against the system of imperial railways, and from that time the preservation of the local railway management has been the chief object towards which, in Saxony, Bavaria, and Würtemberg, local feeling has been directed. It was not till a later period that Bismarck was able, though in a modified form, to carry out his plans.

The result of the legal reform and other laws has been greatly to diminish the duties of the State Governments, for every new imperial law permanently deprives the local parliaments of part of their authority. Generally there remains to them the control of education and religion—their most important duty—police, all questions connected with land tenure, local government, the raising of direct taxes, and, in the larger states, the management of railways. The introduction of workmen's insurance, factory legislation, and other measures dealing with the condition of the working classes by imperial legislation, was at a later period still further to limit the scope of state legislation.

Meanwhile the Government was busy perfecting the administration of the national defences. From the war indemnity large sums had been expended on coast defence, on fortifications, and on replacing the equipment and stores destroyed during the war. A special fund, producing annually about a million pounds, was put aside, from which pensions to the wounded, and to the widows and orphans of those who had fallen, should be provided. It was also desirable to complete the military organization. It must be remembered that technically there is no German army, as there is no German minister of war. *Army organization.* Each state, however small, maintains its own contingent, subject to its own prince, who has the right and the obligation of administering it according to the provisions of the treaty by which he entered the federation. Practically they are closely tied in every detail of military organization. The whole of the Prussian military system, including not only the obligation to military service, but the rules for recruiting, organization, drill, and uniforms, has to be followed in all the states; all the contingents are under the command of the Emperor, and the soldiers have to swear obedience to him in addition to the oath of allegiance to their own sovereign. It is therefore not surprising that, having so little freedom in the exercise of their command, all the princes and free cities (with the exception of the three kings) arranged separate treaties with the king of Prussia, transferring to him (except for certain formal rights) the administration of their contingents, which are thereby definitely incorporated in the Prussian army. The first of these treaties was arranged with Saxe-Coburg-Gotha in 1861; those with the other North German states followed at short intervals after 1866. The last was that with Brunswick, which was arranged in 1885; Duke William had always refused to surrender the separate existence of his army. Owing to the local organization, this does not prevent the contingent of each state from preserving its separate identity; it is stationed in its own district, each state contributing so many regiments.

In 1872 a common system of military jurisprudence was introduced for the whole empire except Bavaria (a revised code of procedure in military courts was accepted by Bavaria in 1898); finally, in February 1874 an important law was laid before the Reichstag codifying the administrative rules. This superseded the complicated system of laws and royal ordinances which had accumulated in Prussia during the fifty years that had elapsed since the system of short service had been introduced; the application to other states of course made a clearer statement of the laws desirable. Most of this was accepted without opposition or debate. On one clause a serious constitutional conflict arose. In 1867 the peace establishment had been provisionally fixed by the constitution at 1 per cent. of the population, and a sum of 225 thalers (£33, 15s.) had been voted for each soldier. This arrangement had in 1871 been again continued to the end of 1874, and the peace establishment fixed at 401,659. The new law would make this permanent. If this were done the power of the Reichstag over the administration would be seriously weakened; their assent would no longer be required for either the number of the army or the money. The Government attached great importance to the clause, but the Centre and the Liberal parties combined to throw it out. A disastrous struggle was averted by a compromise suggested by Bennigsen. The numbers were fixed for the next seven years (the so-called *septennat*); this was accepted by the Government, and carried against the votes of the Centre and some of the Progressives. On this occasion the Fortschrittpartei, already much diminished, split up into two sections. The principle then established has since been maintained; the periodical votes on the army have become the occasion for formally testing the strength of the Government. In 1880 the strength was fixed for the next seven years, 1881–88, at 427,274. The arrangement was revised in 1887, and again in 1893 and in 1898, but on the last two occasions the vote was taken for five instead of seven years.

The Septennat.

The influence of Liberalism, which served the Government so well in this work of construction, brought about also the conflict with the Roman Catholic Church which distracted Germany for many years. The causes were, indeed, partly political. The Ultramontane party in Austria, France, and Bavaria had, after 1866, been hostile to Prussia; there was some ground to fear that it might still succeed in bringing about a Catholic coalition against the empire, and Bismarck lived in constant dread of European coalitions. The Polish sympathies of the Church in Germany made him regard it as an anti-German power, and the formation of the Catholic faction in parliament, supported by Poles and Hanoverians, appeared to justify his apprehensions. But besides these reasons of state there was a growing hostility between the triumphant National parties and the Ultramontanes, who taught that the Pope was greater than the Emperor and the Church than the nation. The conflict had already begun in Baden. As in every other country, the control of the schools was the chief object of contention, but the Government also claimed a control over the education and training of the clergy. With the formation of the empire the conflict was transferred from Baden to Prussia, where there had been for thirty years absolute peace, a peace gained, indeed, by allowing to the Catholics complete freedom; the Prussian constitution ensured them absolute liberty in the management of ecclesiastical affairs; in the ministry for religion and education there was a separate department for Catholic affairs, and (owing to the influence of the great family of the Radziwills) they enjoyed considerable power at court.

Kultur kampf.

The latent opposition was aroused by the Vatican decrees. A small number of Catholics, including several men of learning and distinction, refused to accept Papal Infallibility. They were encouraged by the Bavarian court, which maintained the Josephinist tradition and was jealous of any encroachment of the Papacy; but besides this the Protestants throughout Germany and all opponents of the Papacy joined in the agitation. They made it the occasion for an attack on the Jesuits; even in 1869 there had been almost a riot in Berlin when a chapel belonging to a religious order was opened there. During 1870 and 1871 meetings were held by the Gustavus Adolphus Verein, and a great Protestant conference was called, at which resolutions were passed demanding the expulsion of the Jesuits and condemning the Vatican decrees. As the leaders in these meetings were men like Virchow and Bluntschli, who had been lifelong opponents of Catholicism in every form, the result was disastrous to the Liberal party among the Catholics, for a Liberal Catholic would appear as the ally of the bitterest enemies of the Church; whatever possibility of success the Old Catholic movement might have had was destroyed by the fact that it was supported by those who avowedly wished to destroy the influence of Catholicism. No bishop joined it in Germany or in Austria, and few priests, though the Governments were ready to protect them in the enjoyment of the privileges secured to Catholics, and to maintain them in the use of the temporalities. There was no great following among the people; it was only in isolated places that priests and congregation together asserted their rights to refuse to accept the decrees of the Church. Without the help of the bishops, the leaders had no legal basis; unsupported by the people, they were generals without an army, and the attempt to use the movement for political purposes failed.

Old Catholics.

None the less this was the occasion for the first proceedings against the Catholics, and curiously enough the campaign began in Bavaria. The archbishop of Munich had published the Vatican decrees without the *Regium Placetum*, which was required by the constitution, and the Government continued to treat Old Catholics as members of the Church. In the controversy which ensued, Lutz, the chief member of the ministry, found himself confronted by an Ultramontane majority, and the priests used their influence to stir up the people. He therefore turned for help to the imperial Government, and at his instance a clause was added to the penal code forbidding priests in their official capacity to deal with political matters. (This law, which still exists, is popularly known as the Kanzlei or Pulpit-paragraph.) It was of course opposed by the Centre, who declared that the Reichstag had no right to interfere in what was after all a religious question, and the Bavarian Opposition expressed much indignation that their Government should turn for help to the Protestants of the North in order to force upon the Catholics of Bavaria a law which they could not have carried in that state.

For twenty years the Old Catholics continued to be a cause of contention in Bavaria, until the struggle ended in the victory of the Ultramontanes. In 1875 the parliament which had been elected in 1869 for six years came to an end. In order to strengthen their position for the new elections, the Liberal ministry, who owed their position chiefly to the support of the king, by royal ordinance ordered a redistribution of seats. By the constitution this was within their power, and by clever manipulation of the constituencies they brought it about that the Ultramontane majority was reduced to two. It does not appear that this change represented any change of feeling in the majority of the people. The action of the Government, however, caused great indignation, and in a debate on the address an amendment was carried petitioning the king to dismiss his ministry. They offered their resignation, but the king refused to accept it, publicly expressed his confidence in them, and they continued in office during the lifetime of the king, although in 1881 the growing reaction gave a considerable majority to the Ultramontane party. After the death of the king the prince-regent, Luitpold, still retained the old administration, but several concessions were made to the Catholics in regard to the schools and universities, and in 1890 it was decided that the claim of the Old Catholics to be regarded officially as members of the Church should no longer be recognized.

Meanwhile at Berlin petitions to the Reichstag demanded the expulsion of the Jesuits, and in 1872 an imperial law to this effect was carried; this was again a serious interference with the control over religious matters reserved to the states. In Prussia, the Government having determined to embark on an anti-Catholic policy, suppressed the Catholic division in the ministry, and appointed a new minister, Falk, a Liberal lawyer of uncompromising character. A law was carried placing the inspection of schools entirely in the hands of the state; hitherto in many provinces it had belonged to the clergy, Catholic or Protestant. This was followed by the measures to which the name *Kulturkampf* really applied (an expression used first by Virchow to imply that it was a struggle of principle between the teaching of the Church and that of modern society). They were measures in which the State no longer, as in the school inspection law or in the introduction of civil marriage, defended its prerogatives against the Church, but assumed itself a direct control over ecclesiastical matters.

May Laws.

At the end of 1872 and the beginning of 1873 Falk laid before the Prussian Lower House the draft of four laws. Of these, one forbade ministers of religion from abusing ecclesiastical punishment; the second, which was the most important, introduced a law already adopted in Baden, that no one should be appointed to any office in the Church except a German, who must have received his education in a German gymnasium, have studied for three years in a German university, and have passed a State examination in philosophy, history, German literature, and classics; all ecclesiastical seminaries were placed under the control of the State, and all seminaries for boys were forbidden. Moreover, every appointment to an ecclesiastical benefice was to be notified to the president of the province, and the confirmation could be refused on the ground that there were facts which could support the assumption that the appointment would be dangerous to public order. The third law appointed a court for trying ecclesiastical offences, to which was given the right of suspending both priests and bishops, and a fourth determined the procedure necessary for those who wished to sever their connexion with the Roman Catholic Church.

As these laws were inconsistent with those articles of the Prussian constitution which guaranteed to a religious corporation the independent management of its own affairs, it was therefore necessary to alter the constitution. This was done, and a later law in 1875 repealed the articles altogether.

The opposition of the bishops to these laws was supported even by many Protestants, especially by the more orthodox Lutherans, who feared the effect of this increased subjection of all Churches to the State; they were opposed also by the Conservative members of the Upper House. All, however, was unavailing. Bismarck in this case gave the Liberals a free hand, and the laws eventually were carried and proclaimed on 15th May 1873; hence they got the name of the May laws, by which they are always known. The bishops meanwhile had held a meeting at Fulda, at the tomb of St Boniface, whence they addressed a protest to the king, and declared that they would be unable to recognize the laws as valid. They were supported in this by the Pope, who addressed a protest personally to the Emperor. The laws were put into force with great severity. Within a year six Prussian bishops were imprisoned, and in over 1300 parishes the administration of public worship was suspended. The first sufferer was the cardinal archbishop of Posen, Count Ledochowski. He refused to report to the president of the province appointments of incumbents; he refused also to allow the Government commissioners to inspect the seminaries for priests, and when he was summoned before the new court refused to appear. He was then deprived of the temporalities of his office; but the Polish nobles continued to support him, and he continued to act as bishop. Heavy fines were imposed upon him, but he either could not or would not pay them, and in March 1874 he was condemned to imprisonment for two years, and dismissed from his bishopric. The bishop of Treves, the archbishop of Cologne, and other bishops soon incurred a similar fate. These measures of the Government, however, did not succeed in winning over the Catholic population, and in the elections for the Reichstag in January 1874 the party of the Centre increased in number from 63 to 91; 1,443,170 votes were received by them. In Bavaria the Ultramontanes won a complete victory over the more moderate Catholics. The Prussian Government proceeded to further measures. According to the ordinary practice towards parties in opposition, public meetings were broken up on the smallest pretence, and numerous prosecutions for insult to Government officials were brought against members of the party. The Catholic agitation was, however, carried on with increased vigour throughout the whole empire; over a hundred newspapers were founded (three years before there had been only about six Catholic papers in the whole of Germany), and great numbers of pamphlets and other polemical works were published. The bishops from their prisons continued to govern the dioceses; for this purpose they appointed representatives, to whom they transferred their rights as Ordinary and secretly authorized priests to celebrate services and to perform the other duties of an incumbent. To meet this a further law was passed in the Prussian parliament, forbidding the exercise of ecclesiastical offices by unauthorized persons, and it contained a provision that any one who had been convicted under the law could be deprived of his rights of citizenship, ordered to live in a particular district, or even expelled from the kingdom. The result was that in numerous parishes the police were occupied in searching for the priest who was living there among the people; although his habitation was known to hundreds of people, the police seldom succeeded in arresting him. Bismarck confesses that his doubts as to the wisdom of this legislation were raised by the picture of heavy but honest *gens d'armes* pursuing light-footed priests from house to house. This law was followed by one authorizing the Government to suspend, in every diocese where the bishop continued recalcitrant, the payment of that contribution to the Roman Catholic Church which by agreement had been given by the State since 1817. The only result of this was that large sums were collected by voluntary contribution among the Roman Catholic population.

The Government tried to find priests to occupy the vacant parishes; few consented to do so, and the *Staatskatholiken* who consented to the new laws were avoided by their parishioners. Men refused to attend their administration; in some cases they were subjected to what was afterwards called boycotting, and it was said that their lives were scarcely safe. Other laws excluded all religious orders from Prussia, and civil marriage was made compulsory; this law, which at first was confined to Prussia, was afterwards passed also in the Reichstag.

These laws were all peculiar to Prussia, but similar legislation was carried out in Baden and in Hesse, where in 1872 the Ultramontane and Particularist minister, Dalwick, had retired, and after the interval of a year been succeeded by a Liberal ministry. In Würtemberg alone the Government continued to live peaceably with the bishops.

The Government had used all its resources; it had alienated millions of the people; it had raised up a compact party of nearly a hundred members in parliament. The attempt of the Liberals to subjugate the Church had given to the Papacy greater power than it had had since the time of Wallenstein.

The ecclesiastical legislation and other Liberal measures completed the alienation between Bismarck and the Conservatives. In the Prussian parliament seventy-three members broke off from the rest, calling themselves the "old Conservatives"; they used their position at court to intrigue against him, and hoped to bring about his fall; Count Arnim (*q.v.*) was looked upon as his successor. In 1876, however, the party in Prussia reunited on a programme which demanded the maintenance of the Christian character of the schools, cessation of the Kulturkampf, limitation of economic liberty, and repression of social democracy, and this was accepted also by the Conservatives in the Reichstag. This reunion of the Conservatives became the nucleus of a great reaction against Liberalism. It was not confined to any one department of life, but included Protection as against Free Trade, State Socialism as against individualism, the defence of religion as against a separation of Church and State, increased stress laid on the monarchical character of the State, continued increase of the army, and colonial expansion.

Reaction against Liberalism.

The causes of the change in public opinion, of which this was to be the commencement, are too deep-seated to be discussed here. We must note that it was not peculiar to Germany; it was part of that great reaction against Liberal doctrine which marked the last quarter of the 19th century in so many countries. In Germany, however, it more rapidly attained political importance than elsewhere, because Bismarck used it to carry out a great change of policy. He had long been dissatisfied with his position. He was much embarrassed by the failure of his ecclesiastical policy. The alliance with the Liberals had always been half-hearted, and he wished to regain his full freedom of action; he regarded as an uncontrollable bondage all support that was not given unconditionally. The alliance had been of the nature of a limited co-operation between two hostile powers for a definite object; there had always been suspicion and jealousy on either side, and a rupture had often been imminent, as in the debates on the military Bill and the law reform. Now that the immediate object had been attained, he wished to pass on to other projects in which they could not follow him. Political unity had been firmly established; he desired to use the whole power of the imperial Government in developing the material resources of the country. In doing this he placed himself in opposition to both the financial and the economic doctrines of the Liberals.

The new period which now begins was introduced by some alterations in the official organization. Hitherto almost the whole of the internal business had been concentrated in the imperial chancery (Reichskanzeramt), and Bismarck had allowed great freedom of action to Delbrück, the head of the office. Delbrück, however, had resigned in 1876, justly foreseeing that a change of policy was imminent in which he could no longer co-operate with Bismarck. The work of the office was then divided between several departments, at the head of each of which was placed a separate official, the most important receiving the title of secretary of state. Bismarck, as always, refused to appoint ministers directly responsible either to the Emperor or to Parliament; the new officials in no way formed a collegiate ministry or cabinet. He still retained in his own hands, as sole responsible minister, the ultimate control over the whole imperial administration. The more important secretaries of state, however, are political officials, who are practically almost solely responsible for their department; they sit in the Bundesrath, and defend their policy in the Reichstag, and they often have a seat in the Prussian Ministry. Moreover, a law of 1878, the occasion of which was Bismarck's long absence from Berlin, empowered the chancellor to appoint a substitute or representative (*stellvertreter*) either for the whole duties of his office or for the affairs of a particular department. The signature of a man who holds this position gives legal validity to the acts of the Emperor.

Official changes.

This reorganization was a sign of the great increase of work which had already begun to fall on the imperial authorities, and was a necessary step towards the further duties which Bismarck intended to impose upon them.

Meanwhile the relations with the National Liberals reached a crisis. Bismarck remained in retirement at Varzin for nearly a year; before he returned to Berlin, at the end of 1877, he was visited by Bennigsen, and the Liberal leader was offered the post of vice-president of the Prussian Ministry and vice-president of the Bundesrath. The negotiations broke down, apparently because Bennigsen refused to accept office unless he received a guarantee that the constitutional rights of the Reichstag should be respected, and unless two other members of the party, Forckenbeck and Stauffenberg, were given office. Bismarck would not assent to these conditions, and, even if he had been willing to do so, could hardly have overcome the prejudices of the Emperor. On the other hand, Bennigsen refused to accept Bismarck's proposal for a state monopoly of tobacco. From the beginning the negotiations were indeed doomed to failure, for what Bismarck appears to have aimed at was to detach Bennigsen from the rest of his party and win his support for an anti-Liberal policy.

The session of 1878, therefore, opened with a feeling of great uncertainty. The Liberals were very suspicious of Bismarck's intentions. Proposals for new taxes, especially one on tobacco, were not carried. Bismarck took the opportunity of avowing that his ideal was a monopoly of tobacco, and this statement was followed by the resignation of Camphausen, minister of finance. It was apparent that there was no

Period after 1878.

prospect of his being able to carry through the great financial reform which he contemplated. He was looking about for an opportunity of appealing to the country on some question which would enable him to free himself from the control of the Liberal majority. The popular expectations were expressed in the saying attributed to him, that he would "crush the Liberals against the wall." The opportunity was given by the Social Democrats.

Social Democracy.

The constant increase of the Social Democrats had for some years caused much uneasiness not only to the Government, but also among the middle classes. The attacks on national feeling, the protest against the war of 1870, the sympathy expressed for the Communards, had offended the strongest feelings of the nation, especially as the language used was often very violent; the soldiers were spoken of as murderers, the generals as cut-throats. Attacks on religion, though not an essential part of the party programme, were common, and practically all avowed Social Democrats were hostile to Christianity. These qualities, combined with the open criticism of the institutions of marriage, of monarchy, and of all forms of private property, joined to the deliberate attempt to stir up class hatred, which was indeed an essential part of their policy, caused a widespread feeling that the Social Democrats were a serious menace to civilization. They were looked upon even by many Liberals as an enemy to be crushed; much more was this the case with the Government. Attempts had already been made to check the growth of the party. Charges of high treason were brought against some. In 1872 Bebel and Liebknecht were condemned to two years' imprisonment. In 1876 Bismarck proposed to introduce into the Criminal Code a clause making it an offence punishable with two years' imprisonment "to attack in print the family, property, universal military service, or other foundation of public order, in a manner which undermined morality, feeling for law, or the love of the Fatherland." The opposition of the Liberals prevented this from being carried. Lasker objected to these "elastic paragraphs," an expression for which in recent years there has been abundant use. The ordinary law was, however, sufficient greatly to harass the Socialists. In nearly every state there still existed, as survivals of the old days, laws forbidding the union of different political associations with one another, and all unions or associations of working men which followed political, socialistic, or communistic ends. It was possible under these to procure decisions in courts of justice dissolving the General Union of Workers and the coalitions and unions of working men. The only result was, that the number of Socialists steadily increased. In 1874 they secured nine seats in the Reichstag, in 1877 twelve, and nearly 500,000 votes were given to Socialist candidates.

Legislation against the Socialists.

There was then no ground for surprise that, when in April 1878 an attempt was made on the life of the Emperor, Bismarck used the excuse for again bringing in a law expressly directed against the Socialists. It was badly drawn up and badly defended. The National Liberals refused to vote for it, and it was easily defeated. The Reichstag was prorogued; six days later a man named Nobiling again shot at the Emperor, and this time inflicted dangerous injuries. It is only fair to say that no real proof was brought that the Socialists had anything to do with either of these crimes, or that either of the men was really a member of the Socialist party; nevertheless, a storm of indignation rose against them. The Government seized the opportunity. So great was the popular feeling, that a repressive measure would easily have been carried; Bismarck, however, while the excitement was at its height, dissolved the Reichstag, and in the elections which took place immediately the Liberal parties, who had refused to vote for the first law, lost a considerable number of seats, and with them their control over the Reichstag.

The first use which Bismarck made of the new parliament was to deal with the Social Democrats. A new law was introduced forbidding the spread of Socialistic opinions by books, newspapers, or public meetings, empowering the police to break up meetings and to suppress newspapers. The Federal Council could proclaim a state of siege in any town or district, and when this was done any individual who was considered dangerous by the police could be expelled. The law was carried by a large majority, being opposed only by the Progressives and the Centre. It was applied with great severity. The whole organization of newspapers, societies, and trades unions was at once broken up. Almost every political newspaper supported by the party was suppressed; almost all the pamphlets and books issued by them were forbidden; they were thereby at once deprived of the only legitimate means which they had for spreading their opinions. In the autumn of 1878 the minor state of siege was proclaimed in Berlin, although no disorders had taken place and no resistance had been attempted, and sixty-seven members of the party were excluded from the city. Most of them were married and had families; money was collected in order to help those who were suddenly deprived of their means of subsistence. Even this was soon forbidden by the police. At elections every kind of agitation, whether by meetings of the party or by distribution of literature, was suppressed. The only place in Germany where Socialists could still proclaim their opinions was in the Reichstag. Bismarck attempted to exclude them from it also. In this, however, he failed. Two members who had been expelled from Berlin appeared in the city for the meeting of the Reichstag at the end of 1878. The Government at once asked permission that they should be charged with breaking the law. The Constitution provided that no member of the House might be brought before a court of justice without the permission of the House, a most necessary safeguard. In this case the permission was almost unanimously refused. Nor did they assent to Bismarck's proposal that the Reichstag should assume power to exclude from the House members who were guilty of misusing the liberty of speech which they enjoyed there. Bismarck probably expected, and it is often said that he hoped, to drive the Socialists into some flagrant violation of the law, of such a kind that it would be possible for him completely to crush them. This did not happen. There were some members of the party who wished to turn to outrage and assassination. Most, a printer from Leipzig, who had been expelled from Berlin, went to London, where he founded the *Freiheit*, a weekly paper, in which he advocated a policy of violence. He was thereupon excluded from the party, and after the assassination of the Tsar had to leave England for Chicago. A similar expulsion befell others who advocated union with the Anarchists. As a whole, however, the party remained firm in opposition to any action which would strengthen the hands of their opponents. They carried on the agitation as best they could, chiefly by distributing reports of speeches made in the Reichstag. A weekly paper, the *Social-Democrat*, was established at Zürich. Its introduction into Germany was of course forbidden, but it was soon found possible regularly to distribute thousands of copies every week in every part of the country, and it continued to exist till 1887 at Zürich, and till 1890 in London. In August of 1880 a congress of Socialists was held at the castle of Wyden, in Switzerland, at which about eighty members of the party met, discussed their policy, and separated before the police knew anything of it. Here it was determined that the members of the Reichstag, who were protected by their position, should henceforward be the managing committee of the party, and arrangements were made for contesting the elections of 1881. A similar meeting was held in 1883 at Copenhagen, and in 1887 at St Gallen, in Switzerland. Notwithstanding all the efforts of the Government, though every kind of public agitation was forbidden, they succeeded in winning twelve seats in 1881. The law, which had obviously failed, was renewed in 1881; the state of siege was applied to Hamburg, Leipzig, and Stettin, but all to no purpose; and though the law was twice more renewed, in 1886 and in 1888, the feeling began to grow that the Socialists were more dangerous under it than they had been before.

The elections of 1878, by weakening the Liberal parties, enabled Bismarck also to take in hand the great financial reform which he had long contemplated.

Financial reform.

At the foundation of the North German Confederation it had been arranged that the imperial exchequer should receive the produce of all customs duties and also of excise. It depended chiefly on the taxes on salt, tobacco, brandy, beer, and sugar. So far as the imperial expenses were not covered by these sources of revenue, until imperial taxes were introduced, the deficit had to be covered by contributions paid by the individual states in proportion to their population. All attempts to introduce fresh imperial taxes had failed. Direct taxation was opposed by the governments of the states, which did not desire to see the imperial authorities interfering in those sources of revenue over which they had hitherto had sole control; moreover, the whole organization for collecting direct taxes would have had to be created. At the same time, owing to the adoption of free trade, the income from customs was continually diminishing. The result was that the sum to be contributed by the individual states constantly increased, and the amount to be raised by direct taxation, including local rates, threatened to become greater than could conveniently be borne. Bismarck had always regarded this system with disapproval, but during the first four or five years he had left the care of the finances entirely to the special officials, and had always been thwarted in his occasional attempts to introduce a change. His most cherished project was a large increase in the tax on tobacco, which at this time paid, for home-grown tobacco, the nominal duty of four marks per hundred kilo. (about a farthing a pound), and on imported tobacco twenty-four marks. Proposals to increase it had been made in 1869 and in 1878, and on the latter occasion Bismarck for the first time publicly announced his desire for a state monopoly, a project which he never gave up, but for which he never was able to win any support. Now, however, he was able to take up the work. At his invitation a conference of the finance ministers met in July at Heidelberg; they agreed to a great increase in the indirect taxes, but refused to accept the monopoly on tobacco. At the beginning of the autumn session a union of 204 members of the Reichstag was formed for the discussion of economic questions, and they accepted Bismarck's reforms. In December he was therefore able to issue a memorandum explaining his policy; it included a moderate duty, about 5 per cent., on all imported goods, with the exception of raw material required for German manufactures (this was a return to the old Prussian principle); high finance duties on tobacco, beer, brandy, and petroleum; and protective duties on iron, corn, cattle, wood, wine, and sugar. The whole of the session of 1879 was occupied with the great struggle between Free Trade and Protection, and it ended with a decisive victory for the latter.

Protection.

On the one side were the seaports, the chambers of commerce, and the city of Berlin, the town council of which made itself the centre of the opposition. The victory was secured by a coalition between the agricultural interests and the manufacturers; the latter promised to vote for duties on corn if the landlords would support the duties on iron. In the decisive vote the duty on iron was carried by 218 to 88, on corn by 226 to 109.

The principle of protection which was then adopted has been maintained since; considerable alterations have been made from time to time in the tariff; in 1885 the duty on corn was raised; again in 1885 and 1887, considerable duties were levied on most timbers. The finance duties were also with some exceptions adopted, and have since been maintained. The tax on tobacco was increased to 44 marks, and the duty on imported tobacco raised to 85. The monopoly on tobacco was rejected in 1882 by 273 to 43 votes, and in 1886 that on brandy by 181 to 3. In the next year, after the victory of the coalition, an elaborate law imposing fresh duties on brandy was carried, which was of considerable political importance, for it was adopted by the southern states, who thereby gave up one of their chief privileges. All proposals for a reform of the tax on beer, however, failed. The result of these new taxes was that the income from customs and excise rose from about 230 million marks in 1878–79 to about 700 millions in 1898–99, and Bismarck's object in removing a great burden from the states was attained.

State contributions.

The natural course when the new source of income had been obtained would have been simply to relieve the states of part or all of their contribution. This, however, was not done. The Reichstag raised difficulties on the constitutional question. The Liberals feared that if the Government received so large a permanent source of revenue it would be independent of Parliament; the Centre, that if the contributions of the states to the imperial exchequer ceased, the central Government would be completely independent of the states. Bismarck had to come to an agreement with one party or the other; he chose the Centre, probably for the reason that the National Liberals were themselves divided on the policy to be pursued, and therefore their support would be uncertain; and he accepted an amendment, the celebrated *Franckenstein Clause*, proposed by Franckenstein, one of the leaders of the Centre, by which all proceeds of customs and the tax on tobacco above 130 million marks should be paid over to the individual states in proportion to their population. Each year a large sum would be paid to the states from the imperial treasury and another sum as before paid back to meet the deficit in the form of state contributions. This complicated arrangement has since continued.

From 1871 to 1879 the contribution of the states had varied from 94 to 67 million marks; under the new system the surplus of the contributions made by the states over the grant by the imperial treasury was soon reduced to a very small sum, and in 1884-85 the payments of the empire to the states exceeded the contributions of the states to the empire by 20 million marks, and this excess continued for many years; so that there was, as it were, an actual grant in relief of direct taxation. In Prussia, by the Lex Huene, from 1885 to 1895, all that sum paid to Prussia, so far as it exceeded 15 million marks, was handed over to the local authorities in relief of rates. The increased expenditure on the navy since 1897 has again caused the contributions required from the states to exceed the grants to them from the imperial exchequer.

These events were followed by the disruption of the National Liberal party and a complete change in the parliamentary situation. Already the Liberal ministers, Falk and Hobrecht, had resigned, as well as Forckenbeck the president, and Stauffenberg the vice-president of the Reichstag; in their place there was chosen a Conservative, and Franckenstein, a Catholic. The whole party had voted against the Franckenstein Clause, but a few days later fifteen of the right wing left the party and transferred their support to the Government. For another year the remainder kept together, but there was no longer any real harmony or co-operation; in 1880 nineteen, including most of the ablest leaders, Lasker, Forckenbeck, Bamberger, and Bunsen, left the party altogether. The avowed cause of difference was commercial policy; they were the Free Traders, but they also justly foresaw that the reaction would extend to other matters. They took the name of the *Liberale Vereinigung*, but were generally known as the *Secession*; they hoped to become the nucleus of a united Liberal party in which all sections should join together on the principles of Free Trade and constitutional development. At the elections of 1881 they secured forty-seven seats, but they were not strong enough to maintain themselves, and with great reluctance in 1884 formed a coalition with the Progressives, who had gained greatly in strength owing to the breach among the Government parties. They did so reluctantly, because they would thereby condemn themselves to assume that attitude of purely negative criticism which, during the great days of their prosperity, they had looked down upon with contempt, and were putting themselves under the leadership of Eugen Richter, whom they had long opposed. The new party, the *Freisinnige*, had no success; at the election of 1884 they secured only sixty-seven seats, a loss of thirty-nine; they were subjected to all inconveniences which belonged to opposition; socially, they were boycotted by all who were connected with the Court or Government; they were cut off from all hope of public activity, and were subjected to constant accusations for *Bismarck Beleidigung*. Their only hope was in the time when the Crown Prince, who had shown great sympathy with them, should succeed. They were popularly known as the Crown Prince's party. Lasker soon died; others, such as Forckenbeck and Bunsen, retired from public life, unable to maintain their position at a time when the struggle of class interests had superseded the old conflicts of principle. At the election of 1887 they lost more than half their seats, and, as we shall see, in 1893 the party again broke up.

Party changes.

Secessionists.

Freisinnige.

The remainder of the National Liberals only won forty-five seats in 1881, and during the next three years they were without influence on the Government; and even Bennigsen, unable to follow Bismarck in his new policy, disgusted at the proposals for biennial budgets and the misuse of Government influence at the elections, retired from political life. In 1884 a new development took place: under the influence of Miquel a meeting was held at Heidelberg of the South German members of the party, who accepted the commercial and social policy of the Government, including the Socialist law; their programme received Bismarck's approval, and was accepted by the rest of the party, so that they henceforward were taken into favour by the Government; but they had won the position by sacrificing almost all the characteristics of the older Liberalism; the hope of a reunion for all the different sections which had hitherto kept the name of Liberal was at an end.

These events had a very unfortunate effect on the character of the parliament. From 1878 to 1887 there was no strong party on which Bismarck could depend for support. After 1881 the parties of opposition were considerably strengthened. Alsatians and Poles, Guelphs, Clericals, and Radicals were joined in a common hostility to the Government. Parliamentary history took the form of a hostile criticism of the Government proposals, which was particularly bitter because of the irreconcilable opposition of the Free Traders. Few of the proposals were carried in their entirety, many were completely lost; the tobacco monopoly and the brandy monopoly were contemptuously rejected by enormous majorities; even an increase of the tax on tobacco was refused; the first proposals for a subsidy to the Norddeutsche Lloyd were rejected. The personal relations of the chancellor to Parliament were never so bitter. At the same time, in Prussia there was a tendency to make more prominent the power of the king and to diminish the influence of the parliament. A proposal to introduce biennial budgets was for this reason regarded with great suspicion by the Opposition as a reactionary measure, and rejected. The old feelings of suspicion and jealousy were again aroused; the hostility which Bismarck encountered was scarcely less than in the old days of the conflict. After the elections of 1881 a protest was raised against the systematic influence exercised by Prussian officials. Puttkammer, who had now become minister of the interior, defended the practice, and a royal edict of 4th January 1882 affirmed the monarchical character of the Prussian Constitution, the right of the king personally to direct the policy of the state, and required those officials who held appointments of a political nature to defend the policy of the Government, even at elections.

Political reaction.

One result of the new policy was a reconciliation with the Centre. Now that Bismarck could no longer depend on the support of the Liberals, it would be impossible to carry on the Government if the Catholics maintained their policy of opposition to all Government measures. They had supported him in his commercial reform of 1878, but by opposing the Septennate in 1880 they had shown that he could not depend upon them. It was impossible to continue to treat as enemies of the state a party which had supplied one of the vice-presidents to the Reichstag, and which after the election of 1881 outnumbered by forty votes any other single party. Moreover, the Government, which was now very seriously alarmed at the influence of the Social Democrats, was anxious to avail itself of every influence which might be used against them. In the struggle to regain the adherence of the working men it seemed as though religion would be the most valuable ally, and it was impossible to ignore the fact that the Roman Catholic priests had alone been able to form an organization in which hundreds of thousands of working men had been enlisted. It was therefore for every reason desirable to remedy a state of things by which so many parishes were left without incumbents, a condition the result of which must be either to diminish the hold of Christianity over the people, or to confirm in them the belief that the Government was the real enemy of Christianity. It was not easy to execute this change of front with dignity, and impossible to do so without forsaking the principles on which they had hitherto acted. Ten years were to pass before the work was completed. But the cause of the conflict had been rather in the opinions of the Liberals than in the personal desire of Bismarck himself. The larger political reasons which had brought about the conflict were also no longer valid; the fears to which the Vatican decrees had given rise had not been fulfilled; the failure of the Carlists in Spain and of the Legitimists in France, the consolidation of the new kingdom in Italy,

End of the Kulturkampf.

and the alliance with Austria, had dispelled the fear of a Catholic League. The growth of the Catholic democracy in Germany was a much more serious danger, and it proved to be easier to come to terms with the Pope than with the parliamentary Opposition. It would clearly be impossible to come to any agreement on the principles. Bismarck hoped, indeed, putting all questions of principle aside, to establish a *modus vivendi;* but even this was difficult to attain. An opportunity was given by the death of the Pope in 1878. Leo XIII. notified his accession to the Prussian Government in a courteous despatch; the interchange of letters was followed by a confidential discussion between Bismarck and Cardinal Franchi at Kissingen during the summer of 1878. The hope that this might bring about some agreement was frustrated by the sudden death of the cardinal, and his successor was more under the influence of the Jesuits and the more extreme party. Bismarck, however, was not discouraged.

The resignation of Falk in July 1879 was a sign of the change of policy; he was succeeded by Puttkammer, who belonged to the old-fashioned Prussian Conservatives and had no sympathy with the Liberal legislation. The way was further prepared by a lenient use of the penal laws. On 24th February 1880 the Pope, in a letter to the ex-bishop of Cologne, said he was willing to allow clerical appointments to be notified if the Government withdrew the obnoxious laws. In 1880 a provisional Bill was submitted to Parliament giving the Crown discretionary power not to enforce the laws. It was opposed by the Liberals on the ground that it conceded too much, by the Clericals that it granted too little, but, though carried only in a mutilated form, it enabled the priests who had been ejected to appoint substitutes, and religious worship was restored in nearly a thousand parishes. In the elections of 1881 the Centre gained five more seats, and in 1883 a new law was introduced prolonging and extending that of 1881. Meanwhile a Prussian envoy had again been appointed at the Vatican; all but three of the vacant bishoprics were filled by agreement between the Pope and the king, and the sequestrated revenues were restored. Finally, in 1886, a fresh law, besides other concessions, did away with the *Kultur Examen*, and exempted seminaries from state control. It also abolished the Ecclesiastical Court, which, in fact, had proved to be almost unworkable, for no priests would appeal to it. By this, the real Kulturkampf, the attempt of the state to control the intellect and faith of the clergy, ceased. A further law of 1887 permitted the return to Prussia of those orders which were occupied in charitable work.

As permanent results of the conflict there remain only the alteration in the Prussian Constitution and the expulsion of the Jesuits; the Centre have continued to demand the repeal of this, and to make it the price of their support of Government measures; in 1897 the Bundesrath permitted the return of the Redemptorists, an allied order. With these exceptions absolute religious peace resulted; the Centre to a great extent succeeded to the position which the National Liberals formerly held; in Bavaria, in Baden, in Prussia, they obtained a dominant position, and they became a Government party.

Nationalization of railways.

Meanwhile Bismarck, who was not intimidated by the parliamentary opposition, irritating and embarrassing though it was, resolutely proceeded with his task of developing the material resources of the empire. In order to do so the better he undertook, in addition to his other offices, that of Prussian minister of commerce. He was now able to carry out, at least partially, his railway schemes, for he could afford to ignore Liberal dislike to state railways, and if he was unable to make all the lines imperial, he could make most of them Prussian. The work was continued by his successors, and by the year 1896 there remained only about 2000 kilometres of private railways in Prussia; of these none except those in East Prussia belonged to companies of any great importance. More than this, Bismarck was able to obtain Prussian control of the neighbouring states; in 1886 the Brunswick railways were acquired by the Prussian Government, and in 1895 the private lines in Thuringia. The imperial railways in Elsass-Lothringen are managed in close connexion with the Prussian system, and in 1895 an important step was taken towards extending Prussian influence in the south. A treaty was made between Prussia and Hesse by which the two states together bought up the Hesse-Ludwig railway (the most important private company remaining in Germany), and in addition to this agreed that they would form a special union for the joint administration of all the lines belonging to either state. What this means is that the Hessian lines are now managed by the Prussian department, but Hesse has the right of appointing one director, and the expenses and profits are divided between the two states in proportion to their population. Thus a nucleus and precedent has been formed similar to that by which the Customs Union was begun, and it was hoped that it might be possible to arrange similar agreements with other states, so that in this way a common management for all lines might be established. There is, however, strong opposition, especially in South Germany, and most of the states cling to the separate management of their own lines. Fearful that Prussia might obtain control over the private lines, they have imitated Prussian policy and acquired all railways for the state; there is now a separate railway administration in Saxony, Bavaria, Würtemberg, Baden, Mecklenburg, and Oldenburg. The management of the railways plays an important part in local politics, and occupies much of the attention of Parliament; much of the old opposition to Prussia is revived in defence of the local railways.

Bismarck's policy has been fully justified by results. In nothing has there been so great an increase in practical efficiency as in the working of the railways. And now that the tariffs are fixed by the state, it is possible to use them so as to support the fiscal and commercial policy of the Government. In the early years of the empire it happened that the railway companies fixed the tariffs so as to give an advantage to foreign imports over home industries; now they can be fixed so as to afford, if desirable, an additional protection to home produce.

Canals.

A natural supplement to the nationalization of railways was the development of water communication. This is of great importance in Germany, as all the chief coalfields and manufacturing districts—Silesia, Saxony, Westphalia, and Elsass—are far removed from the sea. The most important works which have been executed in recent years are the canal from Dortmund to the mouth of the Ems, and the Jāhde canal from the Ems to the Elbe, which enables Westphalian coal to reach the sea, and so to compete better with English coal. In addition to this, however, a large number of smaller works have been undertaken, such as the canalization of the Main from Frankfort to the Rhine, and a new canal from the Elbe to Lübeck. The traffic on the great waterways increased fourfold during the period 1870–1900, and so great has been the growth of industry and enterprise that the increased use of water communication does not prevent the railway traffic from increasing with equal rapidity. The great ship canal from Kiel to the Elbe, which was begun in 1887 and completed in 1896, has perhaps even more importance for naval than for commercial purposes.

The change which has taken place in the Rhine is characteristic of modern Germany. This great river, so long the home of romance, has become one of the great arteries of traffic, and while lines of railways on both sides have caused small villages to become large towns, the river itself is navigated by more than 400 steamers. The Prussian Government also planned a great scheme by which the Westphalian coalfields should be directly connected with the Rhine in one direction and the Elbe in the other by a canal which would join together Minden, Hanover, and Magdeburg. This would give uninterrupted water communication from one end of the country to the other, for the Elbe, Oder, and Vistula are all navigable rivers connected by canals. This project, which was a natural continuation of Bismarck's policy, was, however, rejected by the Prussian parliament in 1894. The opposition came from the Agrarians and extreme Conservatives, who feared that it would enable foreign corn to compete on better terms with German corn; they were also jealous of the attention paid by the Government to commercial enterprise in which they were not immediately interested. The proposal continued to be repeatedly discussed, but without success, and it was the rejection of this Bill in 1901 which led to a ministerial crisis and the resignation of Miquel.

Equally important was the action of the Government in developing foreign trade. The first step was the inclusion of Hamburg and Bremen in the Customs Union; this was necessary if German maritime enterprise was to become a national and not merely a local concern, for the two Hansa cities practically controlled the whole foreign trade and owned three-quarters of the shipping; but so long as they were excluded from the Customs Union their interests were more cosmopolitan than national. Both cities, but especially Hamburg, were very reluctant to give up their privileges and the commercial independence which they had enjoyed almost since their foundation. As a clause in the Constitution determined that they should remain outside the Customs Union until they voluntarily offered to enter it, there was some difficulty in overcoming their opposition. Bismarck, with characteristic energy, proposed to take steps, by altering the position of the imperial customs stations, which would practically destroy the commerce of Hamburg, and some of his proposals which seemed contrary to the Constitution aroused a very sharp resistance in the Bundesrath. It was, however, not necessary to go to extremities, for in 1881 the senate of Hamburg accepted an agreement which, after a keen struggle, was ratified by the citizens. By this Hamburg was to enter the Union; a part of the harbour was to remain a free port, and the empire contributed two million pounds towards rearranging and enlarging the harbour. A similar treaty was made with Bremen, the free port of that city being situated near the mouth of the Weser at Bremerhaven; and in 1888, the necessary works having been completed, the cities entered the Union. They have had no reason to regret the change, for no part of the country profited so much by the great prosperity of the following years, notwithstanding the temporary check caused by the serious outbreak of cholera at Hamburg in 1896.

Hamburg and Bremen.

During the first years of the empire Bismarck had occasionally been asked to interest himself in colonial enterprise. He had refused, for he feared that foreign complications might ensue, and that the country might weaken itself by dissipation of energy. He was satisfied that the Germans should profit by the commercial liberty allowed in the British colonies. Many of the Germans were, however, not contented with this, and disputes regarding the rights of German settlers in Fiji caused some change of feeling. The acquisition of German colonies was really the logical and almost necessary sequel of a Protective policy. For that reason it was always opposed by the extreme Liberal party.

Colonies.

The failure of the great Hamburg house of Godefroy in 1879 threatened to ruin the growing German industries in the South Seas, which it had helped to build up. Bismarck therefore consented to apply to the Reichstag for a state guarantee to a company which would take over its great plantations in Samoa. This was refused, chiefly owing to the influence of the Liberal party. Bismarck therefore, who took this rebuff much to heart, said he would have nothing more to do with the matter, and warned those interested in colonies that they must depend on self-help; he could do nothing for them. By the support of some of the great financial firms they succeeded in forming a company, which carried on the business and undertook fresh settlements on the islands to the north of New Guinea. This event led also to the foundation of a society, the *Deutscher Kolonial Verein*, under the presidency of the prince of Hohenlohe-Langenburg, to educate public opinion. Their immediate object was the acquisition of trading stations.

The year 1884 brought a complete change. Within a few months Germany acquired extended possessions in several parts both of Africa and the South Seas. This was rendered possible owing to the good understanding which at that time existed between Germany and France. Bismarck therefore no longer feared, as he formerly had, to encounter the difficulties with Great Britain which would be the natural result of a policy of colonial expansion.

The first acquisition was made in South-West Africa. On several occasions missionaries had applied to the German Government for protection. In 1883 Herr Luderitz, a Bremen tobacco merchant, had acquired by purchase from the natives and half-breed chiefs a trading-station on the Bay of Angra Pequeña and considerable territory in the neighbourhood. He then asked for the protection of the empire. A correspondence between the British and German Foreign Offices showed that the British Government had not hitherto exercised rights of sovereignty over this district, and had refused to undertake the responsibility for the protection of German settlers. In the month of June, therefore, the German flag was hoisted at Angra Pequeña, and shortly afterwards the whole coast from the river Orange to the Portuguese colonies, with the exception of Walfisch Bay, was taken under German protection. During the same year, in consequence of a dispute which had arisen between German traders and natives on the Gulf of Guinea, a gunboat was despatched, and Dr Nachtigal was instructed to proclaim a protectorate over Cameroon. Dr Nachtigal, however, on his own authority, found it desirable to take Togoland also under German rule. Encouraged by this action of the Government, a company, the *Gesellschaft für deutsche Kolonization*, was founded by Dr Peters, who at once went off to the east coast of Africa and succeeded in negotiating treaties with twelve chiefs on the coast off Zanzibar; at the beginning of 1885 these also were taken over by the Government.

Africa.

Similar events took place in the South Seas. The acquisition of Samoa, where German interests were most extensive, was prevented by the arrangement made in 1879 with Great Britain and the United States. But in 1884 and 1885 the German flag was hoisted on the north of New Guinea (to which the name Kaiser Wilhelmsland has been given), on several parts of the New Britain Archipelago (which afterwards became the Bismarck Archipelago), and on the Caroline Islands. The last acquisition was not kept. The Spanish Government claimed the islands, and Bismarck, in order to avoid a struggle which would have been very disastrous to monarchical government in Spain, suggested that the Pope should be asked to mediate. Leo XIII. accepted the offer, which was an agreeable reminiscence of the days when Popes determined the limits of the Spanish colonial empire, all the more gratefully that it was made by a Protestant power. He decided in favour of Spain, Germany being granted certain rights in the islands. The loss of the islands was amply compensated for by the political advantages which Bismarck gained by this attention to the Pope, and, after all, not many years elapsed before they became German.

The Pacific.

Bismarck in his colonial policy had repeatedly explained that he did not propose to found provinces or take over for the Government the responsibility for their administration; he intended to leave the responsibility for their material development to the merchants, and even to entrust to them the actual government. He avowedly wished to imitate the older form of British colonization by means of chartered companies, which had been recently revived in the North Borneo Company; the only responsibility of the Imperial Government was to be their protection from foreign aggression. In accordance with this policy, the territories were not actually incorporated in the empire (there would also have been constitutional difficulties in doing that), and they were officially known as Protectorates (*Schutzgebiete*), a word which thus acquired a new signification. In 1885 two new great companies were founded to undertake the government. The *Deutsch Ost Afrika Gesellschaft*, with a capital of £200,000, took over the territories acquired by Dr Peters, and for the South Seas the *Neu Guinea Gesellschaft*, founded by an amalgamation of a number of firms in 1884, received a charter in 1885. It was not, however, possible to limit the imperial responsibility as Bismarck intended. In East Africa the great revolt of the Arabs in 1888 drove the company out of all their possessions, with the exception of the port of Dar-es-Salam. The company was not strong enough to defend itself; troops had to be sent out by the Emperor under Captain Wissmann, who as imperial commissioner took over the government. This, which was at first a temporary arrangement, was afterwards made permanent.

The New Guinea Company had less formidable enemies to contend with, and with the exception of a period of three years between 1889 and 1892, they maintained a full responsibility for the administration of their territory till the year 1899, when an agreement was made and ratified in the Reichstag, by which the possession and administration was transferred to the empire in return for a subsidy of £20,000 a year, to be continued for ten years. The whole of the colonies have therefore now come under the direct administration of the empire. They are administered under a special department of the Foreign Office, and in 1890 a council of experts on colonial matters was instituted, who should help the director and the chancellor by their advice. It is one of the complaints of the colonial party that a separate Office for colonial affairs has not been created. In 1887 the two chief societies for supporting the colonial movement joined under the name of the *Deutsche Kolonialgesellschaft*. This society, which in 1901 had over 25,000 members, takes a great part in forming public opinion on colonial matters.

This new policy inevitably caused a rivalry of interests with other countries, and especially with Great Britain. In every spot at which the Germans acquired territory they found themselves in opposition to British interests. The settlement at Angra Pequeña caused much ill-feeling in Cape Colony, which was, however, scarcely justified, for it was the reluctance of the Cape ministry to undertake responsibility for the administration of Namaqualand which prevented the British Government from anticipating the Germans in the acquisition of this district. In Togoland and Cameroon British traders had long been active, and the proclamation of British sovereignty was impending when the German flag was hoisted. The settlements in East Africa menaced the old-established British influence over Zanzibar, which was all the more serious because of the close connexion between Zanzibar and the rulers of the Persian Gulf; and the colony of Queensland saw with much concern the German settlement so near their shores. As soon as the acquisitions had been made, however, a period followed during which by a series of treaties the boundaries of German, French, and British possessions were determined in the way of peaceful negotiation. The overthrow of Jules Ferry and the danger of war with France made a good understanding with Great Britain of more importance. Bismarck, by summoning a conference to Berlin to discuss African questions, secured for Germany, though the youngest of colonial powers, a European recognition which was very grateful to the colonial parties; and in 1888, by lending his support to the anti-slavery movement of Cardinal Lavigerie, he won the support of the Centre, who had hitherto opposed the colonial policy. At the same time the anti-slavery agitation was of use in another way, for the proclamation of a general blockade on the east coast of Africa was of considerable assistance to the Germans in their difficult struggle against the Arabs.

Germany and Great Britain.

This period is concluded by the general agreement for the demarcation of Africa which was made in 1890. A similar agreement had been made in 1886 regarding the South Seas. It was made after Bismarck had retired from office, and he, as did the colonial party, severely criticized the details; for the surrender of Zanzibar and Witu cut short the hopes which had been formed of building up a great German empire controlling the whole of East Africa. Many of the colonial party went further, and criticized not only the details, but the principle. They were much offended by Caprivi's statement that no greater injury could be done to Germany than to give her the whole of Africa, and they refused to accept his contention that "the period of flag-hoisting was over," and that the time had come for consolidating their possessions. It must, however, be recognized that a continuation of the ambitious policy of the last few years might easily have involved Germany in dangerous disputes.

It appeared a small compensation that Great Britain surrendered to Germany the island of Heligoland, which she had taken from the Danes in the Napoleonic wars. It was annexed to Prussia; the natives born before the year 1880 were exempted from military service, and till the year 1901 no additional import duties were to be imposed. It has been strongly fortified and made a naval station.

Heligoland.

It was easy for the Opposition to criticize the colonial policy. They could point out that in no case had territory been acquired in which any large number of German emigrants could live and rear families. As late as 1896 the total number of Germans living in the protectorates was less than 2000, and of these more than half were officials and soldiers. The colonies are therefore, and will probably continue to be, useless as a means of providing homes for surplus population. As in the old days, emigrants go to the United States and South America. As markets for German products the colonies still are of the smallest importance; in 1901 the whole value of the trade, import and export, between Germany and her colonies was less than £1,000,000, and the cost of administration, including the grant to the shipping companies, has often exceeded the total trade. Many mistakes have been made in the administration, and cases of misconduct by individual officials have formed the text for attacks on the whole system. Dr Karl Peters, one of the founders of the East African dominion, was in 1897 dismissed from the service. It is noticeable that the colonial party complained of what, on the evidence, was a mere act of justice, as a political blunder, and thereby appeared to identify themselves with his offence and justify the criticisms of the Socialists. Generally, however, these criticisms were premature. Many years must elapse before prosperous plantations can be made in new countries. The colonial policy was one essentially of the future; but whatever the issue be, it was surely wiser, while the opportunity was still open, to take care that Germany, in the partition of the world among European races, should not alone go entirely without a share.

It would be little use acquiring colonies and creating manufactures if the foreign trade was to be in the hands of other nations. As early as 1881 the Government had published a proposal for a subvention to German shipping; it was criticized with peculiar energy by Bamberger and the Free Traders; a Bill introduced in 1884 was abandoned, but in 1885 Bismarck succeeded in carrying a vote by which, for fifteen years, four million marks could annually be devoted to helping a line of mail steamers to the Pacific and Australia and a branch line in the Mediterranean. An agreement was made with the North German Lloyd, one clause of which was that all the new steamers were to be built in Germany; in 1890 a further vote was passed for a line to Delagoa Bay and Zanzibar.

Grants to shipping companies.

This far from exhausts the external activity of the nation and the Government: the establishment of studentships for the study of Oriental languages enabled Germans to make their way in the Turkish and Persian empires, and to open up a fresh market for German goods; by the great excavations at Pergamum and Olympia Germany entered with great distinction on a field in which the way had been shown by France and Great Britain. The progress of technical studies and industrial enterprise enabled Germany to take a leading place in railway and shipbuilding, in the manufacture of military weapons, in chemical experiments, and in electrical work.

It was a part of the new policy not only to combat Social Democracy by repression, but to win the confidence of the working men by extending to them the direct protection of the state. Recent legislation, culminating in the *Gewerbeordnung* of 1869, had, in accordance with the principles of the Liberal Economists, or, as the Germans called it, the Manchester School, instituted freedom from state control in the relations between employers and workmen. The old guilds had been destroyed, compulsory apprenticeship had ceased; little protection, however, was given to the working men, and the restrictions on the employment of women and children were of little use, as there was no efficient system of factory inspection. It was difficult for the men by their own exertions to improve their condition, for the masters had full liberty of association, which the law refused to the workmen. Even before 1870 a protest was raised against this system among the Roman Catholics, who were chiefly concerned for the preservation of family life, which was threatened by the growth of the factory system and also by the teaching of the Social Democrats. Baron von Ketteler, archbishop of Mainz, had maintained that it was the duty of the state to secure to working men work and provision during sickness and old age. The general interest of the Church in the social question was recognized by a congress of the bishops at Fulda. Ketteler's work was continued by Canon Moufang, and Catholics brought forward motions in the Reichstag demanding new factory legislation. The peculiar importance of the Catholic movement is that it alone was able to some extent to meet the Socialists on their own ground. The Catholics formed societies which were joined by large numbers of workmen. Originated by Father Kolping on the Rhine, they soon spread over the whole of Catholic Germany. Herr von Schorlemer-Ast, a Catholic landed proprietor from Westphalia, formed similar associations among the peasants. The result of this has been that the Social Democrats have failed to conquer the Catholic as they have the Protestant districts. A similar movement began among the Protestants after the commercial crisis of 1873, which forms an epoch in German thought, since it was from that year that men first began to question the economic doctrines of Liberalism, and drew attention to the demoralization which seemed to arise from the freedom of speculation and the influence of the stock exchange —a movement which in later years led to some remarkable attempts to remedy the evil by legislation. A minister, Rudolph Todt, and Rudolph Meyer criticized the moral and economic doctrines of Liberalism; his writings led to the foundation of the *Christlich-Social Arbeiter Verein*, which for a few years attained considerable notoriety under the leadership of Adolph Stöcker. The Protestant movement has not succeeded in attaining the same position as has the Catholic among the working men; but it received considerable support among the influential classes at court, and part of the programme was adopted by the Conservative party, which in 1876 demanded restriction of industrial liberty and legislation which would prevent the ruin of the independent artizans.

Social reforms.

Christian Socialism.

In a country where learned opinion has so much influence on public affairs it was of especial importance that several of the younger teachers separated themselves from the dominant Manchester School and asserted the duty of the state actively to promote the well-being of the working classes. At a congress held in Erfurt in 1873, Schmoller, Wagner, Brentano, and others founded the *Verein für Social Politik*, which by its publications has had much influence on German thought.

The peculiar social conditions brought it about that in many cases the Christian Social movement took the form of Anti-Semitism (*q.v.*). In Germany nearly all the bankers and stockbrokers are Jews. Many of the leaders of the Liberal parties, *e.g.*, Bamberger and Lasker, were of Jewish origin; the doctrines of Liberalism were supported by papers owned and edited by Jews; hence the wish to restore more fully the avowedly Christian character of the state, coinciding with the attack on the influence of finance, which owed so much to the Liberal economic doctrines, easily degenerated into attacks on the Jews. The leader in this was Stöcker. During the years 1879 to 1881 the anti-Semite agitation gained considerable importance in Berlin, Breslau, and other Prussian cities, and it culminated in the elections of that year, leading in some cases to riots and acts of violence.

Anti-Semites.

So long as the Government was under the influence of the National Liberals, it was indifferent if not hostile to these movements. The Peasants' Union had actually been forbidden by the police; Bismarck himself was violently attacked for his reputed connexion with a great Jewish firm of bankers. He had, however, kept himself informed regarding these movements, chiefly by means of Hermann Wagener, an old editor of the *Kreuzzeitung*, and in the year 1878 he felt himself free to return in this matter to his older opinions. The new policy suggested in that year was definitely announced at the opening of the session in the spring of 1881, and at the meeting of the new Reichstag in November 1881. It was explained in a speech from the throne, which, as the Emperor could not be present, became an imperial message. This is generally spoken of as the beginning of a new era. The help of the Reichstag was asked for "healing social evils by means of legislation . . . based on the moral foundation of Christianity." Compulsory insurance, the creation of corporate unions among working men under the protection of the state, and the introduction of indirect taxes, were the chief elements in the reform.

The condition of parties was such that Bismarck could not hope to win a majority for his schemes, especially as he could not obtain the monopoly on tobacco on which he depended to cover the expense. The first reform was the restoration of the guilds, to which the Conservatives attached great importance. Since 1869 they continued to exist only as voluntary associations with no public duties; many had been dissolved, and this is said to have brought about bad results in the management of lodging-houses, the condition of apprentices, support during illness, and the maintenance of labour bureaus. It was supposed that, if they could be restored, the corporate spirit would prevent the working men from falling under the influence of the Socialists. The law of 1881, while it left membership voluntary, gave to them many duties of a semi-public nature, especially that of arbitration between masters and men. These were extended by a further law in 1884.

Compulsory insurance.

The really important element was the scheme for a great imperial system by which all working men and women should be provided for in case of sickness, accident, or old age. Bismarck hoped by this to relieve the parishes of the burden of the poor-rate, which would be transferred to the empire; at the same time the power of the Government would be greatly extended. The first proposal in March 1881 was for compulsory insurance against accidents. Every one employed on railways, mines, and factories was to be insured in an imperial office; the premium was to be divided equally between masters, workmen, and the state. It was bitterly opposed by the Liberals, especially by Bamberger; all essential features were altered by the Reichstag, and it was withdrawn by the Government after it had passed the third reading.

In 1882 a fresh scheme was laid before the newly-elected Reichstag dealing with insurance against accident and against sickness. The two parts were separated by the Reichstag; the second, which was the necessary prelude to the other, was passed in 1883. The law was based on an old Prussian principle: insurance was made compulsory, but the state, instead of doing the work itself, recognized the existing friendly and other societies; they were still to enjoy their corporate existence and separate administration, but they were placed under state control, and for this purpose an imperial insurance department was created in the office of the secretary of state for the interior. Uniform regulations were to be followed in all trades and districts; one-third of the premium was paid by the employer, two-thirds by the workmen.

The Accident Law of 1883 was rejected, for it still included the state contribution to which the Reichstag would not assent, and also contributions from the workmen. A new law, drafted according to their wishes, was passed in 1884. It applied only to those occupations, mines and factories, in which the use of machinery was common; it threw the whole burden of compensation on to the masters; but, on the other hand, for the first thirteen weeks after an accident the injured workman received compensation from the sick fund, so that the cost only fell on the masters in the more serious cases. The masters were compelled to insure themselves against the payments for which they might become liable, and for this purpose had to form trades associations, self-governing societies, which in each district included all the masters for each particular trade. The application of this law was subsequently extended to other trades.

It was not till 1889 that the greatest innovation, that of insurance against old age, was carried. The obligation to insure rests on all who are in receipt of wages of not more than two pounds a week. Half the premium, which varies according to the wages received, is paid by the master. The pension begins at the age of seventy, the amount varying by very complicated rules, but the state pays a fixed sum of two pounds ten shillings annually in addition to the pension.

These measures worked well. They were regarded with satisfaction by masters and men alike. Alterations have been made in detail, and further alterations demanded, but the laws have established themselves in practice. The large amount of self-administration has prevented an undue increase of bureaucratic power. The co-operation of masters and men in the administration of the societies has a good effect on the relations of the classes. The expense of administration is, however, considerable. The existence of the separate funds causes much waste of money and labour. The latest proposals are for simplification by establishing a common administration of the sick funds and the old age pensions, and abolishing the separate administration of the different trade benefit societies. It is to be expected that as time goes on the administration will fall more completely into the hands of the state, and that the authority of the imperial insurance department will absorb the older societies.

So far had the social reform gone during this period; except in the matter of insurance, the total result was small. The demands repeatedly made by the Centre and the Conservatives for effective factory legislation and prohibition of Sunday labour were not successful. Bismarck did not wish to lay heavier burdens on the capitalists, and it was not till a later period that they were carried out.

Foreign affairs: the Triple Alliance.

During all this period Bismarck's authority was so great, that in the conduct of foreign affairs he was freed from the criticism and opposition which so often hampered him in his internal policy, and he was able to establish that system of alliances on which for so many years the political system of Europe depended. The close union of the three empires which had existed since the meeting of the Emperors in 1872 did not survive the outbreak of disturbances in the East. Bismarck had maintained an attitude of neutrality, but after the Congress of Berlin he found himself placed between the alternatives of friendship with Austria or Russia. Movements of Russian troops on the western frontier threatened Austria, and the Tsar, in a letter to the German Emperor, stated that peace could only be maintained if Germany gave her support to Russia. Bismarck, now that the choice was forced upon him, determined in favour of Austria, and during a visit to Vienna in October, arranged with Count Andrassy an alliance by which in the event of either being attacked by Russia the other was to assist; if either were attacked by any Power other than Russia, the other was to preserve benevolent neutrality unless the attacking Power was helped by Russia. The effect of this was to protect Austria from attack by Russia, and Germany from the danger of a combined attack by France and Russia. Bismarck with some difficulty procured the consent of the Emperor, who by arranging a meeting with the Tsar had attempted to preserve the old friendship. From that time the alliance with Austria has continued. In 1883 it was joined by Italy, and was renewed in 1887, and in 1891 for six years, and if not then denounced, for twelve.

In 1882, after the retirement of Gortchakoff, the relations with Russia again improved. In 1884 there was a meeting of the three Emperors, and at the same time Bismarck came to a close understanding with France on colonial questions. The period of quiet did not last long. The disaster in Tongking brought about a change of ministry in France, and Bulgarian affairs again alienated Austria and Russia. Bismarck with great skill used the growing foreign complications as a means of freeing himself from parliamentary difficulties at the same time that he secured the position of Germany in Europe.

To meet the increase in the French army, and the open menaces in which the Russian press indulged, a further increase in the German army seemed desirable. The Septennate would expire in 1888. In the autumn of 1886 a proposal was laid before the Reichstag to increase the peace establishment for the next seven years to 468,409 men. The Reichstag would not assent to this, but the opposition parties offered to vote the required increase for three years. Bismarck refused to accept this compromise, and the Reichstag was dissolved. Under his influence the Conservatives and National Liberals formed a coalition or *Cartel* by which each agreed to support the candidates of the other. The elections caused greater excitement than any which had taken place since 1870. The numbers who went to the poll were much larger, and all the opposition parties, except the Catholics, including even the Socialists, suffered severe loss. Bismarck, in order to win the support of the Centre, appealed directly to the Pope, but Windthorst took the responsibility of refusing to obey the Pope's request on a matter purely political. The National Liberals again became a Government party, but their position was much changed. They were no longer, as in the old days, the leading factor. They had to take the second place. They were subordinate to the Conservatives. They could no longer impose their will upon the Government. In the new parliament the Government proposals were accepted by a majority of 223 to 48 (seven members of the Centre voted for it, the others abstained). The opposition consisted chiefly of Socialists and Freisinnige.

Elections of 1887.

The fall of Boulanger removed the immediate danger from France, but for the rest of the year the relations with Russia caused serious apprehensions. Anti-German articles appeared in Russian newspapers. The growth of the Nationalist party in Russia led to measures injurious to German trade and German settlers in Russia. German vessels were forbidden to trade on the Niemen. The increase of the duties on iron injured German trade. Stringent measures were taken to stamp out German nationality in the Baltic provinces, similar to those used by the Germans against the Poles. Foreigners were forbidden to hold land in Russia. The German Government retaliated by a decree of the Reichsbank refusing to deal with Russian paper. Large accumulations of troops on the western frontier excited alarm in Germany and Austria. During a short visit paid by the Tsar to Berlin in November Bismarck discovered that forged despatches misrepresenting the policy of Germany in the Eastern Question had been communicated to the Tsar. This did not seem to remove all danger, and in February 1888 the Government introduced an amendment to the imperial Military law extending the obligation for service from twelve to eighteen years. In this way it was possible to increase the war establishment, excluding the Landsturm, by about half a million men without adding to the burden in time of peace. Another law authorized a loan of £14,000,000 for military equipment. At the same time the text of the Triple Alliance was published. The two laws were adopted without opposition. Under the effect of one of Bismarck's speeches, the Military Bill was unanimously passed almost without debate.

Relations with Russia.

It was probably at the meeting of 1884 that a secret treaty, the existence of which was not known for many years, was arranged between Germany and Russia. The full text has never been published, and the exact date is uncertain. Either state pledged itself to observe benevolent neutrality in case the other were attacked by a third Power. Apparently the case of an attack by France on Germany, or by Austria on Russia, was expressly mentioned. The treaty lapsed in 1890, and owing to Bismarck's dismissal was not renewed. Caprivi refused to renew it because it was doubtful whether by increasing the number of treaties the value of them was not diminished. Under this system it was to be apprehended that if war broke out between Austria and Russia, Austria would claim the support of Germany under the Triple Alliance, Russia neutrality under this treaty. The decision of Germany would theoretically have to depend on the question which party was the aggressor—a question which notoriously is hardly ever capable of an answer. (For this treaty see the debate in the Reichstag of 16th November 1896; the *Hamburger Nachrichten* of 24th October in the same year; and Schulthess, *Europäisches Geschichts-kalendar*, 1896.)

Secret treaty with Russia.

The Emperor William died on 9th March 1888. He was succeeded by his son, who took the title of Frederick III. In Italy, the older title of King of Piedmont has been absorbed in the newer kingdom of Italy; this is not the case in Germany, where the title German Emperor is merely attached to and not substituted for that of King of Prussia. The events of this short reign, which lasted only ninety-nine days, have chiefly a personal interest, and are narrated under the articles FREDERICK and BISMARCK. The illness and death of the Emperor, however, destroyed the last hope of the Liberals that they might at length succeed to power. For a generation they had waited for his accession, and bitter was their disappointment, for it was known that his son was more inclined to follow the principles of Bismarck than those of his own father. The Emperor, crippled and dying though he was, showed clearly how great a change he would, had he lived, have introduced in the spirit of the Government. One of his first acts was severely to reprimand Puttkammer for misusing Government influence at elections. The minister sent in his resignation, which was accepted, and this practice, which had been deliberately revived during the last ten years, was thereby publicly disavowed. Bismarck's own position would naturally have been seriously affected by the fall of a colleague with whom he was closely connected, and another point of internal policy showed also how numerous were the differences between the chancellor and the Emperor. Laws had been passed

Reign of Frederick III.

prolonging the period of both the Prussian and Imperial parliaments from three to five years; when they were laid before the Emperor for his signature he said that he must consider them. Bismarck then pointed out that the constitution of the empire did not authorize the Emperor to withhold his assent from a law which had passed both the Reichstag and the Bundesrath; he could as king of Prussia oppose it by his representatives in the Council, but when it had been accepted there, it was his duty as Emperor to put the law into execution. The Emperor accepted this exposition of the constitution, and after some delay eventually gave his consent also to the Prussian law, which he was qualified to reject.

William II.

He was succeeded by his eldest son, William II. (*q.v.*). The first year of the new reign was uneventful. In his public speeches the Emperor repeatedly expressed his reverence for the memory of his grandfather, and his determination to continue his policy; but he also repudiated the attempt of the extreme Conservatives to identify him with their party. He spent much time on journeys, visiting the chief courts of Europe, and he seemed to desire to preserve close friendship with other nations, especially with Russia and Great Britain. Changes were made in the higher posts of the army and civil service, and Moltke resigned the office of chief of the staff, which for thirty years he had held with such great distinction.

Fall of Bismarck.

The beginning of the year 1890 brought a decisive event. The period of the Reichstag elected in 1887 expired, and the new elections, the first for a quinquennial period, would take place. The chief matter for decision was the fate of the Socialist law; this expired 30th September 1890. The Government at the end of 1889 introduced a new law, which was altered in some minor matters, and which was to be permanent. The Conservatives were prepared to vote for it; the Radicals and Centre opposed it; the decision rested with the National Liberals, and they were willing to accept it on condition that the clause was omitted which allowed the state governments to exclude individuals from districts in which the state of siege had been proclaimed. The final division took place on 25th February 1890. An amendment had been carried omitting this clause, and the National Liberals therefore voted for the Bill in its amended form. The Conservatives were ready to vote as the Government wished; if Bismarck was content with the amended Bill, they would vote for it, and it would be carried; no instructions were sent to the party; they therefore voted against the Bill, and it was lost. The House was immediately dissolved. It was to have been expected that, as in 1878, the Government would appeal to the country to return a Conservative majority willing to vote for a strong law against the Socialists. Instead of this, the Emperor, who was much interested in social reform, published two proclamations. In one addressed to the chancellor he declared his intention, as Emperor, of bettering the lot of the working classes; for this purpose he proposed to call an international congress to consider the possibility of meeting the requirements and wishes of the working men; in the other, which he issued as king of Prussia, he declared that the regulation of the time and conditions of labour was the duty of the state, and the Council of State was to be summoned to discuss this and kindred questions. Bismarck, who was less hopeful than the Emperor, and did not approve of this policy, was thereby prevented from influencing the elections as he would have wished to do; the coalition parties, in consequence, suffered severe loss; Socialists, Centre, and Radicals gained numerous seats. A few days after the election Bismarck was dismissed from office. The difference of opinion between him and the Emperor was not confined to social reform; beyond this was the more serious question as to whether the chancellor or the Emperor was to direct the course of the Government. The Emperor, who, as Bismarck said, intended to be his own chancellor, required Bismarck to draw up a decree reversing a cabinet order of Frederick William IV., which gave the Prussian minister-president the right of being the sole means of communication between the other ministers and the king. This Bismarck refused to do, and he was therefore ordered to send in his resignation.

Chancellorship of Count von Caprivi.

Among those more immediately connected with the Government, his fall was accompanied by a feeling of relief which was not confined to the Opposition, for the burden of his rule had pressed heavily upon all. There was, however, no change in the principles of Government or avowed change in policy; some uncertainty of direction and sudden oscillations of policy showed the presence of a less experienced hand. Bismarck's successor, General von Caprivi, held a similar combination of offices, but the chief control passed now into the hands of the Emperor himself. He aspired by his own will to direct the policy of the state; he put aside the reserve which in modern times is generally observed even by absolute rulers, and by his public speeches and personal influence took a part in political controversy. He made very evident the monarchical character of the Prussian state, and gave to the office of emperor a prominence greater than it had hitherto had.

One result of this was that it became increasingly difficult in political discussions to avoid criticizing the words and actions of the Emperor. Prosecutions for *lèse-majesté* became commoner than they were in former reigns, and the difficulty was much felt in the conduct of parliamentary debate. The rule adopted was that discussion was permitted on those speeches of the Emperor which were officially published in the *Reichsanzeiger*. It was, indeed, not easy to combine that respect and reverence which the Emperor required should be paid to him, with that open criticism of his words which seemed necessary (even for self-defence) when the monarch condescended to become the censor of the opinions and actions of large parties and classes among his subjects. The attempt to combine personal government with representative institutions was one of much interest; it was more successful than might have been anticipated, owing to the disorganization of political parties and the absence of great political leaders; in Germany, as elsewhere, the parliaments had not succeeded in maintaining public interest, and it is worth noting that even the attendance of members was very irregular. There was below the surface much discontent and subdued criticism of the exaggeration of the monarchical power, which the Germans called *Byzantinismus*; but after all the nation seemed to welcome the government of the Emperor, as it did that of Bismarck. The uneasiness which was caused at first by the unwonted vigour of his utterances subsided, as it became apparent how strong was his influence for peace, and with how many-sided an activity he supported and encouraged every side of national life. Another result of the personal government by the Emperor was that it was impossible, in dealing with recent history, to determine how far the ministers of state were really responsible for the measures which they defended, and how far they were the instruments and mouthpieces of the policy of the Emperor.

The first efforts of the "New course," as the new administration was termed, showed some attempt to reconcile to the Government those parties and persons whom Bismarck had kept in opposition. The continuation of social reform was to win over the allegiance of the working men to the person of the Emperor; an attempt was made to reconcile the Guelphs, and even the Poles were taken into favour; Windthorst was treated with marked distinction. The Radicals alone, owing to their ill-timed criticism on the private relations of the imperial family and their continued opposition to the army, were excluded. The attempt, however, to unite and please all parties failed, as did the similar attempt in foreign policy. Naturally enough, it was social reform on which at first activity was concentrated, and the long-delayed factory legislation was now carried out. In 1887 and 1888 the Clerical and Conservative majority had carried through the Reichstag laws restricting the employment of women and children and prohibiting labour on Sundays. These were not accepted by the Bundesrath, but after the International Congress of 1890 an important amendment and addition to the *Gewerbeordnung* was carried to this effect. It was of even greater importance that a full system of factory inspection was created. A further provision empowered the Bundesrath to fix the hours of labour in unhealthy trades; this was applied to the bakeries by an edict of 1895, but the great outcry which this caused prevented any further extension.

Factory laws.

These acts were, however, accompanied by language of great decision against the Social Democrats, especially on the occasion of a great strike in Westphalia, when the Emperor warned the men that for him every Social Democrat was an enemy to the empire and country. None the less, all attempts to win the working men from the doctrinaire Socialists failed. They continued to look on the whole machinery of government, emperor and army, church and police, as their natural enemies, and remained completely under the bondage of the abstract theories of the Socialists, just as much as fifty years ago the German bourgeois were controlled by the Liberal theories. It is strange to see how the national characteristics appeared in them. What began as a great revolutionary movement became a dogmatic and academic school of thought; it often almost seemed as though the orthodox interpretation of Marx's doctrine were of more importance than an improvement in the condition of the working men, and the discussions in the annual Socialist Congress resembled the arguments of theologians rather than the practical considerations of politicians. The party, however, prospered, and grew in strength beyond all anticipation. The repeal of the Socialist law was naturally welcome to them as a great personal triumph over Bismarck; in the elections of 1890 they won thirty-five, in 1893 forty-four, in 1898 fifty-six seats. Their influence was not confined to the artizans; among their open or secret adherents were to be found large numbers of Government *employés* and clerks. In the autumn of 1890 they were able, for the first time, to hold in Germany a general meeting of delegates, which has been continued annually. In the first meetings it appeared that there were strong opposing tendencies within the party which for the first time could be brought to public discussion. On the one side there was a small party, *die Jungen*, in Berlin, who attacked the parliamentary leaders on the ground that they had lent themselves to compromise and had not maintained the old *intransigeant* spirit. In 1891, at Erfurt, Werner and his followers were expelled from the party; some of them drifted into anarchism, others disappeared. On the other hand, there was a large section, the leader of whom was Herr von Vollmar, who maintained that the social revolution would not come suddenly, as Bebel and the older leaders had taught, but that it would be a gradual evolution; they were willing to co-operate with the Government in remedial measures by which, within the existing social order, the prosperity and freedom of the working classes might be advanced; their position was very strong, as Vollmar had succeeded in extending Socialism even in the Catholic parts of Bavaria. An attempt to treat them as not genuine Socialists was frustrated, and they continued in co-operation with the other branch of the party. Their position would be easier were it not for the repeated attempts of the Prussian Government to crush the party by fresh legislation and the supervision exercised by the police. It was a sign of most serious import for the future that in 1897 the electoral law in the kingdom of Saxony was altered with the express purpose of excluding the Socialists from the Saxon Landtag. This and other symptoms caused serious apprehension that some attempt might be made to alter the law of universal suffrage for the Reichstag, and it was policy of this kind which maintained and justified the profound distrust of the governing classes and the class hatred on which Social Democracy depends. On the other hand, there were signs of a greater willingness among the Socialists to co-operate with their old enemies the Liberals in opposition to the commercial policy of the Government, and every step is welcomed which will break down the intellectual isolation in which the working classes are kept.

Progress of Socialism.

In foreign affairs a good understanding with Great Britain was maintained, but the Emperor failed at that time to preserve the friendship of Russia. The close understanding between France and Russia, and the constant increase in the armies of these states, made a still further increase of the German army desirable. In 1890, while the Septennate had still three more years to run, Caprivi had to ask for an additional 20,000 men. It was the first time that an increase of this kind had been necessary within the regular period. When, in 1893, the proposals for the new period were made, they formed a great change. Universal service was to be made a reality; no one except those absolutely unfit were to escape military service. To make enlistment of so large an additional number of recruits possible, the period of service with the colours was reduced to two years. The parliamentary discussion was very confused; the Government eventually accepted an amendment giving them 557,093 for five and a half years instead of the 570,877 asked for; this was rejected by 210 to 162, the greater part of the Centre and of the Freisinnige voting against it. Parliament was at once dissolved. Before the elections the Freisinnige party broke up, as about twenty of them determined to accept the compromise. They took the name of the *Freisinnige Vereinigung*, the others who remained under the leadership of Richter forming the *Freisinnige Volkspartei*. The natural result of this split was a great loss to the party. The Liberal opposition secured only twenty-three seats instead of the sixty-seven they had held before. It was, so far as now can be foreseen, the final collapse of the old Radical party. Nothwithstanding this the Bill was only carried by sixteen votes, and it would have been thrown out again had not the Poles for the first time voted for the Government, since the whole of the Centre voted in opposition.

Military legislation.

This vote was a sign of the increasing disorganization of parties and of growing parliamentary difficulties which were even more apparent in the Prussian Landtag. Miquel, as minister of finance, succeeded indeed in carrying a reform, by which the proceeds of the tax on land and buildings were transferred to the local government authorities, and the loss to the state exchequer made up by increased taxation of larger incomes and industry. The series of measures which began in 1891, and were completed in 1895, won a more general approbation than is usual, and Miquel in this successfully carried out his policy of reconciling the growing jealousies arising from class interests.

A School Bill for Prussia was less successful, and aroused conflicts of principle, which afterwards divided the country. It is remarkable that up to this time there is no general law existing in Prussia regulating the management of the elementary schools. In every province there are different rules as to the age at which attendance is compulsory, as to school management, the regulation of religious education, and the relation of the Church to the schools.

Education proposals.

A clause in the Constitution states that these matters are to be regulated by law, but no law has yet (1902) been carried. In November 1890 a general law was introduced, but it was opposed by the Centre on the ground that it would adversely affect the religious teaching, and Gossler, minister of education, had to resign; he was succeeded by Count Zedlitz, who, in 1892, introduced a new law so drawn up as greatly to strengthen the influence of the Church. This led to a violent agitation; all the Liberal parties joined in opposing it; the agitation spread to the learned classes, and the cry was raised that culture and learning were being handed over to the priests. Caprivi defended the law as part of the great struggle between Christianity and Atheism, but the Ministry was nearly equally divided; the Emperor was dissatisfied with the manner in which it had been introduced, and on 16th March the law was withdrawn. The next day Zedlitz resigned; Caprivi also sent in his resignation, but, at the special request of the Emperor, continued in office as chancellor; he was succeeded by Count Eulenburg as president of the Prussian ministry.

Caprivi's administration was further remarkable for the arrangement of commercial treaties. In 1892 treaties with Austria-Hungary, Italy, Belgium, and Switzerland for twelve years bound together the greater part of the

Commercial treaties.

Continent, and opened a wide market for German manufactures; the idea of this policy was to secure, by a more permanent union of the middle European states, a stable market for the goods which were being excluded owing to the great growth of Protection in France, Russia, and America. These were followed by similar treaties with Rumania and Servia, and in 1894, after a period of sharp customs warfare, with Russia. In all these treaties the general principle was a reduction of the import duties on corn in return for advantages given to German manufactures, and it is this which brought about the struggle of the Government with the Agrarians, which after 1894 took the first place in party politics.

The agricultural interests in Germany had during the middle of the 19th century been in favour of Free Trade. The reason of this was that, till some years after the foundation of the empire, the production of corn and foodstuffs was more than sufficient for the population; as long as they exported corn, potatoes, and cattle, they required no protection from foreign competition, and they enjoyed the advantages of being able to purchase colonial goods and manufactured articles cheaply. Mecklenburg and Hanover,

Agrarians.

the purely agricultural states, had, until their entrance into the Customs Union, followed a completely Free Trade policy. The first union of the Agrarian party, which was formed in 1876 under the name of the Society for the Reform of Taxation, did not place protection on their programme; they laid stress on bimetallism, on the reform of internal taxation, especially of the tax on land and buildings, and on the reform of the railway tariff, and demanded an increase in the stamp duties. These three last points were all to some extent attained. About this time, however, the introduction of cheap corn from Russia began to threaten them, and it was in 1879 that, probably to a great extent influenced by Bismarck, they are first to be found among those who ask for protection.

After that time there was a great increase in the importation of foodstuffs from America. The increase of manufactures and the rapid growth of the population made the introduction of cheap food from abroad a necessity. In the youth of the empire the amount of corn grown in Germany was sufficient for the needs of its inhabitants; the amount consumed in 1899 exceeded the amount produced by about one quarter of the total. At the same time the price, making allowance for the fluctuations owing to bad harvests, steadily decreased, notwithstanding the duty on corn. In twenty years the average price fell from about 235 to 135 marks the 1000 kilo. There was therefore a constant decrease in the income from land, and this took place at a time when the great growth of wealth among the industrial classes had made living more costly. The agriculturists of the north and east saw themselves and their class threatened with loss, and perhaps ruin; their discontent, which had long been growing, broke out into open fire during the discussion of the commercial treaties. As these would inevitably bring about a large increase in the importation of corn from Rumania and Russia, a great agitation was begun in agricultural circles, and the whole influence of the Conservative party was opposed to the treaties. This brought about a curious situation, the measures being only carried by the support of the Centre, the Radicals, and the Socialists, against the violent opposition of those classes, especially the landowners in Prussia, who had hitherto been the supporters of the Government. In order to prevent the commercial treaty with Russia, a great agricultural league was founded in 1893, the *Bund der Landwirthe*; some 7000 landowners joined it immediately. Two days later the Peasants' League, or *Deutsche Bauernbund*, which had been founded in 1885 and included some 44,000 members, chiefly from the smaller proprietors in Pomerania, Posen, Saxony, and Thuringia, merged itself in the new league. This afterwards gained very great proportions. It became, with the Social Democrats, the most influential society which had been founded in Germany for defending the interests of a particular class; it soon numbered more than 200,000 members, including landed proprietors of all degrees. Under its influence a parliamentary union, the *Wirthschaftsvereinigung*, was founded to ensure proper consideration for agricultural affairs; it was joined by more than 100 members of the Reichstag; and the Conservative party fell more and more under the influence of the Agrarians.

Having failed to prevent the commercial treaties, Count Kanitz introduced a motion that the state should have a monopoly of all imported corn, and that the price at which it was to be sold should be fixed by law. On the first occasion, in 1894, only fifty members were found to vote for this, but in the next year ninety-seven supported the introduction of the motion, and it was considered worth while to call together the Prussian Council of State for a special discussion. The whole agitation was extremely inconvenient to the Government. The violence with which it was conducted, coming, as it did, from the highest circles of the Prussian nobility, appeared almost an imitation of Socialist methods; but the Emperor, with his wonted energy, personally rebuked the leaders, and warned them that the opposition of Prussian nobles to their king was a monstrosity. Nevertheless they were able to overthrow the chancellor, who was specially obnoxious to them. In October 1894 he was dismissed suddenly, without warning, and almost without cause, while the Emperor was on a visit to the Eulenburgs, one of the most influential families of the Prussian nobility.

Fall of Caprivi.

Caprivi's fall, though it was occasioned by a difference between him and Count Eulenburg, and was due to the direct act of the Emperor, was rendered easier by the weakness of his parliamentary position. There was no party on whose help he could really depend. The Military Bill had offended the prejudices of conservative military critics; the British treaty had alienated the colonial party; the commercial treaties had only been carried by the help of Poles, Radicals, and Socialists; but it was just these parties who were the most easily offended by the general tendencies of the internal legislation, as shown in the Prussian School Bill. Moreover, the bitter and unscrupulous attacks of the Bismarckian press to which Caprivi was exposed made him unpopular in the country, for the people could not feel at ease so long as they were governed by a minister of whom Bismarck disapproved. There was therefore no prospect of forming anything like a stable coalition of parties on which he could depend.

The Emperor was fortunate in securing as his successor Prince Chlodwig von Hohenlohe. Though the new chancellor once more united with this office that of Prussian minister-president, his age, and perhaps also his character, prevented him from exercising that constant activity and vigilance which his two predecessors had displayed. During his administration even the secretary of state for foreign affairs, Baron Marschall von Bieberstein, and afterwards Count von Bülow, became the ordinary spokesman of the Government, and in the management of other departments the want of a strong hand at the head of affairs was often missed. Between the Emperor, with whom the final direction of policy rested, and his subordinates, the chancellor often appeared to evade public notice. The very first act of the new chancellor brought upon him a severe rebuff. At the opening of the new buildings which had been erected in Berlin for the Reichstag, cheers were called for the Emperor. Some of the Socialist members remained seated. It was not clear that their action was deliberate, but none the less the chancellor himself came down to ask from the House permission to bring a charge of *lèse-majesté* against them, a request which was, of course, almost unanimously refused.

Chancellor Prince v. Hohenlohe.

The Agrarians still maintained their prominent position in Prussia. They opposed all Bills which would appear directly or indirectly to injure agricultural interests. They looked with suspicion on the naval policy of the Emperor, for they disliked all that helps industry and commerce. They would only give their support to the Navy Bills of 1897 and 1900 in return for large concessions limiting the importation of margarine and American preserved meat, and the removal of the Indemnitäts Nachweis acted as a kind of bounty on the export of corn. They successfully opposed the construction of a canal from Westphalia to the Elbe, on the ground that it would facilitate the importation of foreign corn. They refused to accept all the compromises which Miquel, who was very sympathetic towards them, suggested, and thereby brought about his retirement in May 1901.

The opposition of the Agrarians was for many reasons peculiarly embarrassing. The franchise by which the Prussian parliament is elected gave the Conservatives whom they controlled a predominant position. Any alteration of the franchise was, however, out of the question, for that would admit the Socialists. It was, moreover, the tradition of the Prussian court and the Prussian Government (and it must be remembered that the Imperial Government is inspired by Prussian traditions) that the nobility and peasants were in a peculiar way the support of the Crown and the State. The old distrust of the towns, of manufacturers and artizans, still continued. The preservation of a peasant class was considered necessary in the interests of the army. Besides, intellectual and social prejudices required a strong Conservative party. In the south and west of Germany, however, the Conservative party was practically non-existent. In these parts, owing to the changes introduced at the revolution, the nobility, who hold little land, are, comparatively speaking, without political importance. In the Catholic districts the Centre had become absolutely master, except so far as the Socialists threaten their position. Those of the great industrialists who belonged to the National Liberals or the Moderate Conservatives did not command that influence which men of their class generally hold in Great Britain, because the influence of Social Democracy banded together the whole of the working men in a solid phalanx of irreconcilable opposition, the very first principle of which was the hostility of classes. The Government, therefore, were compelled to turn for support to the Centre and the Conservatives, the latter being almost completely under the influence of the old Prussian nobility from the north-east. But every attempt to carry out the policy supported by these parties aroused an opposition most embarrassing to the Government.

The Conservatives distrusted the financial activity which centred round the Exchanges of Berlin and other towns, and in this they had the sympathy of Agrarians and Anti-Semites, as well as of the Centre. The Agrarians believed that the Berlin Exchange was partly responsible for the fall of prices in corn; the Anti-Semites laid stress on the fact that many of the financiers were of Jewish extraction; the Centre feared the moral effects of speculation. This opposition was shown in the demand for additional duties on stamps (this was granted by Bismarck), in the opposition to the renewal of the Bank Charter, and especially in the new regulations for the Exchange which were carried in 1896. One clause in this forbade the dealing in "futures" in corn, and at the same time a special Prussian law required that there should be representatives of agriculture on the managing committee of the Exchange. The members of the Exchanges in Berlin and other towns refused to accept this law. When it came into effect they withdrew and tried to establish a private Exchange. This was prevented, and after two years they were compelled to submit and the Berlin Bourse was again opened.

Exchange regulations.

Political parties now came to represent interests rather than principles. The Government, in order to pass its measures, was obliged to purchase the votes by class legislation, and it bought those with whom it can make the best bargain—these being generally the Centre, as the ablest tacticians, and the Conservatives, as having the highest social position and being boldest in declaring their demands. No great parliamentary leader took the place of Windthorst, Lasker, and Bennigsen; the extra-parliamentary societies, less responsible and more violent, grew in influence. The Anti-Semites gained in numbers, though not in reputation. The Conservatives, hoping to win votes, even adopted an anti-Semite clause in their programme. The general tendency among the numerous

Political bargaining.

societies of Christian Socialism, which broke up almost as quickly as they appeared, was to drift from the alliance with the ultra-Conservatives and to adopt the economic and many of the political doctrines of the Social Democrats. The *National-Socialer Verein* defended the union of Monarchy and Socialism. Meanwhile the extreme spirit of nationality was fostered by the *All-deutscher Verein*, the policy of which would quickly involve Germany in war with every other nation. More than once the feelings to which they gave expression endangered the relations of Germany and Austria-Hungary. The persecution of the Poles in Prussia naturally aroused indignation in Austria, where the Poles had for long been among the strongest elements on which the Government depended; and it was not always easy to prevent the agitation on behalf of the Germans in Bohemia from assuming a dangerous aspect.

In the disintegration of parties the Liberals suffered most. The unity of the Conservatives was preserved by social forces and the interests of agriculture; the decay of the Liberals was the result of universal suffrage. Originally the opponents of the landed interest and the nobility, they were the party of the educated middle class, of the learned, of the officials, and finance. They never succeeded in winning the support of the working men. They had identified themselves with the interests of the capitalists, and were not even faithful to their own principles. In the day of their power they showed themselves as intolerant as their opponents had been. They resorted to the help of the Government in order to stamp out the opinions with which they disagreed, and the claims of the artizans to practical equality were rejected by them, as in earlier days the claims of the middle class had been by the nobles.

The Centre alone maintained itself. Obliged by their constitution to regard equally the material interests of all classes—for they represent rich and poor, peasants and artizans—they were the natural support of the Government when it attempted to find a compromise between the clamour of opposing interests. Their own demands were generally limited to the defence of order and religion, and to some extent coincided with the wishes of the Emperor; but, as we shall see, every attempt to introduce legislation in accordance with their wishes led to a conflict with the educated opinion of the country, which was very detrimental to the authority of the Government. In the state parliaments of Bavaria, Baden, and Hesse their influence was very great. There was, moreover, a tendency for local parties to gain in numbers and influence—the Volkspartei in Würtemberg, the Anti-Semites in Hesse, and the Bauernbund (Peasants' League) in Bavaria. The last demanded that the peasants should be freed from the payment to the state, which represented the purchase price for the remission of feudal burdens. It soon lost ground, however, partly owing to personal reasons, and partly because the Centre in order to maintain their influence among the peasants adopted some features of their programme.

Another class which, seeing itself in danger from the economic changes in society, agitated for special legislation was the small retail traders of the large towns. They demanded additional taxation on the vast shops and stores, the growth of which in Berlin, Munich, and other towns seemed to threaten their interests. As the preservation of the smaller middle class seemed to be important as a bulwark against Socialism, they won the support of the Conservative and Clerical parties, and laws inspired by them were passed in Bavaria, Würtemberg, and Prussia. This *Mittelstand-politik*, as it is called, was very characteristic of the attitude of mind which was produced by the policy of Protection. Every class appealed to the Government for special laws to protect itself against the effects of the economic changes which had been brought about by the modern industrial system. Peasants and landlords, artizans and tradesmen, each formed their own league for the protection of their interests, and all looked to the state as the proper guardian of their class interests.

Mittel-stand-politik

Moral and religious policy.

After the fall of Caprivi the tendency of the German Government to revert to a strong Conservative policy in matters of religion, education, and in the treatment of political discussions became very marked. The complete alienation of the working classes from Christianity caused much natural concern, combined as it was with that indifference to religion which marks the life of the educated classes in the large towns, and especially in Berlin. A strong feeling arose that social and political dangers could only be avoided by an increase in religious life, and the Emperor gave the authority of his name to a movement which produced numerous societies for home mission work, and (at least in Berlin) led to the erection of numerous churches. Unfortunately, this movement was too often connected with political reaction, and the working classes were inclined to believe that the growth of religion was valued because it afforded an additional support to the social and political order. The situation was somewhat similar to that which existed during the last years of Frederick William IV., when the close association of religion with a Conservative policy made orthodoxy so distasteful to large sections of society. The Government, which had not taken warning by the fate of the School Bill, attempted to carry other measures of the same kind. The Emperor had returned to Bismarck's policy of joining social reform with repressive legislation. In a speech at Königsberg in November 1894, he summoned the nobles of Prussia to support him in the struggle for religion, for morality, for order, against the parties of *Umsturz*, or Revolution, and shortly afterwards an amendment of the Criminal Code, commonly called the *Umsturz Vorlage*, was introduced, containing provisions to check attempts to undermine the loyalty of the soldiers, and making it a crime punishable with three years' imprisonment to attack religion, monarchy, marriage, the family, or property by abusive expressions in such a manner as to endanger public peace. The discussion of this measure occupied most of the session of 1895; the Bill was amended by the Centre so as to make it even more strongly a measure for the defence of religion; and clauses were introduced to defend public morality, by forbidding the public exhibition of pictures or statues, or the sale of writings, which, "without being actually obscene, might rudely offend the feeling of modesty." These Clerical amendments aroused a strong feeling of indignation. It was represented that the freedom of art and literature was being endangered, and the Government was obliged to withdraw the Bill. The tendency towards a stricter censorship was shown by a proposal which was carried through the Prussian parliament for controlling the instruction given at the universities by the Privatdocenten. Some of the Conservative leaders, especially Baron von Stumm, the great manufacturer (one of Bismarck's chief advisers on industrial matters), demanded protection against the teaching of some of the professors with whose economic doctrines they did not agree; pastors who took part in the Christian-Social movement incurred the displeasure of the Government; and Professor Delbrück was summoned before a disciplinary court because, in the *Preussische Jahrbücher*,

Umsturz Vorlage.

which he edited, he had ventured to criticize the policy of the Prussian Government towards the Danes in Schleswig. All the discontent and suspicion caused by this policy broke out with greater intensity when a fresh attempt was made in 1900 to carry those clauses of the old *Umsturz Vorlage* which dealt with offences against public morality. The gross immoralities connected with prostitution in Berlin had been disclosed in the case of a murderer called Heinze in 1891; and a Bill to strengthen the criminal law on the subject was introduced but not carried. The measure continued, however, to be discussed, and in 1900 the Government proposed to incorporate with this Bill (which was known as the *Lex Heinze*) the articles from the *Umsturz Vorlage* subjecting art and literature to the control of the criminal law and police. The agitation was renewed with great energy. A *Goethe Verein* was founded to protect *Kultur*, which seemed to be in danger. In the end the obnoxious clauses were only withdrawn when the Socialists used the forms of the House to prevent business from being transacted. It was the first time that organized obstruction had appeared in the Reichstag, and it was part of the irony of the situation that the representatives of art and learning owed their victory to the Socialists, whom they had so long attacked as the great enemies of modern civilization.

Lex Heinze.

These were not the only cases in which the influence of the parties of reaction caused much discontent. There was the question of the right of combination. In nearly every state there still existed old laws forbidding political societies to unite with one another. These laws had been passed in the years immediately after the revolution of 1848, and were quite out of place under modern conditions. The object of them was to prevent a network of societies from being formed extending over large districts, and so acquiring political power. In 1895 the Prussian police used a law of 1850 as a pretext for dissolving the Socialist organization in Berlin, as had been done twenty years before. A large majority of the Reichstag demanded that an imperial law should be passed repealing these laws, and establishing the right of combination, and they refused to pass the revised Civil Code until the chancellor promised that this should be done. Instead of this course being adopted, however, special laws were introduced in most of the states, which, especially in Prussia and Saxony, while they gave the right of combination, increased the power of the police to forbid assemblies and societies. It was apparent that large and influential parties still regarded political meetings as something in themselves dangerous and demoralizing, and hence the demand of the Conservatives that women and young persons should be forbidden to attend. In Prussia a majority of the Upper House and a very large minority of the Lower House (193 to 206) voted for an amendment expressly empowering the police to break up meetings in which anarchistic, socialistic, or communistic doctrines were defended in such a manner as to be dangerous to society; the Saxon Conservatives demanded that women at least should be forbidden to attend socialistic meetings, and it remained illegal for any one under twenty-one years of age to be present at a political meeting. In consequence of the amendments in the Upper House the Prussian law was lost; and at last, in 1899, a short imperial law was carried to the effect that "societies of every kind might enter into union with one another." This was at once accepted by the chancellor; it was the time when the Navy Bill was coming on, and it was necessary to win votes. The general feeling of distrust which this prolonged controversy aroused was, however, shown by the almost contemptuous rejection in 1899 of a Bill to protect artizans who were willing to work against intimidation or violence (the *Zuchthaus Vorlage*), a vote which was the more significant as it was not so much occasioned by the actual provisions of the Bill, but was an expression of the distrust felt for the motives by which the Government was moved and the reluctance to place any further powers in their hands.

Law of combination.

In these cases the Government depended on the support of the Conservatives and Clericals, assisted sometimes by a few National Liberals. This combination of the Conservatives, moved by political and economic motives, and the Clericals, who wished to defend religion and morality, with the Prussian Government, inspired by its traditional aversion from liberty, introduced into the political situation a line of cleavage which cut across the grouping of parties on commercial questions. The result was an attempt to check by legislation the action of those moral and intellectual forces which were embodied partly in the Radical but chiefly in the Socialist party—forces which threatened to undermine the authority of Crown and Church, but were vital to the whole intellectual growth of the country. The learned classes still count for much in German life, and it is dangerous to revive that kind of intellectual discontent which prevailed when, in the 'seventies, the Governments were trying in the same way to crush the rising power of Liberalism. A generation earlier, modern thought attempted to use the whole power of the State so as to mould even the teaching of the Church; now there seemed some danger of an alliance with the Church against modern thought. Politically the power of the Church depends on universal suffrage, and so it came about more than once that an agitation among the intellectual classes was necessary in order to defeat measures inimical to liberty which secured a majority in a parliament elected by universal suffrage. There is no doubt that the restrictive policy of the Government caused much intellectual discontent. When the official teaching is that the maintenance of order and society requires restrictions on thought, and even criminal laws which are repugnant to the general feeling of the community, a moral scepticism is produced which makes a nation restless. The forces of reaction were stronger in Prussia and Saxony than in the south of Germany; and this undoubtedly strengthened the position of the southern states, for it enabled them to appear to some extent as defenders of liberty. There was therefore some increase in particularism, which during Bismarck's government nearly disappeared, and this was helped by the suspicion with which the great personal activity of the Emperor was regarded. Altogether, a good deal of disappointment and dissatisfaction existed with the management of internal affairs. Between the disintegration of parliamentary parties, the growth of Socialists and Catholics, and the increasing number of small groups, a contrast was inevitable with the state of things during the first years of the empire, when there was a strong party guiding national thought and able by the capacity of its leaders to check and assist the Government. The result, however, was, while diminishing the interest in parliamentary debate, to make the nation look with increased interest and satisfaction at the great advances made in practical affairs—commerce and industry, engineering and shipping.

Increase of Prussian autocracy.

The Emperor set himself the task of doing for the German fleet what his grandfather had done for the army. The acquisition of Heligoland enabled a new naval station to be established off the mouth of the Elbe; the completion of the canal from Kiel to the mouth of the Elbe—an old plan of Bismarck's which was begun in 1887 and completed in 1895—by enabling ships of war to pass from the Baltic to the North Sea greatly increased the strategic strength of the fleet. In 1890 a change in the organization separated the command of the fleet from the office of secretary of state, who was responsible for the representation of the Admiralty in the Reichstag, and the Emperor was brought into more direct connexion with the navy. During the first five years of the reign four line-of-battle ships were added and several armoured cruisers for the defence of commerce and colonial interests. With the year 1895 began a period of expansion abroad and great naval activity. The note was given in a speech of the Emperor's on the twenty-fifth anniversary of the foundation of the empire, in which he said, "the German empire has become a world empire." The ruling idea of this new *Welt-Politik* was that Germany could no longer remain merely a Continental power; owing to the growth of population she depended for subsistence on trade and exports; she could not maintain herself amid the rivalry of nations unless the Government was able actively to support German traders in all parts of the world. The extension of German trade and influence has, in fact, been carried out with considerable success. There was no prospect of further territory in Equatorial Africa, and the hopes of bringing about a closer union with the South African Republic were not fulfilled. On the Pacific, however, there were great gains; long-established plans for obtaining a port in China which might serve as a base for the growing trade at Tientsin were carried out at the end of 1897; the murder of two Catholic missionaries was made the pretext for landing troops in the bay of Kiao-chow; and in amends China granted the lease of some fifty square miles of territory, and also a concession for building railways. The Emperor showed his strong personal interest by sending his brother, Prince Henry, in command of a squadron to take possession of this territory, and the visit of a German prince to the Emperor of China strongly appealed to the popular imagination. The Emperor's characteristically rhetorical speeches on this occasion—particularly his identification of his brother with the "mailed fist" of Germany—excited considerable comment. In Turkey the Government, helped again by the personal interest of the Emperor, who himself visited the Sultan at Constantinople, gained important concessions for German influence and German commerce. The Turkish armies were drilled and commanded by German officers, and in 1899 a German firm gained an important concession for building a railway to Baghdad. In Brazil organized private enterprise established a considerable settlement of German emigrants, and though any political power was for the time impossible, German commerce increased greatly throughout South America.

Welt-Politik.

The "mailed fist."

Encouraged by the interest which the events in China had aroused, a very important project was laid before the Reichstag in November 1897, which would enable Germany to take a higher place among the maritime Powers. A completely new procedure was introduced. Instead of simply proposing to build a number of new ships, the Bill laid down permanently the number of ships of every kind of which the navy was to consist. They were to be completed by 1904; and the Bill also specified how often ships of each class were to be replaced. The plan would establish a normal fleet, and the Reichstag, having once assented, would lose all power of controlling the naval budget. The Bill was strongly opposed by the Radicals; the Centre was divided; but the very strong personal influence of the Emperor, supported by an agitation of the newly-formed *Flotten Verein* (an imitation of the English Navy League), so influenced public opinion that the opposition broke down. A general election was imminent, and no party dared to go to the country as the opponents of the fleet.

Naval programme, 1897.

Scarcely had the Bill been carried when a series of events took place which still more fully turned public attention to colonial affairs, and seemed to justify the action of the Government. The war between the United States and Spain showed how necessary an efficient fleet was under modern conditions, and also caused some feeling of apprehension for the future arising from the new policy of extension adopted by the United States. The Government was, however, enabled to acquire by purchase the Caroline Islands from Spain. This was hardly accomplished when events in South Africa occurred which made the nation regret that their fleet was not sufficiently strong to cope with that of Great Britain. The Government used with great address the bitter irritation against Great Britain which had become one of the most deep-seated elements in modern German life. This feeling had its origin at first in a natural reaction against the excessive admiration for English institutions which distinguished the Liberals of an older generation. This reaction was deliberately fostered during Bismarck's later years for internal reasons; for, as Great Britain was looked upon as the home of parliamentary government and Free Trade, a less favourable view might weaken German belief in doctrines and institutions adopted from that country. There also existed in Germany a curious compound of jealousy and contempt, natural in a nation the whole institutions of which centred round the army and compulsory service, for a nation whose institutions were based not on military, but on parliamentary and legal institutions. It came about that in the minds of many Germans the whole national regeneration was regarded as a liberation from British influence. This feeling was deliberately fostered by publicists and historians, and was intensified by commercial rivalry, since in the struggle for colonial expansion and trade Germans naturally came to look on Great Britain, who held the field, as their rival. The sympathy which the events of 1896 and 1899 awakened for the Boers caused all these feelings, which had long been growing, to break out in a popular agitation more widespread than any since the foundation of the empire. It was used by the Nationalist parties, in Austria as well as in Germany, to spread the conception of Pan-Germanism; the Boers as Low Germans were regarded as the representatives of Teutonic civilization, and it seemed possible that the conception might be used to bring about a closer friendship, and even alliance, with Holland. In 1896 the Emperor, by despatching a telegram of congratulation to President Kruger after the collapse of the Jameson Raid, had appeared to identify himself with the national feeling. When war broke out in 1899 it was obviously impossible to give any efficient help to the Boers, but the Government used the opportunity to make an advantageous treaty by which the possession of Samoa was transferred to Germany, and did not allow the moment to pass without using it for the very practical purpose of getting another Bill through the Reichstag by which the navy was to be nearly doubled. Some difficulties which arose regarding the exercise by the British Government of the right of search for contraband of war were also used to stimulate public feeling. The Navy Bill was introduced in January 1900. There were some criticisms of detail, but the passing of the Bill was only a matter of bargaining. Each party wished in return for its support to get some concessions from the Government. The Agrarians asked for restrictions on the importation of food; the

Anglophobia.

Pro-Boer movement.

Navy Bill, 1900.

Centre for the Lex Heinze and the repeal of the Jesuit law; the Liberals for the right of combination.

The murder of the German ambassador, Baron von Ketteler, at Peking in 1900 compelled the Government to take a leading part in the joint expedition of the Powers to China. A force of over 20,000 men was organized by voluntary enlistment from among the regular army; and the supreme command was obtained by the Emperor for Count von Waldersee, who had succeeded Moltke as chief of the staff. The Government was, however, sharply criticized for not first consulting the Reichstag in a matter involving the first military expedition since the foundation of the Empire. It was desirable in such circumstances that a younger and more vigorous statesman than Prince Hohenlohe should be placed at the head of affairs before the Reichstag met; and on 17th October he resigned, and was succeeded as Chancellor by Count von Bülow, the Foreign Secretary.

AUTHORITIES.—*Das deutsche Reich zur Zeit Bismarcks*, by HANS BLUM (1893), and ONCKEN, *Das Zeitalter des Kaiser Wilhelm*, vol. 2 (Berlin, 1890), give a connected history of the empire.—SCHULTHESS's *Europäischer Geschichtskalendar*, Nordlingen (a work similar to the *Annual Register*), is invaluable as a book of reference for recent German history; see also *Die politische Geschichte der Gegenwart*, by MÜLLER (continued by WIPPERMANN, 1871–1900). For constitutional questions see the parts dealing with Germany in MARQUARDSEN'S *Handbuch des öffentlichen Rechts der Gegenwart* (Leipzig, 1896, &c.), and LOWELL, *Governments and Parties in Continental Europe* (Longmans, 1896). For economic and statistical information the most useful work is the *Handwörterbuch der Staatswissenschaften*, edited by CONRAD and ELSTER (Jena, 1890–97, new edition, 1898, &c.); as also the *Statistisches Jahrbuch des deutschen Reichs*. For political history and party politics the reader must refer to the special works issued by the different parties as *Die National-Liberale Partei, 1867–1892* (Leipzig, 1892); *Politisches A B C-Buch*, by EUGEN RICHTER; *Conservatives Handbuch; Geschichte des Kultur-kampfes*, by MAJUNKE (Münster, 1896); *Geschichte der deutschen Social-democratie*, by F. MEHRING, Part II. (Stuttgart, 1898). See also the biographies of *Boettieher*, by EDUARD STEPHANI (Leipzig, 1887); *Roon*, by his son (Breslau, 1892); *Mallincrodt*, by OTTO PFUEFF (1892); *Forckenbeck*, by PHILIPPSEN (1898); and *Windthorst*, by KRUPP (1898), the two latter in the series called *Männer der Zeit*, and also *Windthorst*, by MENZENBACH (1891–92). For the Christian Social movement and social reform, DAWSON, *Bismarck and State Socialism* (Sonnenschein, 1891); NITTI, *Catholic Socialism;* GOYAU, *L'Allemagne religieuse* (Paris, 1898); KANNENGIESSER, *Les Allemands Catholiques.* See also the list of works appended to the article on BISMARCK. (J. W. HE.)

GERMAN LITERATURE SINCE 1870.

I. In the years immediately following the Franco-German war the conditions existing in Germany were unfavourable to literary production, and the re-establishment of the German Empire left little or no trace on the national literature. All minds were for a time engrossed by the "Kulturkampf," which broke out in 1872 between the state and the papal authority; by the financial difficulties—the so-called "Gründertum"—due to unscrupulous speculation in Berlin; and, finally, by the rapid rise of social democracy as a political force. The first volume of Karl Marx's (1818–1883) *Das Kapital*, the chief text-book of the party, had appeared in 1867. But even if these disturbing factors had been wanting, the general atmosphere of German intellectual life was not buoyant enough to inspire a literary revival. The influence of Hegel, and the various schools which had gone out from him, was still paramount, and the "historical" method, which found characteristic expression in D. F. Strauss's (1808–1874) *Der alte und der neue Glaube* (1872), had spread over all fields of intellectual activity. To many, H. Lotze's (1817–1881) compromise between science and metaphysics was a relief from the oppression of Hegelian tradition, but, in literature and art, the dominant force was still, as before the war, the philosophy of Schopenhauer; and in his *Philosophie des Unbewussten* (1869) E. von Hartmann (born 1842) endeavoured to bring pessimism into harmony with idealism.

Philosophy.

In lyric poetry the dull monotony was broken by the victory at Sedan, the singers of the Revolution of 1848 being among the first to welcome the triumph of German arms and the unification of the nation. F. Freiligrath (1810–1876), E. Geibel (1815–1884), O. von Redwitz (1823–1891), and even G. Herwegh (1817–1875) regarded the establishment of the empire with enthusiasm; but at the same time these older revolutionists could ill conceal a certain disappointment: the united Germany of 1871 was not what they had dreamed of in their youth, when all hopes were set on the Frankfort Parliament. Geibel, whose *Heroldsrufe* appeared in 1871, was a favourite poet with all classes, and his shallow, musical verses are characteristic of the period.

Lyric of the war.

The group of writers whom Maximilian II. of Bavaria gathered round him in Munich, between 1852 and 1860, and of whom Geibel was the centre, gave the tone to German letters at the beginning of the new era. J. V. von Scheffel (1826–1886), author of *Der Trompeter von Säckingen* (1854), was the undisputed master of the story in verse, a form of poetry particularly associated with this school. *Till Eulenspiegel redivivus* (1874), J. Wolff's (born 1834) first verse-romance, was followed by *Der Rattenfänger von Hameln* (1875), *Der wilde Jäger* (1877), and *Tannhäuser* (1880)—the sentiment of the last-mentioned poem forming a striking contrast to the pessimism and satire of *Der neue Tannhäuser* (1869), an epic by E. Grisebach (born 1845). With Wolff it is usual to class R. Baumbach (born 1841), author of a number of charming tales in verse, such as *Zlatorog* (1877) and *Frau Holde* (1880). *Die Völkerwanderung* (1866–68) is an ambitious epic by H. Lingg (born 1820), while *Dreizehnlinden* (1878), by a Catholic poet, F. W. Weber (1813–1894), depicts the struggle between Christianity and Saxon heathendom in the early centuries of German history. R. Hamerling (1830–1889) also gave new vitality to the epic in his grandiose poems, *Ahasver in Rom* (1860) and *Der König von Sion* (1869). Among the older lyric poets of the Munich circle, F. von Bodenstedt (1819–1894), the author of *Mirza Schaffy*, shared Geibel's popularity, while the pessimism of the age is deeply engrained in the verse of H. Lorm (born 1821), H. Leuthold (1827–1879), and F. von Schmid (pseudonym "Dranmor," 1823–1888).

The Munich School.

The most important writer of the group is Paul Heyse (born 1830), who made his reputation with a volume of "Novellen" as far back as 1855. Since then Heyse has written more than a hundred short stories, all of which are characterized, if not by invariable truth to nature, at least by beauty of form and grace of style. In 1873 Heyse published his first novel, *Kinder der Welt*, which is one of the representative works of the period, reflecting admirably the pessimism and religious scepticism on the one hand, and on the other the jubilant hopefulness of the German capital after the war. *Im Paradiese* (1875), a romance of art-life in Munich, was followed in 1876 by *Der Roman einer Stiftsdame.* Heyse's recent novels, such as *Merlin* (1892) and *Über allen Gipfeln* (1895), continue the conflict which this author has always carried on against modern realism, but they are inferior to *Kinder der Welt.* As a lyric poet Heyse also occupies an important place, but his dramas have failed to maintain a hold upon the stage. The historical plays of Martin Greif (born 1839) have met with a similar fate, Greif's talents being lyric rather than dramatic.

P. Heyse.

The novel continued to be what it was before the war, the most vigorous form of German literature, but the novelists who were popular in 1871 were almost all past middle age. H. Laube (1806–1884) and K. Gutzkow (1811–1878) were still writing fiction, and B. Auerbach (1812–1882) expressed his enthusiasm for German unity in a novel called *Waldfried* (1874). Fritz Reuter's (1810–1874) masterly "plattdeutsch" stories remained universal favourites, while another North German, Theodor Storm (1817–1888), in his *Chroniknovellen* (1877–1886), put the crown to his work as a prose-writer. Storm and Heyse were acknowledged masters of the "Novelle" in an age which was not ripe for the manlier art of Gottfried Keller. The most widely read novelists at this time were Spielhagen and Freytag. Ten years before the war Friedrich Spielhagen, who was born in 1829, had established himself in the first rank of

The novel.

German novelists, and in 1876, as a worthy successor to *Problematische Naturen* (1860) and *In Reih' und Glied* (1866), he published *Sturmflut*, a novel in which the financial instability of Berlin was brought into parallelism with a great storm on the Baltic coasts. Among the best of Spielhagen's later books are *Plattland* (1878), *Quisisana* (1879), *Angela* (1881), *Noblesse oblige* (1888), *Sonntagskind* (1893), and *Freigeboren* (1900), but they are not to be compared with the masterpieces of his first period.

Historical fiction.

In 1872 Gustav Freytag (1816–1884) commenced the most ambitious work which the Franco-German war inspired, *Die Ahnen* (1872–81), a cycle of romances which follows the fortunes of a German family from prehistoric times to the Revolution of 1848. Generally speaking, however, the historical novel was a weak feature of the literature of this period; the example set by Scheffel in *Ekkehard* (1857) found no worthy imitators. G. Ebers (1837–1898) made the antiquarian novel fashionable with *Eine ägyptische Königstochter* (1864), which he followed up with similar works of small literary value; F. Dahn's (born 1834) historical romances, especially *Ein Kampf um Rom* (1876), found many readers, though Dahn is a scholar and historian rather than an artist; and other historical novelists, such as G. Taylor (pseudonym for A. Hausrath, born 1837) and E. Eckstein (born 1845), were hardly more successful than Dahn or Ebers. An original figure in the literature of this period is W. Jordan (born 1819), whose alliterative epic, *Die Nibelunge* (1867–1874), has a certain rugged grandeur. But although neither poetry nor fiction showed much promise, Germany was in those years making solid contributions to her intellectual possessions in other fields.

Historians.

L. von Ranke (1795–1886), still the dominant force in German historical science, published between 1881 and 1888 nine volumes of his crowning work, *Weltgeschichte;* while H. von Sybel (1817–1895) described *Die Begründung des deutschen Reichs durch Wilhelm I.* (1889–1894). But the historian who identified himself most completely with the new order of things, whereby Prussia assumed the leading rôle in the united empire, was H. von Treitschke (1834–1896); the trenchant vigour of Treitschke's lectures and of his *Deutsche Geschichte im neunzehnten Jahrhundert* (1879–1894) made him one of the most influential teachers of the younger generation. Hardly less important as an educative force was the Swiss historian, J. Burckhardt (1818–1897), whose masterly *Kultur der Renaissance in Italien* appeared in 1860. But the determining factor in this essentially unliterary era was Bismarck (1815–1898), the record of whose life and work is to be found in his *Reden* (16 vols., 1885–1891), his *Gesammelte Werke* (4 vols., 1890), and *Politische Briefe* (3 vols., 1890), as well as in the personal records of H. Kohl and M. Busch.

II. Towards the end of the first decade of the period under consideration signs of a change became visible.

Philosophy and criticism.

The philosophy of Schopenhauer, it is true, still dominated the intellectual life of the nation, but natural science and materialism had many adherents, and were appreciably weakening the influence of Schopenhauer. At the universities Hegelianism was giving way to a new movement, the motto of which was "Zurück zu Kant," and on the basis of this movement German theology, as represented by A. Ritschl (1822–1889) and his disciples—notably A. Harnack (born 1851)—entered upon a new period of development. Of the older Hegelians, Kuno Fischer (born 1824) was the most eminent, and his *Geschichte der neueren Philosophie*—especially in its latest edition, 1889–1901—is one of the outstanding achievements of recent German philosophy. People now began to have leisure to revise their opinions of the German classical poets. Schiller, it was found, no longer occupied the place that had once been his, and a number of (mostly unfinished) biographies by J. Minor, O. Brahm, R. Weltrich, and O. Harnack endeavoured to form a conclusive estimate of that writer. On the other hand, a marked change came over the nation's attitude towards Goethe, a poet to whom neither the era of Hegel nor that of Schopenhauer had been favourable. Indications of a warmer appreciation of Goethe were the lectures on the poet delivered by Herman Grimm (1828–1901) in 1877, the foundation of the Goethe Archive and the Goethe Society at Weimar in 1885, and the issue of a monumental edition of the poet's works (1887 ff.). The increased attention which has been paid to Goethe in recent years has also resulted in a large number of popular biographies, the best of which are by R. M. Meyer (published 1894) and A. Bielschowsky (vol. i., 1896). In general criticism, the chief writer between 1870 and 1880 was Karl Hillebrand (1829–1884), while, at the universities, Wilhelm Scherer (1841–1886), whose masterly *Geschichte der deutschen Litteratur* appeared in 1883, had and still has many followers.

The drama.

In the summer of 1876 Richard Wagner's (1813–1883) long struggle for his art ended with the inauguration of the "Festspielhaus" at Bayreuth and the first complete representation of *Der Ring des Nibelungen; Tristan und Isolde*, it may be noted, was performed in 1865, *Die Meistersinger von Nürnberg* in 1868, while his last work, *Parsifal*, was produced in 1882. Since about 1880 Wagner's music-dramas, which give artistic expression to the pessimism of the time, have held the chief place in the repertory of the German theatres. To Wagner on the one hand, and to the careful and artistic work of the Court Theatre of Meiningen on the other, was due the revival of German dramatic art which began in the 'eighties. The classical iambic tragedy was cultivated by the Munich School, by A. Wilbrandt (born 1837), whose *Arria und Messalina* appeared in 1874, and A. Lindner (1831–1888), author of *Brutus und Collatinus* (1867) and *Die Bluthochzeit* (1871); and it was also characteristic of the time that Halm was popular, while Hebbel and Grillparzer were neglected. Superior to Wilbrandt's iambic tragedies were his comedies, *Die Maler* (1872), *Jugendliebe* (1873), and his dramas of a later period, *Die Tochter des Herrn Fabricius* (1883) and *Der Meister von Palmyra* (1889). The really popular playwrights at this date, however, were R. Benedix (1811–1873) and his successors, A. L'Arronge (born 1833), G. von Moser (born 1825), F. von Schönthan (born 1849), and O. Blumenthal (born 1852); and social dramas on French models, such as P. Lindau's (born 1839) *Ein Erfolg* (1874) and *Gräfin Lea* (1879), were more to the taste of the public than the verse-dramas of H. Kruse (1818–1902), of the Austrian F. Nissel (1831–1893), or a tragedy like A. Fitger's (born 1840) *Die Hexe* (1876). Apart from Wagner, the only German dramatist of importance between 1870 and 1880 was Ludwig Anzengruber (1839–1889), an Austrian, whose first play, *Der Pfarrer von Kirchfeld* (1870), reflected the liberal ideas that were then in the air; and this was followed by a series of masterly dramas, mostly in dialect, such as *Der Meineidbauer* (1871), *Die Kreuzelschreiber* (1872), *Der G'wissenswurm* (1875), *Der Doppelselbstmord* (1876), and *Das vierte Gebot* (1878).

L. Anzengruber.

Compared with the peasant-literature of the middle of the century, Anzengruber marks an advance, in so far as his peasants are less violently adapted to artificial literary ideals: in this respect he is to some extent a forerunner of the realistic school. The North German theatre had no writer who could be compared with Anzengruber, but in 1882 hopes were raised by Ernst von Wildenbruch's historical tragedy, *Die Karolinger.* Wildenbruch, who was born at Beirut in Syria in 1845, first attracted attention by two "Heldenlieder," *Vionville* (1874) and *Sedan* (1875), on the war of 1870–71, in which he had himself taken part. His dramas, *Die Karolinger*, *Harold* (1882), *Der Menonit* (1882), *Christoph Marlowe* (1884), and *Das neue Gebot* (1886), were followed in 1888 by *Die Quitzows*, with which the author touched the height of his popularity. This play was the first of a series of dramas, including *Der Generalfeldoberst* (1889), *Der neue Herr* (1891), *Der Junge von Hennersdorf* (1896), on subjects borrowed from the history of Prussia. Wildenbruch has also written *Die Haubenlerche* (1891), a realistic drama of modern life, and, more recently, *Heinrich und Heinrichs Geschlecht* (1896), a double drama on Emperor Heinrich IV., and *Die Tochter des Erasmus* (1900). As a dramatist Wildenbruch combines a keen sense of stage effect with strong patriotism and a somewhat effusive pathos, but higher dramatic or poetic qualities are only sparingly present in his work.

E. von Wildenbruch.

The writers of fiction, who took a leading place before the realistic movement set in, were, like their predecessors, influenced by mid-century traditions, but, in the novel as in the drama, the younger generation was beginning to make more exacting artistic demands. Since 1869 the North German, A. Wilbrandt, whose work as a dramatist has already been mentioned, had been known to the public as a novelist, but *Adams Söhne*, his first book worthy of note, only appeared in 1892. It was succeeded by *Hermann Ifinger* (1892), *Der Dornenweg* (1894), *Die Osterinsel* (1895), *Die Rothenburger* (1895), and *Hildegard Mahlmann* (1897), novels which, although old-fashioned in style and technique, discussed themes of actual interest, such as Böcklin's art and Nietzsche's philosophy. This somewhat factitious interest in Wilbrandt's books is wanting in the novels of Wilhelm Jensen (born 1837); it is unfortunate, however, that the delicate poetic talent revealed in some of Jensen's earlier "Novellen" is entirely lost amidst the diffuseness and formlessness of the many volumes he has published since 1866. A novelist whose style is more in accordance with modern taste is Hans Hopfen (born 1835), while the humourist of the group is Wilhelm Raabe (born 1831), who wrote his early work under the pseudonym of "Jakob Corvinus." Raabe combines with a sentimentalism not unlike Jean Paul's a very modern pessimism, and has a clearer sense for the actual aspect of what he describes than either Wilbrandt or Jensen; his most characteristic novels, however, such as *Der Hungerpastor* (1865) and *Abu Telfan* (1867), appeared before the period under discussion. Other humorous writers are H. Seidel (born 1842), who since 1871 has published a series of charming sketches (*Leberecht Hühnchen*, 1880), which are true to the best traditions of German humour, and W. Busch (born 1832), author of *Max und Moritz* (1858), *Die fromme Helene* (1871). Hans Hoffmann (born 1848) is seen to more advantage in the *Geschichten aus Hinterpommern* (1891), in which he is a disciple of Storm and Reuter, than in his ambitious novels on Prussian history. A humorist who stands somewhat alone is the Hegelian professor of æsthetics, F. T. Vischer (1807–1887), who in 1878 brought out an admirable satirical novel, *Auch Einer*, and in 1882 his collected lyrics as *Lyrische Gänge.* Younger writers of fiction, whose style has more in common with the group of novelists under consideration than with the realistic school presently to be discussed, are Ernst von Wildenbruch, E. Wichert (1831–1902), A. Stern (born 1835), Isolde Kurz (born 1853), and Ricarda Huch (born 1864). The two most eminent Austrian novelists of the period are Marie von Ebner-Eschenbach (born 1830) and Ferdinand von Saar (born 1833). The former of these wrote in 1876 an excellent novel, *Bozena*, but her "Novellen" first made her name known outside Austria; the genial humour and the light ironical touch of *Neue Erzählungen* (1881), *Dorf und Schlossgeschichten* (1883)—above all, of the excellent story, *Zwei Comtessen* (1885)—are unique of their kind. Frau von Ebner-Eschenbach is also the author of several longer novels, *Das Gemeindekind* (1887), *Unsühnbar* (1890), *Glaubenslos?* (1893), and a collection of subtle *Aphorismen* (1880); she is unquestionably the most gifted woman writer in recent German literature. Ferdinand von Saar has written comparatively little—a few dramas, several volumes of short stories (*Novellen aus Oesterreich*, 1876; *Herbstreigen*, 1897), a handful of *Gedichte* (1882), and *Wiener Elegien* (1892), but his delicacy, his lightness of touch, and the deep undercurrent of pessimism in all his work place him in the front rank of modern poets and prose-writers. The story in dialect bulks largely in recent Austrian literature, a typical novelist of this class being Peter Rosegger (born 1843 in Styria). Rosegger's *Schriften des Waldschulmeisters* appeared in 1875, and have been followed by a large number of similar stories, all sentimental in tone. An Austrian, too, is K. E. Franzos (born 1848), whose early novels and sketches describe Galician life (*Aus Halbasien*, 1876; *Die Juden von Barnow*, 1877), while L. von Sacher-Masoch (1835–1895) has written a series of vivid *Galizische Geschichten* (1876–81) and *Judengeschichten* (1878). But the two masters of German prose at this epoch, Gottfried Keller and Konrad Ferdinand Meyer, were neither Austrians nor Germans.

The novel.

Austrian writers.

Gottfried Keller was born at Zurich in 1819, and died there in 1890. His ambition was to be an artist, and, with this object, he spent two years in Munich; in 1848 a bursary allowed him to study at the University of Heidelberg, and two years later he went to Berlin with a view to becoming a dramatist. From 1861 to 1876 Keller was town-clerk in his native town. Meanwhile, in 1846 and again in 1851, he published volumes of poetry, and in 1854, after a protracted delay, his fine autobiographical novel, *Der grüne Heinrich.* This work was followed by a volume of short stories, entitled *Die Leute von Seldwyla* (1856). Although both *Der grüne Heinrich* and the "Novellen"—above all, such stories as *Romeo und Julia auf dem Dorfe* and *Die drei gerechten Kammmacher*—were unrivalled in the literature of their time, Keller's importance was not generally recognized until the appearance of a second edition and an additional volume (1874) of *Die Leute von Seldwyla.* In 1872 he published a cycle of *Sieben Legenden*, and in 1879–80 a revised edition of *Der grüne Heinrich.* The *Züricher Novellen*, including the masterpieces, *Der Landvogt von Greifensee* and *Das Fähnlein der sieben Aufrechten*, appeared in 1878, *Das Sinngedicht* in 1882, and a less successful novel, *Martin Salander*, in 1886. Original and inspired although much of Keller's lyric poetry is, his genius could only move at ease in prose. He is, without question, the most eminent German novelist of the century. Of all modern German writers, he alone was endowed with that *naïveté* which Schiller regarded as characteristic of the highest form of genius. (*Cf.* J. Baechtold, *Gottfried Kellers Leben*, 3 vols., Berlin, 1894–97.)

G. Keller.

K. F. Meyer (1825–1898), who turned to literature comparatively late in life, was also a native of Zurich. Two volumes of verse, which appeared in 1864 and 1871, attracted little attention, but his epics, *Huttens letzte Tage* (1871) and *Engelberg* (1872), were widely read; and these were followed by the novels on which his reputation rests—*Das Amulet* (1873), *Jürg Jenatsch* (1876), *Der Heilige* (1880), *Plautus im Nonnenkloster* (1882), *Die Hochzeit des Mönchs* (1884), *Die Versuchung des Pescara* (1887), *Angela Borgia* (1890). In the choice of his subjects Meyer shows a preference for the virile personalities of the Renaissance, whom he describes with an objectivity unusual in German writers; above all, his novels are masterpieces in form and style. (*Cf.* A. Frey, *K. F. Meyer*, Stuttgart, 1900.)

K. F. Meyer.

III. The last fifteen years of the 19th century were distinguished in Germany by a remarkable literary activity. Since about 1885 Berlin has unmistakably asserted itself as the intellectual and artistic metropolis, and the leadership in literature has passed into the hands of a new generation of writers, who have grown up as citizens of the empire. An all-important condition, however, for any healthy revival of literature in Germany was that it should be freed from the clogging elements of mid-century tradition—above all, from the levelling influence of Hegelianism and the collective ideals of socialism. The liberator from tradition, the writer who embodies most completely the spirit of the period, is Friedrich Nietzsche.

F. W. Nietzsche. Friedrich Wilhelm Nietzsche was born at Röcken, near Lützen, on 15th October 1844. He was educated at Pforta, and subsequently studied classical philology at Bonn and Leipzig. In 1870 Nietzsche was appointed professor of classical literature at Basel, but in 1879 was obliged to resign this position owing to ill-health. The next ten years were spent partly in Italy, partly at high altitudes in Switzerland, until in 1889 he became insane. He died at Weimar on 25th August 1900. *Die Geburt der Tragödie aus dem Geiste der Musik* (1872), Nietzsche's first book, was written under the influence of Schopenhauer and Wagner, and discussed the Dionysiac origin of the Greek drama. In the *Unzeitgemässen Betrachtungen* (4 vols., 1873-76) he laid, in a trenchant, polemical style, a foundation for the new ideas of the time. The first of these *Betrachtungen* was an attack on Strauss's *Der alte und der neue Glaube;* the second gave definite form to Nietzsche's attack on the Hegelian ideals of a "historical" culture. The third *Betrachtung, Schopenhauer als Erzieher*, expressed the writer's indebtedness and that of his time to the great thinker of the previous generation; while the last, devoted to his friend and master, Richard Wagner, was written at a time when Nietzsche was already struggling to free himself from Wagner's influence. The writings of the next period of Nietzsche's life, *Menschliches, Allzumenschliches* (1878–1880), *Morgenröte* (1881), and *Die fröhliche Wissenschaft* (1882), show his philosophic ideas in the process of crystallization; these books represent a preliminary, positive stage, in which their author was casting aside traditional prejudices. The full development of his thought is to be found in *Also sprach Zarathustra* (1883-91)—the most original philosophic and poetic masterpiece of modern German literature—in *Jenseits von Gut und Böse* (1886), and *Zur Genealogie der Moral* (1887). Finally, *Der Fall Wagner* (1888) and *Nietzsche contra Wagner* (1889), gave full expression to the breach between Nietzsche and Wagner. Of a comprehensive work, *Der Wille zur Macht, Versuch einer Umwertung aller Werte*, which was intended to contain a summary of his whole philosophy, only fragments were completed, which have been published in posthumous volumes. So far as it is possible to speak at present, Nietzsche represents the final stage of the revolt against Hegelianism. Individualism here takes the place of collectivism, and pessimism gives way to a vigorous optimism. The individual, not the race; the "Herrenmensch," not the slave; self-assertion, not self-less renunciation—these are the chief ideas round which Nietzsche's ethics turn. Above all, he looks forward to the human race emerging from an effete culture, and re-establishing itself on a new basis, in harmony with primitive instincts. Nietzsche follows in Schopenhauer's footsteps by being not only a philosopher, but also a stylist; his musical language and clear, finely balanced sentences are a marked advance on the superficiality and clumsiness that have lain heavy on German prose since the days of "Young Germany." (*Cf.* E. Forster-Nietzsche, *Das Leben Friedrich Nietzsche's*, I.-II., Leipzig, 1895-97; H. Lichtenberger, *La Philosophie de Nietzsche*, Paris, 1898; T. Ziegler, *Friedrich Nietzsche*, Berlin, 1900.)

The full import of this individualistic philosophy—which was to some extent foreshadowed by a work like *Der Wert des Lebens* (1865), by E. Dühring (born 1833)—was not understood until Nietzsche himself could no longer appreciate his recognition; but the antagonism which he expressed to conventional ideals of culture early met with an enthusiastic response. The influence of the *Unzeitgemässen Betrachtungen* is to be seen in J. Langbehn's *Rembrandt als Erzieher*, a book which, appearing in 1890, was for some years extraordinarily popular. Under the auspices of realism, which had taken root not only in France, but also in Russia and Scandinavia, the German people began to take a more serious interest in literature. The inspirers of the German movement were Flaubert, the brothers Goncourt, Zola and Maupassant, Tolstoi and Dostoieffski, while, as regards the drama, the chief stimulus came from Norway; plays by both Björnson and Ibsen were seen on the German stage before 1880. The new movement was accompanied by a corresponding change in the spirit of German criticism, which is to be observed in the work of O. Brahm (born 1856), P. Schlenther (born 1854)—both of whom studied under Wilhelm Scherer—and the brothers Heinrich and Julius Hart (born 1855 and 1859). M. G. Conrad (born 1846), K. Bleibtreu (born 1859), and Arno Holz (born 1863) formulated the principles of German realism, while, under the guidance of the Viennese critic, Hermann Bahr (born 1862), contemporary Austrian literature at an early date abandoned realism in favour of symbolism and decadence. Max Nordau (born 1849) has written several volumes of vigorous and independent criticism, while, of the older writers, Spielhagen and Fontane welcomed every new development with encouragement. The Danish critic, Georg Brandes, who in his own literature created a literary school on the basis of realism, has also exerted very considerable influence on recent German criticism.

The realistic movement. Criticism.

Fiction. The new school in German fiction virtually began with the novels of a writer who was well known as poet and journalist long before the Franco-German war; in 1878 Theodor Fontane (1819–1898) brought out his first romance, *Vor dem Sturm*, and this was followed by several other more or less successful stories, such as *Grete Minde* (1880) and *Schach von Wuthenow* (1883). Fontane's realism was not, however, pronounced until he wrote *L'Adultera* (1882) and *Graf Petöfy* (1884). In the following years appeared *Irrungen, Wirrungen* (1887), *Stine* (1890), *Frau Jenny Treibel* (1892), *Effi Briest* (1895), and *Der Stechlin* (1898). *Effi Briest*, one of the masterpieces of modern fiction, marks the culminating point of Fontane's work. The strictly realistic novels of the period were written by H. Conradi (1862–1890), Max Kretzer (born 1854), M. G. Conrad, H. Heiberg (born 1840), K. Bleibtreu, K. Alberti (born 1862), and H. Sudermann. In his early work, *Meister Timpe* (1888), Kretzer gave promise of being the leading German realist, but his subsequent books were disappointing. A want of stability was characteristic, however, of the whole movement in Germany; the idealistic trend of the German mind proved ill adapted for the uncompromising realism of the French writers, and the German adherents of the school ultimately sought to escape from the consequences of their theories—Kretzer, for example, in the supernaturalism of his novel, *Das Gesicht Christi* (1897), Hauptmann in *Hanneles Himmelfahrt* (1893) and *Die versunkene Glocke* (1896). Even Sudermann, whose *Frau Sorge* (1887), *Die Geschwister* (1888), *Der Katzensteg* (1889), and the brilliant, though sensational romance, *Es war* (1894), are among the best novels of this period, has never been consistently realistic. Novelists whose work, although popular, has little abiding value, are T. H. Pantenius (born 1843), E. von Wolzogen (born 1855), J. C. Heers (born 1859), G. von Ompteda (born 1863), and F. Holländer (born 1867). Of the large number of women engaged in writing fiction, the most distinguished are—besides Isolde Kurz and Ricarda Huch, already mentioned—I. Frapan (born 1852), G. Reuter (born 1859), Clara Viebig (born 1860), and Helene Böhlau (born 1859). The last-mentioned is the author, amongst other works, of an admirable story of Munich art-life, *Der Rangierbahnhof* (1896), *Ratsmädelgeschichten* (1888–1897), and *Das Recht der Mutter* (1897).

At no period in Germany were literature and the theatre in such close touch as at the end of the 19th and opening of the 20th centuries: more than ever before, the theatre became the arena in which all literary battles were fought out. Since about 1875 the German theatre and German acting had undergone a steady improvement, and E. von Wildenbruch has already been mentioned as a pioneer of the new drama. With Wildenbruch is to be associated Richard Voss (born 1851), who, in such plays as *Alexandra* (1888), *Eva* (1889), and *Die neue Zeit* (1891), stands nearer the younger writers than in his verse tragedy, *Luigia San Felice* (1882). But, as far as the drama is concerned, the new movement did not set in definitely until the end of 1889. In October of that year G. Hauptmann's play, *Vor Sonnenaufgang*, was produced on the recently founded "Freie Bühne" in Berlin; and a month later *Die Ehre*, by H. Sudermann, met with a more enthusiastic reception than had fallen to the lot of a German play for many years.

The drama.

Gerhart Hauptmann, who was born in 1862, at Salzbrunn in Silesia, is the most original modern German writer. His earliest work was an epic, *Promethidenlos* (1885), written in the style popular at the middle of the century; and in 1889 and 1890 his two first social dramas, *Vor Sonnenaufgang* and *Das Friedensfest*—both of which show the influence of Holz's realistic theories—were performed. They were followed in 1891 by *Einsame Menschen*, for which Ibsen's later plays served as models. Hauptmann's genius found a more congenial subject in *Die Weber* (1892)—originally in Silesian dialect as *De Waber*—a powerful play on the sufferings of the Silesian weavers in 1844. Slighter pieces were *College Crampton* (1892), an admirable study of an artist fallen upon evil days, and a "thieves' comedy," *Der Biberpelz* (1893). In 1893 Hauptmann also brought out another work which attracted general attention, *Hanneles Himmelfahrt*, in which a sordid realism is contrasted with the poetic mysticism of a child's dream. *Florian Geyer* (1895) is a tragedy of the 16th century, but on so large a scale and so historically realistic that it found little favour on the stage. Most popular of all Hauptmann's works is the allegorical dramatic poem, *Die versunkene Glocke* (1896), which did not, however, afford his peculiar genius the same scope as the plays of actual life, and to this form of drama he returned in his next work, *Fuhrmann Henschel* (1898), perhaps the finest tragedy that the German realistic movement has produced. A humorous poetic fantasy, *Schluck und Jau*, appeared in 1900, *Michael Kramer* also in 1900, and in the following year *Der rote Hahn*, a sequel to *Der Biberpelz*. (*Cf.* P. Schlenther, *Gerhart Hauptmann*, Berlin, 1898). As a dramatist, Hermann Sudermann has been more influenced than Hauptmann by the traditions of the German theatre. A native of East Prussia, where he was born in 1857, Sudermann passed through a severe apprenticeship to literature before *Frau Sorge* and *Die Ehre* brought him fame. The popularity of *Die Ehre* was due partly to its satire on conventional ideas of honour, partly to the realism with which the stock figures of the "bürgerliche Drama" were described. *Sodoms Ende* (1891), Sudermann's next play, although it met with less success, showed a marked advance in dramatic construction, while *Heimat* (1893), the theme of which is similar to that of *Die Ehre*, carried its author's reputation beyond the boundaries of Germany. Since then Sudermann has added to his dramas of contemporary life *Schmetterlingsschlacht* (1895), *Das Glück im Winkel* (1896), *Johannisfeuer* (1900), and *Es lebe das Leben!* (1902). Although a keen observer, and never deficient in interesting ideas, Sudermann is, in the first instance, a practical playwright, and the theatrical element in his work occasionally overshadows its finer literary qualities. In the one-act plays, grouped under the titles *Morituri* (1896), in *Johannes* (1898), and *Die drei Reihersfedern* (1899), Sudermann has abandoned the drama of modern life for fields in which he is less at home; most important of these is the second, a prose tragedy on John the Baptist, in which the psychological conflict is treated with a refinement that recalls Hebbel. (*Cf.* W. Kawerau, *Hermann Sudermann*, Magdeburg, 1897).

G. Hauptmann.

H. Sudermann.

Since the production of *Die Ehre*, the drama has occupied the foreground of interest in Germany. It is true that the permanent repertory of the German theatre has, so far, been but little enriched by the activity in this form of literature, but it is at least a healthy sign that German playwrights are unwilling to rest content with their successes, and are constantly experimenting with new forms. Besides Hauptmann and Sudermann, the most talented dramatists of the present day are Max Halbe (born 1865), whose *Jugend* (1893) and *Mutter Erde* (1897), are, however, better than any plays he has since published; O. E. Hartleben (born 1864), author of *Hanna Jagert* (1893), *Rosenmontag* (1900), and other plays; W. Kirchbach (born 1857); and G. Hirschfeld (born 1873). The most consistently realistic dramatist is Johannes Schlaf (born 1862), whose first drama, *Familie Selicke* (1889), written in collaboration with Arno Holz, is typical of the movement. E. Rosmer (pseudonym for Elsa Bernstein, born 1866) has written, besides several realistic pieces, a drama in verse, *Königskinder* (1895), which may be compared with Hauptmann's *Versunkene Glocke*. A lighter vein is exemplified by the graceful comedies (*Der Talisman*, 1893; *Jugendfreunde*, 1897, &c.) of Ludwig Fulda (born 1862); by the plays of Max Dreyer (born 1862), especially *Der Probekandidat* (1899), and of Otto Ernst (pseudonym for O. E. Schmidt, born 1862). In Austria the drama still retains the specifically national character it has possessed throughout the century. The most eminent writers for the stage here are Arthur Schnitzler (born 1862), whose *Anatol* (1893) and *Liebelei* (1896) show an almost French lightness of touch; Hermann Bahr and Philipp Langmann (born 1862); while J. J. David (born 1859), best known as a novelist, has also written plays. Lastly, Hugo von Hofmannsthal's (born 1874) *Theater in Versen* (1899) reveals a poetic talent of extraordinary delicacy.

The most characteristic expression of German literature in every period is to be found in the lyric. The present epoch is no exception, although, apart from Liliencron, it is not possible to point to a single poet of the first order. But, regarded as a whole, the modern German lyric shows a remarkable variety of new tones and pregnant poetic ideas; it has been more influenced by the individualism and optimism of Nietzsche—himself a lyric poet of considerable gifts—than has either novel or drama. Detlev von Liliencron, who, born in 1844, belongs to the older generation, was the first to break with the traditions of the German lyric as handed down from the Romantic epoch; in his *Adjutantenritte* (1883) he opposed to the melancholy and sentimentality of the Munich school a vigorous and healthy delight in life. While the lyric of Keller, Meyer, Saar, the Prince of Schönaich-Carolath (born 1852), Isolde Kurz, and Ricarda Huch is essentially conservative in character, A. Holz, J. Schlaf, and W. Arent (born 1864) made, to some extent under the influence of Walt Whitman, a complete break with the past. Since the appearance of Arent's lyric anthology, *Moderne Dichtercharaktere*, in 1885, the number of essentially modern poets has greatly increased; among the more characteristic are Richard Dehmel (born 1863), K. Henckell (born 1864), J. H. Mackay (born 1864, at Greenock), G. Falke (born 1853), F. Avenarius (born 1856), L. Jacobowski (1868–1900), F. Evers (born 1871), F. Dörmann (born 1870), and K. Busse (born 1872). The latest development of the German lyric—a return to the mystic and symbolic—is to be seen in the work of Stefan George (born 1865). Epic poetry, although little in harmony with the spirit of the time, is not altogether neglected; the brothers Hart have published the first volumes of *Das Lied der Menschheit* (1887 ff.), an epic planned on an ambitious scale; and in Austria Marie delle Grazie (born 1864) has followed in Hamerling's footsteps with *Robespierre* (1894), an epic in two volumes. Lastly, the extraordinary popularity of the *cabaret*, or so-called "Ueberbrettl," in recent years has not been without some effect on literature. Particularly associated with this movement are E. von Wolzogen (born 1885) and O. J. Bierbaum (born 1865), and it is significant that a collection of Bierbaum's lyrics (*Irrgarten der Liebe*, 1901)

The modern lyric.

has been the most popular volume of poetry published in Germany since the days of Bodenstedt and Geibel.

Authorities.—T. Ziegler. *Die geistigen und socialen Strömungen des neunzehnten Jahrhunderts*, 2nd edition. Berlin, 1901. —R. M. Meyer. *Die deutsche Litteratur des neunzehnten Jahrhunderts*, 2nd edition. Berlin, 1900.—A. Bartels. *Die deutsche Dichtung der Gegenwart*, 4th edition. Leipzig, 1901. —A. von Hanstein. *Das jüngste Deutschland*, 2nd edition. Leipzig, 1901.—B. Litzmann. *Das deutsche Drama in der litterarischen Bewegungen der Gegenwart*, 4th edition. Hamburg, 1887.—K. Francke. *German Literature as determined by Social Forces*, 4th edition. New York, 1901.—J. G. Robertson. *History of German Literature.* Edinburgh, 1902. (J. G. R.)

Gérôme, Jean Léon (1824– ——), French painter, was born 11th May 1824 at Vesoul (Haute-Saône). He went to Paris in 1841 and worked under Paul Delaroche, whom he accompanied to Italy (1844–45). On his return he exhibited "The Cock-fight," which gained him a third-class medal in the Salon of 1847. "The Virgin with Christ and St John" and "Anacreon, Bacchus, and Cupid" took a second-class medal in 1848. He exhibited "Bacchus and Love, Drunk," a "Greek Interior," and "Souvenir d'Italie," in 1851; "Pæstum" (1852); and "An Idyll" (1853). In 1854 Gérôme made a journey to Turkey and the shores of the Danube, and in 1857 visited Egypt. To the exhibition of 1855 he contributed a "Pifferaro," a "Shepherd," "A Russian Concert," and a large historical canvas, "The Age of Augustus and the Birth of Christ." The last was somewhat confused in effect, but in recognition of its consummate ability the State purchased it. Gérôme's reputation was greatly enhanced at the Salon of 1857 by a collection of works of a more popular kind: the "Duel: after a Masquerade" (see Plate), "Egyptian Recruits crossing the Desert," "Memnon and Sesostris," and "Camels Watering," the drawing of which was criticized by Edmond About. In "Cæsar" (1859) Gérôme tried to return to a severer class of work, but the picture failed to interest the public. "Phryne before the Areopagus," "Le Roi Candaule," and "Socrates finding Alcibiades in the House of Aspasia" (1861), gave rise to some scandal by reason of the subjects selected by the painter, and brought down on him the bitter attacks of Paul de Saint-Victor and Maxime Ducamp. At the same Salon he exhibited the "Egyptian chopping Straw," and "Rembrandt biting an Etching," two very minutely finished works. Gérôme's best paintings are of Eastern subjects; among these may be named the "Turkish Prisoner," and "Turkish Butcher" (1863); "Prayer" (1865); "The Slave Market" (1867); and "The Harem out Driving" (1869). He often illustrated history, as in "Louis XIV. and Molière" (1863); "The Reception of the Siamese Ambassadors at Fontainebleau" (1865); and the "Death of Marshal Ney" (1868). Gérôme has also been successful as a sculptor; he executed, among other works, "Omphale" (1887), and the statue of the duc d'Aumale which stands in front of the Château of Chantilly (1899). His "Bellona" (1892), in ivory, and metal, precious stones, which was also exhibited in the Royal Academy of London, attracted great attention. The artist then began an interesting series of "Conquerors," wrought in gold, silver, and gems—"Bonaparte entering Cairo" (1897); "Tamerlane" (1898); and "Frederick the Great" (1899). Gérôme was elected member of the Institut in 1865.

Gerona, a maritime frontier province in the extreme north-east of Spain, with an area of 2272 square miles. The population in 1877 was 299,702, and in 1897 298,497. The proportion of illegitimate births (1·50 per cent.) is the lowest in Spain. The province is divided into six administrative districts and 249 parishes. Its general aspect is mountainous, especially in the western districts. Most of the lower chains are covered with splendid forests of oak, pine, and chestnut. More than a hundred mineral springs are scattered over the province. The climate is generally temperate and rainy during several months in the valleys and near the coast, cold in the Cerdana and Rivas districts during eight months, whilst Gerona, La Bisbal, and Santa Coloma are quite Mediterranean in their hot summers and mild winters. The principal local industry is fishing, which in 1898 occupied 2653 hands and 518 boats, the fish being valued at £28,000; there are thirty-one factories for salting fish. Next in importance is the cork industry, occupying 8000 hands at San Feliu de Guixols, Palafrugell, and Cassa. There are also important hydraulic cement, estealite, and ochre works, and no fewer than twenty-two of the towns are centres of manufactures of linen, cotton, woollen stuffs, paper, iron foundries, cloth, leather, steel, copper, and furniture. The commerce of the province is important, Port Bou being, after Irun, the most active outlet for the trade not only with France but with the rest of the Continent by land and railway. The main railway from Barcelona to France runs through the province, and there is another line from Gerona to Olot; there are besides several good steam tramways connecting industrial centres. There are sixteen productive coal mines, turning out some 40,000 tons a year. Agriculture is in a backward state. Official data (1898) show that 78,000 acres produce wheat; 42,352 acres barley, oats, rye, maize; 18,000 acres vines; 38,500 acres olives. The capital, Gerona, has greatly developed its local industries. It is still a fortified and walled town, with a citadel used as a state prison. Population, 16,000.

Gers, a department in the south of France, watered by the river Gers.

Area, 2429 square miles. From 274,391 in 1886 the population decreased to 236,204 in 1901. There were in 1896 832 schools, with 27,000 pupils, and 6 per cent. of the population was illiterate. The area under cultivation amounted in 1896 to 1,393,700 acres, 751,200 of which were plough-land and 256,990 vineyards. There are few industries beyond the manufacture of the esteemed brandy of Armagnac, the distillation of which in 1898 amounted to 178,000 gallons. Auch, the capital, has a population of 11,500.

Gettysburg, capital of Adams county, Pennsylvania, U.S.A., on the Philadelphia and Reading and the Western Maryland railways. It was the scene of one of the most important battles in the Civil War. This took place on 1st, 2nd, and 3rd July 1863, between the Union forces, numbering 78,043, under General Meade, and the Confederates, numbering from 70,000 to 77,000, under General Lee, and resulted in the defeat of the latter. The former lost in killed, 3072; wounded, 14,497; missing, 5434; total, 23,003. The latter lost in killed, 2592; wounded, 12,709; missing, 5150; total, 20,451. The site of the battle has been acquired by the general Government and made a national cemetery, in which the bodies of 3580 Union soldiers have been buried. It was at the dedication of this cemetery in November 1863 that President Lincoln delivered his celebrated "Gettysburg Oration." Population (1890), 3221; (1900), 3495, of whom 58 were foreign-born and 234 negroes.

Ghadames. Ghat. See Tripoli.

Ghazipur, a town and district of British India, in the Benares division of the North-West Provinces. The town is on the left bank of the Ganges, 44 miles east of Benares. Population (1881), 32,885; (1891), 44,970; (1901), 39,186. Municipal income (1897–98), Rs.38,979. Death-rate (1897), 60·31 per thousand. The District of Ghazipur has an area of 1462 square miles. It had a population in 1881 of 1,014,099, and in 1891 of 1,077,909, giving an average

"THE DUEL AFTER THE BALL." By J. L. GÉRÔME.

(From a Photograph by Goupil and Co.)

density of 737 persons per square mile. In 1901 the population was 914,148, showing a decrease of 11 per cent. The land revenue and rates were Rs.11,81,745, the incidence of assessment being R.1–2–8 per acre; the cultivated area in 1896–97 was 558,410 acres, of which 188,348 were irrigated, mostly from wells; the number of police was 2191; the number of vernacular schools in 1896–97 was 88, with 4336 pupils; the registered death-rate in 1897 was 27 per thousand. There are 84 indigo factories, employing 2501 persons, with an annual outturn valued at Rs.1,55,000, and three printing-presses. The main line of the East Indian Railway traverses the southern portion of the district, with a branch to the Ganges bank opposite Ghazipur town, 35 miles in all.

Ghazni, a city of Afghanistan, 78 miles south-west of Kabul. Its position, as determined by recent surveys, is in 33° 33′ N. and 68° 28′ E., its altitude above sea-level being 7280 feet. It is still in the condition of decay which was described by Yate in 1875, and nothing substantially was added to our information regarding its condition or history by the investigations of the officers with Stewart's force, which passed upwards from Kandahar to Kabul in 1879, or with Roberts's force, which passed downwards in 1880. A very considerable trade in fruit, wool, skins, &c., is carried on between Ghazni and India by the povindah Khafilas, which yearly enter India in the late autumn and pass back again to the Afghan highlands in the early spring. The povindah merchants belong chiefly to Nasir, Suliman Khel, and other Ghilzai clans. They invariably make use of the Gomul pass route which leads to the British frontier at Dera Ismail Khan. The opening up of this pass and the British occupation of Wana, by offering protection to the merchants from Waziri blackmailing, largely increased the traffic. In 1890 the estimated value of imports and exports on the Gomul trade route was about 20 lakhs of rupees annually.

Gheel, a town of Belgium, in the province and 25 miles east of the town of Antwerp, with a station on the railway line between Herenthals and Moll. It is chiefly notable for its unique system of treatment for the insane, which dates from the 13th century. The asylum, a large structure flanked by the residences of the medical staff, stands in well-kept grounds. The village proper, and each of ten neighbouring villages, is divided into two portions, for each of which a doctor and his assistant (a fully qualified practitioner) are appointed, with four *surveillants*, all being subordinate to the medical director of the colony. Patients on arrival enter the asylum, where for five days they are under observation. If at the end of that time it is judged advisable for them to enter a private family, great care is exercised in choosing a home for them. The local keepers, or *nourriciers*, are people of known good character, and the sanitary condition of their houses is closely inspected, the *surveillants* being authorized to enter them at any hour of the day or night. The *pensionnaires* (private patients) are provided with regular occupation and recreation suited to their tastes and social position. There is an excellent Harmonic Society, in which sane and insane alike take part. No person with a tendency to suicide, homicide, or vicious habits is admitted into the colony. The cost of maintenance varies from 300 francs per annum for a pauper patient (defrayed by the district or parish to which he belongs), which includes his clothing, to 3000 or 4000 francs for patients of a higher class. The sum paid by patients to the inhabitants amounts to over 800,000 francs a year. Population (communal, 1899), 13,151.

Ghent (Flemish, *Gent*; French, *Gand*), capital of the Belgian province of East Flanders, at the confluence of the Lys and the Scheldt, which by their ramifications form many islands, 30 miles west-south-west of Antwerp. Since 1875 the narrow and unhealthy lanes in which the population was crowded together have given way to well-aired streets and elegant squares. Ancient buildings, such as the Hôtel de Ville (14th century) and the Cathedral of St Bavon (12th century), have been partially restored. The vast ruins of the Count's Castle, of the 9th and the 12th centuries, covering 43,000 square feet, have been cleared of all the houses that abutted on it. The glacis of the citadel, erected by the Dutch in 1822, has been converted into a public park. New public buildings have been raised, such as the Hôtel du Gouvernement Provincial and the Institute of Sciences, comprising the laboratories of the Faculté des Sciences and technical schools in connexion with the university. The canal connecting Ghent with Terneuzen, on the Scheldt, in Holland (1827), has been widened and deepened (to a depth of 21·3 feet), and united with three basins in the city and an outer harbour, to which in 1897 there entered as many as 1000 vessels. The two chief branches of industry are, first, textiles—cotton and linen spinning and weaving, employing 17,000 workers, 540,232 spindles for cotton, and 195,000 spindles for linen weaving. The second branch is the cultivation of ornamental plants—orchids, ferns, azaleas, &c. The grounds of a single establishment of this kind cover 49½ acres. The population, 131,000 in 1875, amounted to 163,000 in 1899, an increase in twenty-five years of 32,000, or 24 per cent.

Ghika, Dimitrie (1816–1897), Rumanian statesman, son of the Wallachian Hospodar (or Prince) Gregor Ghika, was born on 31st May 1816. As a youth he studied at Vienna and Berlin, and obtained a commission in the Russian Imperial Guard. After extensive travels through Europe he returned to Bucarest, and became a member of the Court of Appeal. He distinguished himself as prefect of police at Bucarest under Prince Stirbeĭ, was a member of the Divan of 1857, and in 1859 had attained prominence enough to offer himself as a candidate for the princedom of Wallachia. He retired, however, in favour of Couza, under whom he held, in 1860, the office of minister of public instruction. In the following year he was minister of finance under Catargi, on the fall of whose ministry he became president of the council and minister of the interior. Under the rule of Charles of Hohenzollern, Ghika was soon called to office again as minister of the interior, and in 1868 formed a cabinet in which he held the portfolio of finance, and for a time that of foreign affairs. Going out of office in 1870, he was from 1871 to 1875 president of the Chamber. Hitherto he had been identified with the Conservatives, but he now combined with others to form a "central" party; and when this was dissolved in 1879, he joined the Liberals, under whom he was president of the Senate till 1888. In that year the Liberal coalition broke up: Ghika made an unsuccessful attempt to form a Liberal and Dissident Liberal cabinet, and held no further office till the return of the Liberals to power in 1895. He then became once more president of the Senate, and held this post till his death, which took place at Bucarest on 27th February 1897. An adroit politician and a capable administrator, he played a leading part in the making of Rumania and in its development as a constitutional monarchy, but left no great measure to keep alive his reputation as a statesman. (See RUMANIA.) (H. SY.)

Ghika, Helene (1828–1888), Rumanian novelist, better known under her literary pseudonym "Dora d'Istria," was born at Bucarest on 22nd January 1828, being the daughter of Prince Michael (brother of Gregor) Ghika. Carefully educated under a Greek master, Grigor Pappadopulos, she showed herself such an apt pupil that, at the early age of fifteen, she commenced a translation of the *Iliad* into German. After continuing her education in Dresden, Venice, and Berlin, she married, in 1849, the Russian prince Kolzow Massalski, and settled with him in St Petersburg. After a few years of unhappy union, however, she separated from him and removed, in 1855, to Florence, which was her home until her death in 1888. During all the years of her residence in that city she was very busy with her pen, and published a number of works characterized by depth of research and brightness of description. Chief among them may be noted *La vie monastique dans l'église Orientale* (1855); *La Suisse allemande* (1856); *Pélerinage au tombeau du Dante*, describing the festival in honour of the anniversary of Dante's birth, to which she received an official invitation; *Les Lacs Helvétiques* (1864). One of the last, and not least important, of her works was *Gli Albanesi in Rumenia, Storia dei principi Ghika nei secoli, xvii., xviii., xix.* (Florence, 1873). She also wrote largely for the *Revue des Deux Mondes*, and was a contributor to *Scribner's Magazine.*

Ghika, Ion (1817–1897), Rumanian statesman and diplomatist, was born at Bucarest in 1817. From 1837 to 1840 he was a student in Paris, where he fell under the influence of the Liberal and Romantic movement, then at its height. Returning to Bucarest, he joined the ranks of the Opposition, and in 1841 was concerned in the conspiracy of Ibraila. From 1843 to 1845 he was professor of mathematics and political economy in the university of Jassy, and in 1844 helped his lifelong friend Vasilie Alecsandri to found the Liberal journal *Progresul*, which was speedily suppressed by the Government. He took a prominent part in the Revolution of 1848, and was sent by the provisional Government as *chargé d'affaires* to Constantinople. Here he won the confidence of Lord Stratford de Redcliffe, on whose recommendation he received from the Sultan in 1854 the appointment of governor of Samos. The neighbouring seas, at that time infested with pirates, were swept clear by the untiring energy of Ghika, who thus rendered an important service to the Allied forces at the time of the Crimean War. He received in 1856 the title of prince of Samos, and continued to rule the island with conspicuous success till 1857. After a brief tenure of ministries in Moldavia and Wallachia, he returned to Bucarest, and became the leader of the Liberal party. As president of the council and minister for foreign affairs in the provisional Government of 1866, he played the chief part in the nomination of Charles of Hohenzollern as prince of Rumania, and became the first prime minister of the new *régime.* Forced to resign in 1867 by a vote of want of confidence, he joined the Opposition, and took part in the Republican movement of 1870. In December of that year he again became prime minister, but in the following March, being implicated in the attempt to overthrow Prince Charles, was dismissed from office. After repeatedly holding the vice-presidency of the Senate, he was in 1881 appointed Rumanian minister in London, where his brilliant powers of intellect and profound sympathy with Western culture gave him a distinguished place in society. He retired in 1890, and died at his estate Gherganĭ on 4th May 1897. Prince Ion Ghika ranks high among Rumanian authors for his charm of style and power of graphic representation—qualities best displayed in his correspondence with Vasilie Alecsandri. Many of these letters are of prime importance to the student of Rumanian economic problems. Equally noteworthy are his *Convorbiri Economici*, and his work in collaboration with D. Sturza, *Ajutorul Comerciantlui.* His position as a writer was recognized by his election to the presidency of the Rumanian Academy. The ability he displayed in so many different fields of activity entitles him to be called the most remarkable man Rumania has yet produced; and, if he did not always keep clear of the intrigues and inconsistencies of Balkan politics, he yet was in no small degree the author of his country's prosperity. (See RUMANIA.) (H. SY.)

Giant's Causeway, a promontory of columnar basalt on the north coast of county Antrim, Ireland. In 1883 an electric railway, the first in the United Kingdom, was opened for traffic, connecting the Causeway with Portrush and Bushmills. After a protracted lawsuit the Causeway, and certain land in the vicinity, have been declared to be private property, and a small charge is now made for admission.

Gibara, one of the old fortified north-coast cities of the eastern province of Cuba, 80 miles north by west of Santiago de Cuba. It has an extensive banana export trade, and lays claim to have been originally discovered by Columbus. Population about 7000.

Gibbons, James (1834– ——), cardinal of the Roman Catholic Church and American archbishop, was born in Baltimore, Md., 23rd July 1834, and baptized in the cathedral over which he was afterwards destined to preside. Entering St Charles College, Md., he completed there his classical studies in 1857, and passed to St Mary's Seminary, Baltimore, where he finished his theological training and was ordained priest 30th June 1861. After a short time spent on the missions of Baltimore, he was called to be secretary to Archbishop Spalding and assistant at the cathedral. When, in 1866, the Second Plenary Council of Baltimore considered the matter of new diocesan developments, he was selected to organize the new Vicariate Apostolic of North Carolina, and was consecrated bishop in August 1868. He devoted four years to missionary work, preaching, lecturing, and organizing with great success. During the years spent in North Carolina he wrote, for the benefit of his mission work, *The Faith of our Fathers*, a simple, scholarly presentation of the doctrines and principles of the Catholic Church. He was transferred to Richmond, Va., in 1872, and in 1877 was made coadjutor to Archbishop Bayley of Baltimore. In October of the same year he succeeded to the archbishopric. Pope Leo XIII. in 1884 selected him to preside over the Third Plenary Council of Baltimore, and in June 1886 created him a cardinal priest, with the title of Santa Maria Trastevere. His simplicity of life, foresight, and prudence have made him a power in the Church. Thoroughly American, and a lover of the people, he is in close touch with all that tends to benefit the nation and to ennoble its citizenship, and his public utterances manifest the true instincts of a popular leader. He has contributed frequently to the leading magazines. As an author he is known principally by his works on religious subjects. *The Faith of our Fathers* has passed through forty editions; his other books are *Our Christian Heritage* and *The Ambassador of Christ.* He had been for many years an ardent advocate for the establishment of a Catholic University, but it was not until the Third Plenary Council of Baltimore, 1884, that he saw the realization of his desires in the establishment of the Catholic University of America at Washington. He enjoyed the distinction of being its first chancellor and president of the board of trustees.

Gibraltar, a British fortress and Crown colony at the western entrance to the Mediterranean. The southern point of the rock is known as Europa Point, in longitude 5° 21′ 0″ W., latitude 36° 6′ 30″ N., and 11½ nautical miles distant from the opposite African coast. The town is crowded together at the north-west angle, and covers about one-ninth of the whole area; a small part only of the town is on level ground, and those of its narrow streets and lanes which run away from the shore of the bay are for the most part little more than ramps and rough stairs formed of rubble stones, which contract in places into mere stone steps. The climate of Gibraltar is pleasant, mild in winter and only moderately hot in summer; the heat, however, though not excessive is lasting, and rain seldom falls in the five months from May to September; from October to May the climate is generally delightful, warm sunshine prevailing, tempered by cool breezes; the periods of bad weather, although blustering enough at times, are seldom of more than a few days' duration. The thermometer in summer rarely reaches 90° in the shade; from 83° to 85° may be taken to be the average maximum for July and August, which are the hottest months. The average annual rainfall is 37·56 inches, and in twenty years, from 1880 to 1899, the heaviest recorded rainfall was 59·35 inches, and the lightest 16·75. Although the number of persons employed in and dependent upon Gibraltar has of late considerably increased, especially since the new dockyard works were begun in 1895, the population actually resident has not grown. As Crown leases, of which there are many, fall in they are often not renewed; and as houses are rebuilt they are adapted for a better class of tenant, and so the poorer classes are being gradually driven out, and go to live in the adjoining Spanish town of Linea de la Concepcion, which, itself a mere suburb of Gibraltar, is said to contain some 40,000 inhabitants, or nearly twice the population of the mother city. It has been estimated that some ten thousand workers come daily from Linea to Gibraltar. The population (1900) was estimated at 24,701; the garrison and its families account for nearly 6000, the civil population numbers not quite 17,000, and there are about 2400 resident aliens, chiefly working men, domestic servants, and professional men. Aliens, who are not duly accredited consuls, are not allowed to reside without a special permit signed by the chief of police, which has to be renewed every three months; and by an Order in Council, taking effect from November 1900, like disabilities were extended to British subjects not previously resident. When Gibraltar was taken by the British most of the Spanish inhabitants left. The bulk of the present inhabitants are of Italian or Genoese descent; there are a fair number of Maltese, and two or three thousand Jews: these never intermarry with other races, and form a society of their own. The language is Spanish, spoken not very correctly. English is in every case an acquired language, and is hardly, if ever, spoken by the people in their own homes.

The recorded births, marriages, and deaths are as follows:—

	Births.	Marriages.	Deaths.
1883 . .	640	190	525
1888 . .	645	163	474
1893 . .	651	149	404
1899 . .	657	208	511

Gibraltar is a Crown colony. Of local government, properly so called, there is none. There is a sanitary commission, which is vested with large powers over buildings and streets, like those of local authorities in England. Its members are for the most part nominees of the Government, with little or no knowledge of the rights of owners of property. An appeal from their decisions lies to the supreme court, but as their decisions are not always made known to those injuriously affected by them within the time limited for appeal, the protection is of no special value. Apart from the garrison and the civil officials, there are comparatively few members of the Anglican Church; the great majority of the inhabitants belong to the Roman communion. The Jews have four synagogues. The Protestant dissenters have two places of worship, Presbyterian and Wesleyan. Education is not compulsory for the civil population, but most if not all children receive a fair education at private or private-aided schools. The number of children on the roll of the private-aided schools was, in 1899, 1086 boys and 732 girls; total, 1818. There is no direct taxation. The main sources of revenue are: (i.) duties upon wines, spirits, malt liquors, and tobaccos; (ii.) port and harbour dues; (iii.) tavern and other licenses; (iv.) posts and telegraphs; (v.) ground and other rents; (vi.) stamps and miscellaneous. The returns prior to 1898 are given in pesetas (5 = $), which have been converted in the following table into sterling at an average of exchange 30 = £1.

	(i.)	(ii.)	(iii.)	(iv.)	(v.)	(vi.)	Total Revenue.
	£	£	£	£	£	£	£
1883 .	8,092	15,404	4,842	737	7,079	4,479	40,634
1888 .	9,732	18,446	5,288	6,444	6,472	3,004	49,386
1893 .	9,050	12,843	4,474	7,382	6,268	10,745	50,762
1899 .	18,245	6,179	4,053	9,191	5,931	16,355	59,954

Before 1886 the colony derived no revenue from the post office, which was administered from London as a branch of the General Post Office. The depreciation of the Spanish currency during the war with the United States led, in 1898, to the reintroduction of British currency as the legal tender money of Gibraltar. An indirect result of this was a large increase in the revenue of the post office, the old issues of postage stamps in Spanish currency being largely bought by stamp dealers and collectors. Notwithstanding the legal change of currency, the Spanish dollar still remains the current coin in everyday use; much of the retail business of the town being done with people living in Spain, the dollar more than holds its own.

Great changes have been made in the defences of Gibraltar during recent years. Guns of the older types have been removed and replaced by those of the latest pattern. The heaviest pieces, instead of being at or near the sea-level, are now high up, many of them upon the very crest-ridge of the rock, 1200 or 1300 feet above the sea. Guns so placed have a great advantage over an enemy's ships, the decks, the weakest part of the ship, being exposed to the plunging fire of the higher-placed guns. Guns on the crest-line have the further advantage of being able to fire all round the horizon; an elaborate system of range-finding has been carefully worked out. With the completion of the new docks and works (see DOCKYARDS) the importance of Gibraltar as a naval base will be greatly increased. The new dockyard will be able to undertake all the repairs of a squadron. There will be an enclosed harbour, in which a fleet can anchor secure from the attacks of torpedo boats. As part of the same scheme commercial wharves are being constructed for coaling steamers alongside, and the loading and discharging of cargo. There will be from 30 to

35 feet of water over the enclosed area at low water ordinary spring tides. Three dry docks, from 450 to 850 feet in available length, will provide for the simultaneous repair of three or four vessels; these will be at the south end of the harbour. At the north end will be the commercial wharves, at which a considerable number of vessels will be able to coal or load and unload at one time in 30 feet of water. With the defences the food and water supply is in close connexion. Cold stores have been erected, in which frozen meat can be kept for an indefinite period. The water supply has also been largely increased. There are very few good wells in Gibraltar; nearly all the water used for drinking and cooking consists of rain water stored in tanks underground; most of the better class of houses have their own rain-water tanks, and there are large tanks belonging to the war department for the supply of the garrison. Large additional storage tanks have been constructed by the sanitary commission, with specially prepared collecting areas high up the rock. The collecting areas have been enlarged from 3 to 16 acres, and the capacity of the storage tanks from $1\frac{1}{3}$ to $6\frac{1}{3}$ million gallons. The tanks are excavated from the solid rock; the water will thus be kept in the dark and cool, and secure from the effects of an enemy's fire.

The general trade of Gibraltar has undergone little change of late years: one must go a long way back to find a time when there was much active business. At the point of contact of two continents, on the direct line of ocean trade with the Far East, in regular steam communication with North and South America, Gibraltar is by its position fitted to be a trade centre of the world; but the dead hand of Islam upon Morocco and protection in Spain have strangled commerce. There are no trustworthy statistics of the trade: up to the year 1898 wine, beer, and spirits were the only goods which paid duty. In that year a duty of 1d. per pound was for the first time put upon tobacco, and produced £1444. This duty was in force during part only of the year 1898; in 1899 the duty at the same rate produced £7703. The chief business is the coaling of passing steamers; this gives work to several thousand men. Goods are also landed for re-export to Morocco, but the bulk of the Morocco trade, much of which formerly came to Gibraltar, is now done by lines of steamers trading to and from Morocco direct to British, German, or French ports. A fair amount of retail business is done with the passengers of ocean steamers which call on their way to and from the East and from North and South America. The steam tonnage cleared is shown in the following table:—

	British.	Foreign.	Total.
	Tons.	Tons.	Tons.
1883 . .	3,771,075	859,711	4,630,786
1888 . .	5,033,088	876,489	5,909,577
1893 . .	3,521,164	1,036,696	4,557,860
1899 . .	3,214,965	1,048,536	4,263,501

The money, weights, and measures in legal use are British. Before 1898 Spanish money only was used, and though no longer legal it keeps its hold on the people, so that there is practically a double coinage.

To the works mentioned in the ninth edition of the *Encyclopædia Britannica*, vol. x., may be added:—MONTERO. *Historia de Gibraltar.* Cadiz, 1860.—Colonel IRBY. *Ornithology of the Straits.* London, 1875.—BUSK. *Transactions of the Zoological Society,* vol. x. p. 53. 1876.—Professors RAMSAY and GEIKIE. *Geology of Gibraltar.* London, 1878.—NAVARETTE. *Las llaves del Estrecho.* Madrid, 1882.—FIELD. *Gibraltar.* New York, 1888.—WALKER. *A Year's Insect Hunting in Gibraltar.* London, 1888.

(H. M*.)

Giers, Nicholas Karlovitch de (1820–1895), Russian minister for foreign affairs, was born on the 21st of May 1820. Like his predecessor, Prince Gortchakoff, he was educated at the lyceum of Tsarskoe Selo, near St Petersburg, but his career was much less rapid, because he had no influential protectors, and was handicapped by being a Protestant of Teutonic origin. At the age of eighteen he entered the service of the Eastern department of the ministry of foreign affairs, and spent more than twenty years in subordinate posts, chiefly in South-eastern Europe, until he was promoted in 1863 to the post of minister plenipotentiary in Persia. Here he remained for six years, and, after serving as a minister in Switzerland and Sweden, he was appointed in 1875 director of the Eastern department and assistant minister for foreign affairs under Prince Gortchakoff, whose niece he had married. No sooner had he entered on his new duties than his great capacity for arduous work was put to a severe test. Besides events in Central Asia, to which he had to devote much attention, the Herzegovinian insurrection had broken out, and he could perceive from secret official papers that the incident had far-reaching ramifications unknown to the general public. Soon this became apparent to all the world. While the Austrian officials in Dalmatia, with hardly a pretence of concealment, were assisting the insurgents, Russian volunteers were flocking to Servia with the connivance of the Russian and Austrian Governments, and General Ignatieff, as ambassador in Constantinople, was urging his Government to take advantage of the palpable weakness of Turkey for bringing about a radical solution of the Eastern question. Prince Gortchakoff did not want a radical solution involving a great European war, but he was too fond of ephemeral popularity to stem the current of popular excitement. Alexander II., personally averse from war, was not insensible to the patriotic enthusiasm, and halted between two opinions. M. de Giers was one of the few who gauged the situation accurately. As an official and a man of non-Russian extraction he had to be extremely reticent, but to his intimate friends he condemned severely the ignorance and light-hearted recklessness of those around him. The event justified his sombre previsions, but did not cure the recklessness of the so-called patriots. They wished to defy Europe in order to maintain intact the treaty of San Stefano, and again M. de Giers found himself in an unpopular minority. He had to remain in the background, but all the influence he possessed was thrown into the scale of peace. His views, energetically supported by Count Schuvaloff, finally prevailed, and the European congress assembled at Berlin. He was not present at the congress, and consequently escaped the popular odium for the concessions which Russia had to make to Great Britain and Austria. From that time he was practically minister of foreign affairs, for Prince Gortchakoff was no longer capable of continued intellectual exertion, and lived mostly abroad. On the death of Alexander II. in 1881 it was generally expected that M. de Giers would be dismissed as deficient in Russian nationalist feeling, for Alexander III. was credited with strong anti-German Slavophil tendencies. In reality the young Tsar had no intention of embarking on wild political adventures, and was fully determined not to let his hand be forced by men less cautious than himself. What he wanted was a minister of foreign affairs who would be at once vigilant and prudent, active and obedient, and who would relieve him from the trouble and worry of routine work while allowing him to control the main lines, and occasionally the details, of the national policy. M. de Giers was exactly what he wanted, and accordingly the Tsar not only appointed him minister of foreign

"The Return of the Victors." By Sir John Gilbert, R.A.

(By permission of the Corporation of Birmingham.)

affairs on the retirement of Prince Gortchakoff in 1882, but retained him to the end of his reign in 1894. In accordance with the desire of his august master, M. de Giers followed systematically a pacific policy. Accepting as a *fait accompli* the existence of the Triple Alliance, created by Bismarck for the purpose of resisting any aggressive action on the part of Russia and France, he sought to establish more friendly relations with the cabinets of Berlin, Vienna, and Rome. To the advances of the French Government he at first turned a deaf ear, but when the *rapprochement* between the two countries was effected with little or no co-operation on his part, he utilized it for restraining France and promoting Russian interests. In private life M. de Giers had none of the brilliancy of his illustrious predecessor. To the outside world he seemed a taciturn, solemn, and rather commonplace person, who had few human sympathies, and whose idea of happiness was to sit in his chancellery surrounded with heaps of official documents. Those who knew him well were aware that his somewhat uncouth exterior covered many amiable qualities, and that his habitual careworn expression concealed a good deal of quiet humour. He died on 26th January 1895, soon after the accession of Nicholas II. (D. M. W.)

Giessen, a town and important railway junction of Germany, grand-duchy of Hesse-Darmstadt, on the Lahn, 41 miles by rail north from Frankfort-on-Main. The town hall contains the collections of the Upper Hessian Historical Association; the arsenal is now used as barracks. There is a new Evangelical church (1891). In 1889 new buildings were erected for the university, and in 1887–90 new medical schools. In 1900 the university was attended by 855 students, and had 82 professors. The old university buildings have been appropriated to the library, containing about 200,000 volumes. Giessen is the seat of an agricultural college. It has also a monument to von Liebig, the chemist, who was professor here from 1824 to 1852. There is a large lignite mine in the vicinity, and large tobacco and cigar factories in the town. Population (1885), 18,836; (1900), 25,564.

Gifu, or IMAÏZUMI, a city of Japan, capital of the ken (government) of Central Nippon, which comprises the two provinces of Mino and Hida. It lies east by north of Lake Biwa, on the Central Railway, about 172 miles from Tôkyô and 64 miles from Kyôtô, on a tributary of the Kiso, which flows to the Bay of Mia Uro. Population (1880), 12,500; (1898), 31,000. The ken has an area of about 4000 square miles, and is thickly peopled, with a population of over 1,000,000 in 1900. The whole district is subject to frequent earthquakes, and Gifu was nearly ruined during the disturbances which lasted from October 1891 to March 1892, when as many as 2588 shocks were registered at this place.

Gijon, a Spanish seaport on the Bay of Biscay, in the province of Oviedo. Population (1897), 43,392. Important works have been in progress since 1892 to create an excellent harbour of refuge at Musel, at the extremity of the bay of Gijon, which will also be a mineral loading port, capable of accommodating vessels of any size. More than a quarter of the works have been completed, and they have already attracted much trade. The value of the import trade was £384,440 in 1898, Great Britain figuring for £160,743. The principal imports were machinery, iron, and metal work, and iron ore for the works at Mieres, Duro, and Moreda. The exports in 1898 were valued at £122,200, the United Kingdom taking £28,349. With the increasing output of coal in the province, Gijon exported 302,217 tons of coal in 1898, being an increase of 25,826 tons since 1897. The shipping in 1898 numbered 1980 vessels of 313,000 tons. The town has grown apace, not only with the movement of the port, but with the summer influx of people, who come for the bathing. New suburbs have sprung into existence, broader streets have been built, the public gardens improved, statues raised to the memory of Jovellanos and Pelayo, duke of Asturias, and a new town hall, theatre, and markets erected. The bull-ring, recently restored, can hold 12,000 persons. Besides the institute, Gijon has a nautical school, a school of arts and handicrafts, and numerous primary schools educating large numbers of children. The glass factory is the best in Spain; porcelain factories, iron works, and petroleum refineries are in a flourishing condition; manufactures of preserves, soap, candles, chocolate, and liqueurs are among the rising local industries.

Gílán (*Ghilan*), one of the northern provinces of Persia, on the south-west shore of the Caspian, between 36° 20′ and 38° 30′ N., and 48° 50′ and 50° 30′ E. It is divided into the following administrative districts:—Rasht (with the capital of the province and its immediate neighbourhood), Fúman (with Tulam and Masúlah, where are iron mines), Gesker, Tálesh (with Tálesh, Dúláb, Shandarmán, Asalom, Gíl Dúláb, Kargánrúd, Masal, Enzeli, the port of Rasht), Sheft, Manjíl (with Rahmatábád and Amarlú), Langarúd (with Rúdsar and Ránehkúh), Dilmán, and Lashtnishah (on the lower Safíd rúd). Gílán means "land of the Gíl," and the Gíl were an old tribe which the ancient Greeks mentioned as the Gelae. A man of Gílán is called a "Gílek," and the dialect which he speaks is "Gílekí." The land-tax paid by the province is £48,840, or £14,560 less than in 1876. The value of the exports and imports from and into Gílán, much of them in transit, is about £1,860,000. The Government abolished the farm system in Gílán in March 1900, in the hope that the customs dues would yield a considerably higher revenue. The Crown lands of Gílán have been much neglected, and the revenue derived from them is stated to amount to no more than 153,500 krans, or a little over £3000. The fisheries of the whole Persian littoral of the Caspian, having been conceded to a Russian firm for an annual payment of £16,000, which is paid direct into the Treasury, cannot be considered as revenue of Gílán.

Gilbert, Sir John (1817–1897), English painter and illustrator, was one of the eight children of George Felix Gilbert, a member of a Derbyshire family. He was born at Blackheath on the 21st of July 1817, went to school there, and even in childhood, without any instruction whatever, displayed an extraordinary fondness for drawing and painting. Nevertheless, his father's lack of means compelled him to accept employment for the boy in the office of Messrs Dickson & Bell, estate agents, in Charlotte Row, London. It was even then clear that he possessed, as if by nature, an amazing power of dramatically realizing subjects the pictorial qualities of which he intuitively recognized, and that "the young Gilbert thought in pictures." Yielding to his natural bent, his parents agreed that he should take up art in his own way, which included but little advice from others, his only teacher being Haydon's pupil, George Lance, the fruit painter. This artist gave him brief instructions in the use of colour. Gilbert, who studied in none of the schools, worked indefatigably, in a somewhat florid mood, from nature, and thus like an old master attained such skill that no artistic methods came amiss to him, while, like Millais, "he thought out his subjects by instinct." In 1836 Gilbert appeared in public for the first time. This was at the gallery of the Society of British Artists, where he sent drawings, the subjects of which were characteristic, being "The Arrest of Lord Hastings," from Shakespeare, and "Abbot Boniface," from *The Monastery* of Scott. "Inez de Castro" was in the same gallery in the next year; it was the first of a long series of works in the same medium, representing similar themes, and was accompanied, from 1837, by a still greater number of works in oil which were exhibited at the British Institution. These included "Don Quixote giving advice to Sancho Panza," 1841; "Brunette and Phillis," from *The Spectator*, 1844; "The King's Artillery at Marston Moor," 1860; and "Don Quixote comes back for the last time to his Home and Family," 1867. In that year the Institution was finally closed. Gilbert exhibited at the Royal Academy from 1838, beginning with the "Portrait of a Gentleman," and continuing, except between 1851 and 1867, till his death to exhibit there many of his best and more ambitious works. These included such capital instances as "Holbein painting the Portrait of Anne Boleyn," "Don Quixote's first Interview with the Duke and Duchess," 1842; "Charlemagne visiting the Schools," 1846. "Touchstone and the Shepherd," and "Rembrandt," a very fine piece, were both there in 1867; and in 1873 "Naseby," one of his finest and most picturesque designs, was also at the Royal Academy. Gilbert was elected A.R.A. 29th January 1872, and R.A. 29th June 1876. Besides these mostly large and powerful works, the artist's true arena of display was undoubtedly the gallery of the Old Water Colour Society, to which from 1852, when he was elected an Associate exhibitor, till he died forty-five years later, he contributed not fewer than 270 drawings, most of them admirable because of the largeness of their style, massive coloration, broad chiaroscuro, and the surpassing vigour of their designs. These qualities won for him the title of "The Rubens of his time," and, taken with the great distinction of his works on larger scales, induced the leading critics to claim for him opportunities for painting mural pictures of great historic themes as decorations of national buildings. "The Trumpeter," "The Standard-Bearer," "Richard II. resigning his Crown" (now at Liverpool), "The Drug Bazaar at Constantinople," "The Merchant of Venice," and "The Turkish Water-Carrier," are but examples of that wealth of art which added to the attractions of the gallery in Pall Mall. There Gilbert was elected a full Member in 1855, and president of the Society in 1871, shortly after which he was knighted. Gilbert, as an illustrator of books, magazines, and periodicals of every kind, including newspapers, produced an astounding number of designs, all of which possessed extraordinary value, nor did he repeat himself in any. Energy, abundance of invention, and picturesqueness existed in all of them; yet their multitude did not affect his painting pictures, nor exhaust his powers in the least degree. To the success of the *Illustrated London News* his designs lent powerful aid, and he was eminently serviceable in illustrating the *Shakespeare* of Mr Howard Staunton. He illustrated a great proportion of the dramatic literature and poetry of England, and of other countries besides. Sir John Gilbert died 6th October 1897. He was a member of many artistic societies besides those mentioned above, and was a Knight of the Legion of Honour. (F. G. S.)

Gilbert, Sir Joseph Henry (1817–1901), English chemist, was born at Hull on 1st August 1817. He studied chemistry first at Glasgow under Thomas Thomson, then at University College, London, in the laboratory of A. T. Thomson, also attending Graham's lectures, and finally at Giessen under Liebig. On his return to England from Germany he acted for a year or so as assistant to his old master A. T. Thomson at University College, and in 1843, after spending a short time in the study of calico dyeing and printing near Manchester, accepted the directorship of the chemical laboratory at the famous experimental station established by Sir J. B. Lawes at Rothamsted, near St Albans, for the systematic and scientific study of agriculture. This position he held for fifty-eight years, until his death on 23rd December 1901. The work which he carried out during that long period in collaboration with Sir John Lawes was of a most comprehensive character, involving the application of many branches of science, such as chemistry, meteorology, botany, animal and vegetable physiology, and geology; and its influence in improving the methods of practical agriculture extended all over the civilized world. Some account of the results obtained will be found in the article AGRICULTURE. Sir Joseph Henry Gilbert was chosen a fellow of the Royal Society in 1860, and in 1867 was awarded a Royal medal jointly with Sir John Lawes. In 1880 he presided over the Chemical Section of the British Association at its meeting at Swansea, and in 1882 he was president of the Chemical Society, of which he had been a member almost from its foundation in 1841. For six years from 1884 he filled the Sibthorpian chair of rural economy at Oxford, and he was also an honorary professor at the Royal Agricultural College, Cirencester. He was knighted in 1893, the year in which the jubilee of the Rothamsted experiments was celebrated.

Gilbert, William Schwenk (1836– ——), English playwright and humorist, son of William Gilbert (a descendant of Sir Humphrey Gilbert), was born in London on the 18th of November 1836. His father was the author of a number of novels, the best known of which were *Shirley Hall Asylum* (1863) and *Dr Austin's Guests* (1866). Several of these novels — which were characterized by a singular acuteness and lucidity of style, by a dry, subacid humour, by a fund of humanitarian feeling, and by a considerable medical knowledge, especially in regard to the psychology of lunatics and monomaniacs—were illustrated by his son, who developed a talent for whimsical draughtsmanship. Young Gilbert was educated at Boulogne, at Ealing, and at King's College, graduating B.A. from the University of London in 1856. The termination of the Crimean war was fatal to his project of competing for a commission in the Royal Artillery, but he obtained a post in the Education Department of the Privy Council Office (1857–61). Disliking the routine work, he left the Civil Service, entered the Inner Temple, was called to the bar in November 1864, and joined the northern circuit. His practice was inconsiderable, and his military and legal ambitions were eventually satisfied by a captaincy in the volunteers and appointment as a magistrate for Middlesex (June 1891). In 1861 the comic journal *Fun* was started by H. J. Byron, and Gilbert became from the first a valued contributor. Failing to obtain an *entrée* to *Punch*, he continued sending excellent comic verse to *Fun*, with humorous illustrations, the work of his own pen, over the signature of "Bab." A collection of these lyrics, in which deft craftsmanship unites a titillating satire on the deceptiveness of appearances with the irrepressible nonsense of a Lewis Carroll, was issued separately in 1869 under the title of *Bab Ballads*, and was followed by *More Bab Ballads*. The two collections and *Songs of a Savoyard* were united in a volume issued in 1898, with many new illustrations. The best of the old cuts, such as those depicting the "Bishop of Rum-ti-Foo" and the "Discontented Sugar Broker," were happily preserved intact.

While remaining a staunch supporter of *Fun*, Gilbert was soon immersed in other journalistic work, and his position as dramatic critic to the *Illustrated Times* turned his attention to the stage. He had not to wait long for an opportunity. Early in December 1866 T. W. Robertson was asked by Miss Herbert, lessee of the St James's Theatre, to find some one who could turn out a bright Christmas piece in a fortnight, and suggested Gilbert; the latter promptly produced *Dulcamara*, a burlesque of *L'Elisire d'Amore*, written in ten days, rehearsed in a week, and duly performed at Christmas. He sold the piece outright for £30, a piece of rashness which he had cause to regret, for it turned out a commercial success. In 1870 he was commissioned by Buckstone to write a blank verse fairy comedy, based upon *Le Palais de la Vérité*, the novel by Madame de Genlis. The result was *The Palace of Truth*, a fairy drama, poor in structure but clever in workmanship, which served the purpose of Mr and Mrs Kendal in 1870 at the Haymarket. This was followed in 1871 by *Pygmalion and Galatea*, another three-act "mythological comedy," a clever and effective but artificial piece. Another fairy comedy, *The Wicked World*, written for Buckstone and the Kendals, was followed in March 1873 by a burlesque version, in collaboration with Gilbert à Beckett, entitled *The Happy Land*. Gilbert's next dramatic ventures inclined more to the conventional pattern, combining sentiment and a cynical humour in a manner strongly reminiscent of William Gilbert the novelist. Of these pieces, *Sweethearts* was given at the Prince of Wales's Theatre, 7th November 1874; *Tom Cobb* at the St James's, 24th April 1875; *Broken Hearts* at the Court, 9th December 1875; *Dan'l Druce* (a drama in darker vein, suggested to some extent by *Silas Marner*) at the Haymarket, 11th September 1876; and *Engaged* at the Haymarket, 3rd October 1877. The first and last of these proved decidedly popular. *Gretchen*, a verse drama in four acts, appeared in 1879. A one-act piece, called *Comedy and Tragedy*, was produced at the Lyceum, 26th January 1884. Two dramatic trifles of later date were *Foggerty's Fairy* and *Rozenkrantz and Guildenstern*, a travesty of *Hamlet*, performed at the Vaudeville in June 1891. Several of these dramas were based upon short stories by Gilbert, a number of which had appeared from time to time in the Christmas numbers of various periodicals. The best of them have been collected in the volume entitled *Foggerty's Fairy, and other Stories*. In the autumn of 1871 Gilbert commenced his memorable collaboration (which lasted over twenty years) with Sir Arthur Sullivan. The first two comic operas, *Thespis; or The Gods grown Old* (26th September 1871) and *Trial by Jury* (Royalty, 25th March 1875) were merely essays. Like one or two of their successors, they were, as regards plot, little more than extended "Bab Ballads." Later (especially in the *Yeomen of the Guard*), much more elaboration was attempted. The next piece was produced at the Opera Comique (17th November 1877) as *The Sorcerer*. At the same theatre were successfully given *H.M.S. Pinafore* (25th May 1878), *The Pirates of Penzance; or The Slave of Duty* (3rd April 1880), and *Patience; or Bunthorne's Bride* (23rd April 1881). In October 1881 the successful *Patience* was removed to a new theatre, the Savoy, specially built for Gilbert and Sullivan by Richard D'Oyly Carte. *Patience* was followed, on 25th November 1882, by *Iolanthe; or The Peer and the Peri*; and then came, on 5th January 1884, *Princess Ida; or Castle Adamant*, a re-cast of a charming and witty fantasia which Gilbert had written some years previously, and had then described as a "respectful perversion of Mr Tennyson's exquisite poem." The impulse reached its fullest development in the operas that followed next in order—*The Mikado; or The Town of Titipu* (14th March 1885); *Ruddigore* (22nd January 1887); *The Yeomen of the Guard* (3rd October 1888); and *The Gondoliers* (7th December 1889). After the appearance of *The Gondoliers* a temporary misunderstanding occurred between the composer and librettist. Gilbert wrote several more librettos, and of these *Utopia Limited* (1893) and the exceptionally witty *Grand Duke* (1896) were written in conjunction with Sullivan. Yet there were many to whom it seemed that the old spell was broken. The plan of paradox and musical theme upon which the partners had hitherto relied was becoming too well worn, and no ingenuity could disguise the repetition of devices and methods, tricks of jest and of rhythm, which they had taught their sincerest admirers to anticipate. As a master of metre Gilbert had shown himself consummate, as a dealer in quips and paradoxes and ludicrous dilemmas, unrivalled. Even for the music of the operas he deserves some credit, for the rhythms were frequently his own (as in "I have a Song to Sing, O"), and the metres were in many cases invented by himself. One or two of his librettos, such as that of *Patience*, are virtually flawless. Enthusiasts are divided only as to the comparative merit of the operas. *Princess Ida* and *Patience* are in some respects the daintiest and the most idyllic. There seems a genuine, if limited, vein of poetry in *The Yeomen of the Guard*. Some of the drollest songs are in *Pinafore* and *Ruddigore*. *The Gondoliers* has the most charming *légèreté*, while with the general public *The Mikado* proves the most popular.

Gilgit, an outlying province in the extreme north-west of India, over which Kashmir has reasserted her sovereignty. Only a part of the basin of the river Gilgit is included within its political boundaries. There is an intervening width of mountainous country, represented chiefly by glaciers and ice-fields, and intersected by narrow sterile valleys, measuring some 100 to 150 miles in width, to the north and north-east, which separates the province of Gilgit from the Chinese frontier beyond the Muztagh and Karakoram. This part of the Kashmir borderland includes Kanjut (or Hunza) and Ladak. To the north-west, beyond the sources of the Yasin and Ghazar in the Shandur range (the two most westerly tributaries of the Gilgit river) is the deep valley of the Yarkhun or Chitral. Both Kanjut (or Hunza) and Chitral are included within the sphere of the Gilgit Agency, which, as a branch of the Kashmir Agency, extends British influence over the whole borderland south of Afghanistan and China. Chitral, Yasin, Panyal, the Gilgit valley, Hunza and Nagar, Astor, and the Indus valley from Bunji to Batera, together with the hills of the upper Panjkora and Swat, all fall within the political sphere of the British Agency at Gilgit, although the political boundaries of Kashmir administration only enclose the lower Gilgit valley and a portion of the Indus valley bordering Chilas.

Within these wider limits of the Agency are many mixed races, speaking eleven different languages, which have all been usually classed together under the name Dard. The Dard, however, is unknown beyond the limits of the Kohistan district of the Indus valley to the south of the Hindu Koh, the rest of the inhabitants of the Indus valley belonging to Shin republics, or Shinaka. The great mass of the Chitral population are Kho (speaking Khowar), and they may be accepted as representing the aboriginal population of the Chitral valley. (See HINDU KUSH.) Between Chitral and the Indus the "Dards" of Dardistan are chiefly Yeshkuns and Shins, and it would appear from the proportions in which these people occupy the country that they must have primarily moved up from the valley of the Indus in successive waves of conquest, first the

Yeshkuns, and then the Shins. No one can put a date to these invasions, but Biddulph is inclined to class the Yeshkuns with the Yuechi who conquered the Baktrian kingdom about 120 B.C. The Shins are obviously a Hindu race (as is testified by their veneration for the cow), who spread themselves northwards and eastwards as far as Baltistan, where they collided with the aboriginal Tatar of the Asiatic highlands. But the ethnography of "Dardistan," or the Gilgit Agency (for the two are, roughly speaking, synonymous), requires further investigation, and it would be premature to attempt to frame anything like an ethnographical history of these regions until the neighbouring provinces of Tangir and Darél have been more fully examined. No material exists on which even an approximate estimate of the population of that rough tract of country which is comprised within the Gilgit Agency can be based. The area of the Gilgit valley falling directly under Kashmir administration is about 2000 square miles, but the total area of those border districts over which British political influence extends cannot be less than 30,000.

In general appearance and dress all the mountain-bred peoples extending through these northern districts are very similar. Thick felt coats reaching below the knee, loose "pyjamas" with cloth "putties" and boots (often of English make) are almost universal, the distinguishing feature in their costume being the felt cap worn close to the head and rolled up round the edges. They are on the whole a light-hearted, cheerful race of people, but it has been observed that their temperament varies much with their habitat—those who live on the shadowed sides of mountains being distinctly more morose and more serious in disposition than the dwellers in valleys which catch the winter sunlight. They are, at the same time, bloodthirsty and treacherous to a degree which would appear incredible to a casual observer of their happy and genial manners, exhibiting a strange combination (as has been observed by a careful student of their ways) of "the monkey and the tiger." Addicted to sport of every kind, they pursue no manufacturing industries whatsoever, but they are excellent agriculturists, and show great ingenuity in their local irrigation works and in their efforts to bring every available acre of cultivable soil within the irrigated area. Gold washing is more or less carried on in most of the valleys north of the river Gilgit, and gold dust (contained in small packets formed with the petals of a cup-shaped flower) is an invariable item in their official presents and offerings. Gold dust still constitutes part of the annual tribute which, strangely enough, is paid by Hunza to China, as well as to Kashmir.

Routes in the Gilgit Agency.—One of the oldest recorded routes through this country is that which connects Mastuj in the Chitral valley with Gilgit, passing across the Shandur range (12,250). It now forms the high-road between Gilgit and Chitral, and has been engineered into a passable route. From the north three great glacier-bred affluents make their way to the river of Gilgit, joining it at almost equal intervals, and each of them affords opportunity for a rough passage northwards. (1) The Yasin river, which follows a fairly straight course from north to south for about 40 miles from the foot of the Darkôt pass across the Shandur range (15,000) to its junction with the river Gilgit, close to the little fort of Gupis, on the Gilgit–Mastuj road. Much of this valley is cultivated and extremely picturesque. At the head of it is a grand group of glaciers, one of which leads up to the well-known pass of Darkôt. (2) Twenty-five miles (by map measurement) below Gupis the Gilgit receives the Ashkuman affluent from the north. The little Lake of Karumbar is held to be its source, as it lies at the head of the river. The same lake is sometimes called the source of the river Yarkhun or Chitral; and it seems possible that a part of its waters may be deflected in each direction. The Karumbar, or Ashkuman, is nearly twice the length of the Yasin, and the upper half of the valley is encompassed by glaciers, rendering the route along it uncertain and difficult. (3) Forty miles or so below the Ashkuman junction, and nearly opposite the little station of Gilgit, the river receives certain further contributions from the north which are collected in the Hunza and Nagar basins. These basins include a system of glaciers of such gigantic proportions that they are probably unrivalled in any part of the world. The glacial head of the Hunza is not far from that of the Karumbar, and, like the Karumbar, the river commences with a wide sweep eastwards, following a course roughly parallel to the crest of the Hindu Kush (under whose southern slopes it lies close) for about 40 miles. Then striking south for another 40 miles, it twists amidst the barren feet of gigantic rock-bound spurs which reach upwards to the Muztagh peaks on the east and to a mass of glaciers and snow-fields on the west, hidden amidst the upper folds of mountains towering to an average of 25,000 feet. The next great bend is again to the west for 30 miles, before a final change of direction to the south at the historical position of Chalt and a comparatively straight run of 25 miles to a junction with the Gilgit. The valley of Hunza lies some 10 miles from the point of this westerly bend, and 20 (as the crow flies) from Chalt. Much has been written of the magnificence of Hunza valley scenery, surrounded as it is by a stupendous ring of snow-capped peaks and brightened with all the radiant beauty that cultivation adds to these mountain valleys; but such scenery must be regarded as exceptional in these northern regions.

Glaciers and Mountains.—Conway and Godwin Austen have described the glaciers of Nagar which, enclosed between the Muztagh spurs on the north-east and the frontier peaks of Kashmir (terminating with Rakapushi) on the south-west, and massing themselves in an almost uninterrupted series from the Hunza valley to the base of those gigantic peaks which stand about Mount Godwin Austen, seem to be set like an ice-sea to define the farthest bounds of the Himalaya. From its uttermost head to the foot of the Hispar, overhanging the valley above Nagar, the length of the glacial ice-bed known under the name of Biafo is said to measure about 90 miles. Throughout the mountain region of Kunjut (or Hunza) and Nagar the valleys are deeply sunk between mountain ranges which are nowhere less than 15,000 feet in altitude, and which must average above 20,000 feet. As a rule, these valleys are bare of vegetation. Where the summits of the loftier ranges are not buried beneath snow and ice they are bare, bleak and splintered, and the nakedness of the rock scenery extends down their rugged spurs to the very base of them. On the lower slopes of tumbled débris the sun in summer beats with an intensity which is unmitigated by the cloud drifts which form in the moister atmosphere of the monsoon-swept summits of the Himalaya. Sun-baked in summer and frost-riven in winter, the mountain sides are but immense ramps of loose rock débris, only awaiting the yearly melting of the upper snow-fields, or the advent of a casual rainstorm, to be swept downwards in an avalanche of mud and stones into the gorges below. Here it becomes piled and massed together, till the pressure of accumulation forces it out into the main valleys, where it spreads in alluvial fans and silts up the plains. This formation is especially marked throughout the high level valleys of the Gilgit basin.

Passes.—Each of these northern affluents of the main stream is headed by a pass, or a group of passes, leading either to the Pamir region direct, or into the upper Yarkhun valley from which a Pamir route diverges. The Yasin valley is headed by the Darkôt pass (15,000 feet), which drops into the Yarkhun not far from the foot of the Baroghil group over the main Hindu Kush watershed. The Ashkuman is headed by the Gazar and Kora Bohrt passes, leading to the valley of the Ab-i-Punja; and the Hunza by the Kilik and Mintaka, the connecting links between the Taghdumbash Pamir and the Gilgit basin. They are all about the same height—15,000 feet. All are passable at certain times of the year to small parties, and all are uncertain. In no case do they present insuperable difficulties in themselves, glaciers and snow-fields and mountain staircases being common to all; but the gorges and precipices which distinguish the approaches to them from the south, the slippery sides of shelving spurs whose feet are washed by raging torrents, the perpetual weary monotony of ascent and descent over successive ridges multiplying the gradient indefinitely—these form the real obstacles blocking the way to these northern passes.

Gilgit Station.—The pretty little station of Gilgit (4400 feet above sea) spreads itself in terraces above the right bank of the river nearly opposite the opening leading to Hunza, almost nestling under the cliffs of the Hindu Koh which separates it on the south from the savage mountain wilderness of Darél and Kohistan. It includes a residency for the local political officer, with about half a dozen homes for the accommodation of officials, barracks suitable for a battalion of Kashmir troops, and a hospital. Evidences of Buddhist occupation are not wanting in Gilgit, though they are few and unimportant. Such as they are, they appear to prove that Gilgit was once a local Buddhist centre, and that the old Buddhist route between Gilgit and the Peshawar plain passed through the gorges and clefts of the unexplored Darél valley to Thakot under the northern spurs of the Black Mountain.

Connexion with India.—The Gilgit river joins the Indus a few miles above the little post of Bunji, where an excellent suspension bridge spans the river. The valley is low and hot, and the scenery between Gilgit and Bunji is monotonous; but the road is now maintained in excellent condition. A little below Bunji the Astor river joins the Indus from the south-east, and this deep pine-clad valley indicates the continuation of the high-road from Gilgit to Kashmir *viâ* the Tragbal and Burzil passes. Another well-known route connecting Gilgit with the Abbottabad frontier of the Punjab lies across the Babusar pass (13,000 feet), linking the lovely Hazara valley of Kaghán to Chilas; Chilas (4150 feet) being on the Indus, some 50 miles below Bunji. This is a more direct connexion between Gilgit and the plains of the Punjab than that afforded by the Kashmir route *viâ* Gurais and Astor, which latter route involves two considerable passes—the Tragbal (11,400) and the Burzil (13,500); but the intervening strip of absolutely independent territory (independent alike of Kashmir and the Punjab), which includes the hills bordering the road from the Babusar pass to Chilas, renders it a risky route for travellers unprotected by a military escort. Like the Kashmir route, it is now defined by a good military road.

AUTHORITIES.—BIDDULPH. *The Tribes of the Hindu Kush.* Calcutta, 1880.—W. LAWRENCE. *The Kashmir Valley.* London, 1895.—TANNER. "Our Present Knowledge of the Himalaya." *Proc. R.G.S.*, vol. xiii., 1891.—DURAND. *Making a Frontier.* London, 1899. — *Report of Lockhart's Mission.* Calcutta, 1886.—E. F. KNIGHT. *Where Three Empires Meet.* London, 1892.—F. YOUNGHUSBAND. "Journeys in the Pamirs and Adjacent Countries." *Proc. R.G.S.*, vol. xiv., 1892.—CURZON. "Pamirs." *Jour. R.G.S.*, vol. viii., 1896.—LEIBNÉR. *Dardistan.* (T. H. H*.)

Gilly, a town of Belgium, in the province of Hainaut, 2 miles north-east of Charleroi by rail. It has coal-pits and numerous factories, which include glass and nail works. Population (communal, 1899), 23,298.

Gilman, Daniel Coit (1831-——), American educationalist, was born in Norwich, Connecticut, 6th July 1831. He graduated at Yale in 1852, studied in Berlin, and between 1856 and 1870 was professor of physical geography at Yale, in 1872 becoming president of the University of California, at Berkeley, near San Francisco. In 1875 he was chosen first president of Johns Hopkins University at Baltimore, a post which he filled until 1901. His influence upon higher education in America has been great. Under his direction Johns Hopkins became the first university in the United States to develop a strong graduate department under competent professors, in which holders of bachelors' degrees pursued non-professional and advanced work (leading to the degree of Doctor of Philosophy) in philology, biology, physics, and other subjects. Johns Hopkins retains its superiority, in this respect, among the institutions of the old southern states; and its methods have been widely spread by the work of the recipients of its higher degrees. Some of Dr Gilman's papers and addresses are gathered in a volume, entitled *University Problems in the United States* (1898), representing his mature conclusions on many educational themes. He is also the author of a work on *James Monroe in his Relations to the Public Service during Half a Century* (1883) in the American Statesmen Series, and a *Life of James D. Dana*, the geologist (1899).

Ginsburg, Christian David (1831-——), Hebrew scholar, was born at Warsaw, 25th December 1831. Coming to England shortly after the completion of his education in the Rabbinic College at Warsaw, Dr Ginsburg continued his study of the Hebrew Scriptures, with special attention to the Megilloth. The first result of these studies was a translation of the Song of Songs, with a commentary historical and critical, published in 1857, and containing a careful elucidation of the text in accordance with the established laws of historico-grammatical exegesis. A similar translation of Ecclesiastes, followed by treatises on the Karaites, on the Essenes, and on the Kabbalah, kept the author prominently before Biblical critics while he was preparing the first sections of his *magnum opus*, the critical study of the Massorah. Beginning in 1867 with the publication of Jacob ben Chajim's Introduction to the Rabbinic Bible, Hebrew and English, with notices, and the Massoreth Ha-Massoreth of Elias Levita, in Hebrew, with translation and commentary, Dr Ginsburg at once became an authority on Biblical Hebrew criticism. In 1870 he was appointed one of the first members of the committee for the revision of the English version of the Old Testament. His life-work culminated in the publication of the Massorah, in three volumes folio (1880–86), followed by the Masoretico-critical edition of the Hebrew Bible (1894), and the elaborate introduction to it (1897). In attempting to appreciate the value of Dr Ginsburg's work, and the vast labour it has entailed, it is necessary to bear in mind the character and peculiarities of the Massorah itself. This elaborate code of marginal references and exhaustive notes, collating and calling attention to the minutest peculiarities of style, grammar, or spelling, originated in the wise forethought of the Jewish scribes, who thus endeavoured to guard against even the most trivial variation in copying the Holy Scriptures. After being, as its name signifies, an oral tradition, the Massorah was reduced to writing, probably about the 3rd century before Christ, by the Jewish scholars of Palestine.

The growing vastness of the work soon rendered it impossible to transcribe the whole of the Massorah in any single manuscript of the Bible, and consequently portions only were copied. Gradually these portions were written in a contracted form and purposely rendered difficult by the copyists, who expended their ingenuity in the fantastical transcription of words which they had long ceased to understand. Such are the MSS. which Dr Ginsburg has deciphered, transcribed, and collated. He had one predecessor in the field, the learned Jacob ben Chajim, who in 1524–25 published the second Rabbinic Bible, containing what has ever since been known as the Massorah; but neither were the materials available nor was criticism sufficiently advanced for a complete edition. It was reserved for Dr Ginsburg to take up the subject almost where it was left by those early pioneers, and to collect portions of the Massorah from the countless MSS. scattered throughout Europe and the East. Dr Ginsburg's latest contribution to the branch of learning which he has made so peculiarly his own is a critical treatise "on the relationship of the so-called Codex Babylonicus of A.D. 916 to the Eastern Recension of the Hebrew Text." In this work he proves that the St Petersburg Codex, for so many years accepted as the genuine text of the Babylonian School, is in reality a Palestinian text carefully altered so as to render it conformable to the Babylonian recension.

Giolitti, Giovanni (1842– ——), Italian statesman, was born at Mondovì on 27th October 1842. After a rapid career in the financial administration he was, in 1882, appointed councillor of state and elected to parliament. As deputy he chiefly acquired prominence by attacks on Magliani, treasury minister in the Depretis cabinet, and on 9th March 1899 was himself selected as treasury minister by Crispi. On the fall of the Rudinì cabinet in May 1892, Giolitti, with the help of a Court clique, succeeded to the premiership. His term of office was marked by misfortune and misgovernment. The building crisis and the commercial rupture with France had impaired the situation of the state banks, of which one, the Banca Romana, had been further undermined by maladministration. A bank law, passed by Giolitti, failed to effect an improvement. Moreover, he irritated public opinion by raising to senatorial rank the director-general of the Banca Romana, Signor Tanlongo, whose irregular practices had become a byword. The Senate declined to admit Tanlongo, whom Giolitti, in consequence of an interpellation in parliament upon the condition of the Banca Romana, was obliged to arrest and prosecute. During the prosecution Giolitti abused his position as premier to abstract documents bearing on the case. Simultaneously a parliamentary commission of inquiry investigated the condition of the state banks. Its report, though acquitting Giolitti of personal dishonesty, proved disastrous to his political position, and obliged him to resign. His fall left the finances of the state disorganized, the pensions fund depleted, diplomatic relations with France strained in consequence of the massacre of Italian workmen at Aigues-Mortes, and Sicily and the Lunigiana in a state of revolt, which he had proved impotent to suppress. After his resignation he was impeached for abuse of power as minister, but the supreme court quashed the impeachment by denying the competence of the ordinary tribunals to judge ministerial acts. For several years Giolitti, while retaining his seat in the Chamber, was compelled by public opinion to play a passive part, but later he took the leadership of a group of deputies, with whose help he succeeded by degrees in regaining some portion of his former influence.

Girgeh, or Girga, a town and former capital of Upper Egypt, on the left bank of the Nile. It is an important railway station on the Nile valley line, 336 miles from Cairo, with a population in 1900 of about 15,000, and probably occupies the site of This (Tini), one of the oldest places in Egypt. It stood formerly at some distance from the river, but is now on the bank, the intervening space having been washed away, together with a large part of the town, by the stream continually encroaching on its left bank.

Girgenti, a town, episcopal see, and capital of the province of Girgenti, Sicily, Italy, about midway on the south coast, but 3 miles from the sea and 58 miles south from Palermo. A new aqueduct from Poltano, 23 miles distant, has been made since 1897. Population (1881), 20,391; (1901), 25,069.

Gironde, a department in the south-west of France, bathed by the Atlantic Ocean, and watered by the Garonne and the Dordogne, which unite under the name of the Gironde.

Area, 4141 square miles. The population increased from 775,845 in 1886 to 820,781 in 1900. Births in 1899, 14,908, of which 1817 were illegitimate; deaths, 16,216. There were in 1896 1280 schools, with 93,000 pupils, and the illiterate formed 4 per cent. of the population. The area under cultivation comprised in 1896 1,974,400 acres, of which 499,000 acres were arable and 336,000 acres vineyard. Woods and forests occupy more than 740,000 acres, principally in the region of the Landes. In 1899 the produce of wheat amounted to the value of £980,000; rye yielded £21,000; oats, £38,000; maize, £40,000. The natural pastures returned a value of £607,000. A little tobacco also is cultivated. The great source, however, of the wealth of the Gironde is its wine, which in 1899 yielded a value of more than 3½ millions sterling. Gironde has no great industries except those connected with alimentation. Gironde in 1899 owned 50,160 horses, 139,330 cattle, 236,710 sheep, and 67,800 pigs. The distilleries of alcohol have, however, assumed large proportions, turning out in 1898 no less than 1,282,000 gallons. Bordeaux, the capital, had in 1901 a population of 257,471.

Girvan, a police burgh, market and fishing town of Ayrshire, Scotland, at the mouth of the river Girvan, 21½ miles south-south-west of Ayr by rail. The harbour has been improved by the building of a pier and breakwater, and a sewage scheme has been carried out. There is a Roman Catholic church and convent. Population (1881), 4505; (1901), 4019.

Gitschin (Czech, *Jičin*), the chief town of a government district in Bohemia, Austria. It has a garrison of 834 men, and an important corn trade, together with large sugar refineries, and the manufacture of paper, soda-water, beer, &c. Population, mostly Czech (1890), 8457; (1900), 9790.

Giurgevo, or Giurgiu, a town in Rumania, on the left bank of the Danube opposite Rustchuk in Bulgaria. It is the seat of a court of first instance, has four Rumanian churches, one Greek church, and two synagogues. Its port is at Smarda, 2½ miles east of the town. Giurgevo is the terminus of the first railway constructed in Rumania (Bucarest–Giurgiu), and is a town of considerable commercial importance. The export trade in 1898 was valued at £591,660. Population (1900), 13,977.

Givet, a town and important railway junction in the arrondissement of Rocroi, department of Ardennes, France, 40 miles by rail north of Mézières. The fortifications, with the exception of the citadel of Charlemont, were demolished in 1892. In the new quarter is a statue of the musician Méhul (1892). The town has considerable river traffic; total tonnage entered 1900, 32,332, consisting chiefly of coal, copper, and stones. Population (1881), 4932; (1901), 7011.

Gladbach, or MÜNCHEN-GLADBACH, a town of Prussia, in the Rhine province, 16 miles by rail west by south from Düsseldorf. There are monuments to the Emperor William I. (1897) and to Bismarck (1900). The cotton and other industries still flourish vigorously, and there is also manufacture of account books, cloth, stove tiles, paper, hosiery, linen, shoes, and breweries. Population (1885), 44,230; (1900), 58,014.

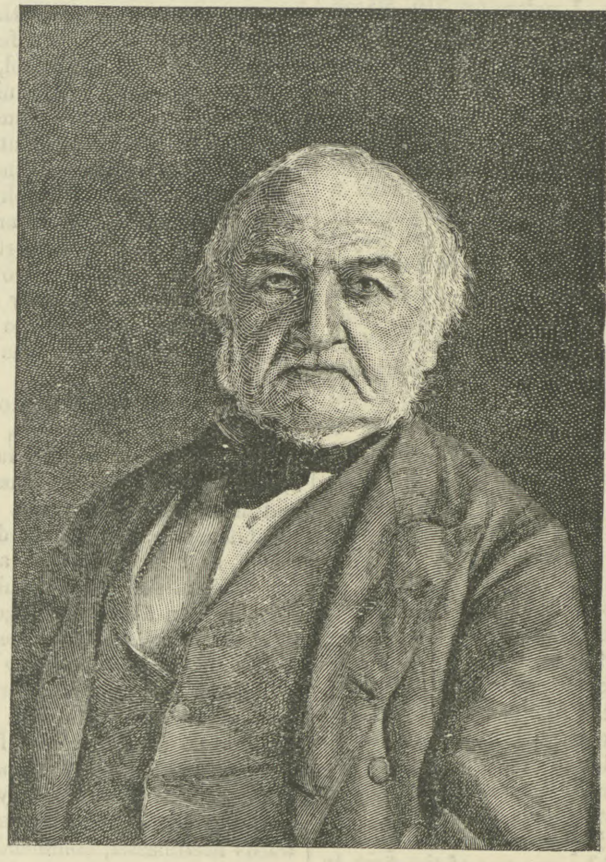
Gladstone, John Hall (1827– ——), English chemist, was born at Hackney, London, on 7th March 1827. From childhood he showed great aptitude for science; geology was his favourite subject, but since this in his father's opinion did not afford a career of promise, he devoted himself to chemistry, which he studied under Graham at University College, London, and Liebig at Giessen. In 1850 he became chemical lecturer at St Thomas's Hospital, and three years later was elected a fellow of the Royal Society at the unusually early age of twenty-six. From 1858 to 1861 he served on the Royal Commission on Lighthouses, and from 1864 to 1868 was a member of the War Office committee on gun-cotton. From 1874 to 1877 he was Fullerian professor of chemistry at the Royal Institution, in 1874 he was chosen first president of the Physical Society, and in 1877–79 he was president of the Chemical Society. In 1897 the Royal Society recognized his fifty years of scientific work by awarding him the Davy medal. Dr Gladstone's researches have been large in number and wide in range, dealing to a great extent with problems that lie on the border-line between physics and chemistry—with that physical chemistry which was the creation of the latter part of the 19th century. Thus a number of his inquiries, and those not the least important, have been partly chemical, partly optical. He determined the optical constants of hundreds of substances, with the object of discovering whether any of the elements possesses more than one refractive equivalent. Again, he investigated the connexion between the optical behaviour, specific gravity, and chemical composition of ethereal oils, and the relation between molecular magnetic rotation and the refraction and dispersion of nitrogenous compounds. So early as 1856 he showed the importance of the spectroscope in chemical research, and he was one of the first to notice that the Fraunhofer spectrum at sunrise and sunset differs from that at midday, his conclusion being that the earth's atmosphere must be responsible for many of its absorption lines, which indeed have been subsequently traced to the oxygen and water-vapour in the air. Another portion of his work was of an electro-chemical character. His studies, with Hibbert, in the chemistry of the storage battery have added largely to our knowledge, while the "copper-zinc couple," with which his name is associated together with that of Tribe, among other things afforded a simple means of preparing certain organo-metallic compounds, and thus promoted research in branches of organic chemistry where those bodies are especially useful. Mention may also be made of his work on phosphorus, on explosive substances such as iodide of nitrogen, gun-cotton, and the fulminates, on the influence of mass in the process of chemical transformations, and on the effect of carbonic anhydride on the germination of plants. Dr Gladstone has always taken a great interest in educational questions, and from 1873 to 1894 he was a representative for Chelsea on the London School Board, of which for three years he acted as vice-chairman.

Gladstone, William Ewart (1809–1898), British statesman, was born on 29th December 1809 at No. 62 Rodney Street, Liverpool. His forefathers were Gledstanes of Gledstanes, in the upper ward of Lanarkshire; or, in Scottish phrase, Gledstanes of that Ilk. As years went on their estates dwindled, and by the beginning of the 17th century Gledstanes was sold. The adjacent property of Arthurshiel remained in the hands of the family for nearly a hundred years longer. Then the son of the last Gledstanes of Arthurshiel removed to Biggar, where he opened the business of a maltster. His grandson, Thomas Gladstone (for so the name was modified), became a corn-merchant at Leith. He happened to send his eldest son, John, to Liverpool to sell a cargo of grain there, and the energy and aptitude of the young man attracted the favourable notice of a leading corn-merchant of Liverpool, who recommended him to settle in that city. Beginning his commercial career as a clerk in his patron's house, John Gladstone lived to become one of the merchant-princes of Liverpool, a baronet, and a member of parliament. He died in 1851, at the age of eighty-seven. Sir John Gladstone was a pure Scotsman, a Lowlander by birth and descent. He married Anne, daughter of Andrew Robertson of Stornoway, sometime Provost of Dingwall. Provost Robertson belonged to the Clan Donachie, and by this marriage the robust and business-like qualities of the Lowlander were blended with the poetic imagination, the sensibility, and fire of the Gael.

Childhood and Education.

John and Anne Gladstone had six children. The fourth son, William Ewart, was named after a merchant of Liverpool who was his father's friend. He seems to have been a remarkably good child, and much beloved at home. In 1818 or 1819 Mrs Gladstone, who belonged to the Evangelical school, said in a letter to a friend, that she believed her son William had been "truly converted to God." After some tuition at the vicarage of Seaforth, a watering-place near Liverpool, the boy went to Eton in 1821. His tutor was the Rev. Henry Hartopp Knapp. His brothers, Thomas and Robertson Gladstone, were already at Eton. Thomas was in the fifth form, and William, who was placed in the middle remove of the fourth form, became his eldest brother's fag. He worked hard at his classical lessons, and supplemented the ordinary business of the school by studying mathematics in the holidays. Mr Hawtrey, afterwards headmaster, commended a copy of his Latin verses, and "sent him up for good"; and this experience first led the young student to associate intellectual work with the ideas of ambition and success. He was not a fine scholar, in that restricted sense of the term which implies a special aptitude for turning English into Greek and Latin, or for original versification in the classical languages. "His composition," we read, "was stiff," but he was imbued with the substance of his authors; and a contemporary who was in the sixth form with him recorded that "when there were thrilling passages of Virgil or Homer, or difficult passages in the *Scriptores Graeci* to translate, he or Lord Arthur Hervey was generally called up to edify the class with quotation or translation." By common consent he was pre-eminently God-fearing, orderly, and conscientious. "At Eton," said Bishop Hamilton of Salisbury, "I was a thoroughly idle boy, but I was saved from some worse things by getting to know Gladstone." His most intimate friend was Arthur Hallam, by universal acknowledgment the most remarkable Etonian of his day; but he was not generally popular or even widely known. He was seen to the greatest advantage, and was most thoroughly at home, in the debates of the Eton Society, learnedly called "The Literati" and vulgarly "Pop," and in the editorship of the *Eton Miscellany*. He left Eton at Christmas 1827. He read for six months with private tutors, and in October 1828 went up to Christ Church, where, in the following year, he was nominated to a Studentship.

At Oxford Gladstone read steadily, but not laboriously, till he neared his final Schools. During the latter part of his undergraduate career he took a brief but brilliant share in the proceedings of the Union, of which he was successively Secretary and President. He made his first speech on 11th February 1830. Brought up in the nurture and admonition of Canning, he defended Roman Catholic emancipation, and thought the Duke of Wellington's Government unworthy of national confidence. He opposed the removal of Jewish disabilities, arguing, we are told by a contemporary, "on the part of the Evangelicals," and pleaded for the gradual extinction, in preference to the immediate abolition, of slavery. But his great achievement was a speech against the Whig Reform Bill. One who heard this famous discourse says: "Most of the speakers rose, more or less, above their usual level, but when Mr Gladstone sat down we all of us felt that an epoch in our lives had occurred. It certainly was the finest speech of his that I ever heard." Bishop Charles Wordsworth said that his experience of Gladstone at this time "made me (and I doubt not others also) feel no less sure than of my own existence that Gladstone, our then Christ Church undergraduate, would one day rise to be Prime Minister of England." In December 1831 Gladstone crowned his career by taking a double first-class. Lord Halifax (1800–1885) used to say, with reference to the increase in the amount of reading requisite for the highest honours: "My double-first must have been a better thing than Peel's; Gladstone's must have been better than mine."



William Ewart Gladstone (1895).
(From a photograph by Elliott and Fry, London.)

Now came the choice of a profession. Deeply anxious to make the best use of his life, Gladstone turned his thoughts to Holy Orders. But his father had determined to make him a politician. Quitting Oxford in the spring of 1832, Gladstone spent six months in Italy, learning the language and studying art. In the following September he was suddenly recalled to England, to undertake his first parliamentary campaign. The fifth Duke of Newcastle was one of the chief potentates of the High Tory party. His frank claim to "do what he liked with his own" in the representation of Newark has given him a place in political history. But that claim had been rudely disputed by the return of a Radical lawyer at the election of 1831. The Duke was anxious to obtain a capable candidate to aid him in regaining his ascendancy over the rebellious borough. His son, Lord Lincoln, had heard Gladstone's speech against the Reform Bill delivered in the Oxford Union, and had written home that "a man had uprisen in Israel." At his suggestion the Duke invited Gladstone to stand for Newark in the Tory interest against Mr Serjeant Wilde, afterwards Lord Chancellor Truro. The last of the Unreformed Parliaments was dissolved on the 3rd December 1832. Gladstone, addressing the electors of Newark, said that he was bound by the opinions of no man and no party, but felt it a duty to watch and resist that growing desire for change which threatened to produce "along with partial good a melancholy preponderance of mischief." The first principle to which he looked for national salvation was, that the "duties of governors are strictly and peculiarly religious, and that legislatures, like individuals, are bound to carry throughout their acts the spirit of the high truths they have acknowledged." The condition of the poor demanded special attention; labour should receive adequate remuneration; and he thought favourably of the "allotment of cottage grounds." He regarded slavery as sanctioned by Holy Scripture, but the slaves ought to be educated, and gradually emancipated. The contest resulted in his return at the head of the poll.

Entry into Parliament.

The first Reformed Parliament met on 29th January 1833, and the young member for Newark took his seat for the first time in an assembly which he was destined to adorn, delight, and astonish for more than half a century. His maiden speech was delivered on the 3rd June, in reply to what was almost a personal challenge. The Colonial Secretary, Mr Stanley, afterwards Lord Derby, brought forward a series of resolutions in favour of the extinction of slavery in the British colonies. On the first night of the debate Lord Howick, afterwards Lord Grey, who had been Under-Secretary for the Colonies, and who opposed the resolutions as proceeding too gradually towards abolition, cited certain occurrences on Sir John Gladstone's plantation in Demerara to illustrate his contention that the system of slave-labour in the West Indies was attended by great mortality among the slaves. Gladstone in his reply—his first speech in the House—avowed that he had a pecuniary interest in the question, "and, if he might say so much without exciting suspicion, a still deeper interest in it as a question of justice, of humanity, and of religion." If there had recently been a high mortality on his father's plantation, it was due to the age of the slaves rather than to any peculiar hardship in their lot. It was true that the particular system of cultivation practised in Demerara was more trying than some others; but then it might be said that no two trades were equally conducive to health. Steel-grinding was notoriously unhealthy, and manufacturing processes generally were less favourable to life than agricultural. While strongly condemning cruelty, he declared himself an advocate of emancipation, but held that it should be

The question of slavery.

effected gradually, and after due preparation. The slaves must be religiously educated, and stimulated to profitable industry. The owners of emancipated slaves were entitled to receive compensation from Parliament, because it was Parliament that had established this description of property. "I do not," said Gladstone, "view property as an abstract thing; it is the creature of civil society. By the legislature it is granted, and by the legislature it is destroyed." On the following day King William IV. wrote to Lord Althorp: "The King rejoices that a young member has come forward in so promising a manner as Viscount Althorp states Mr W. E. Gladstone to have done." In the same session Gladstone spoke on the question of bribery and corruption at Liverpool, and on the temporalities of the Irish Church. In the session of 1834 his most important performance was a speech in opposition to Hume's proposal to throw the Universities open to Dissenters.

On 10th November 1834 Lord Althorp succeeded to his father's peerage, and thereby vacated the leadership of the House of Commons. The Prime Minister, Lord Melbourne, submitted to the King a choice of names for the Chancellorship of the Exchequer and leadership of the House of Commons; but His Majesty announced that, having lost the services of Lord Althorp as Leader of the House of Commons, he could feel no confidence in the stability of Lord Melbourne's Government, and that it was his intention to send for the Duke of Wellington. The Duke took temporary charge of affairs, but Peel was felt to be indispensable. He had gone abroad after the session, and was now in Rome. As soon as he could be brought back he formed an administration, and appointed Gladstone to a Junior Lordship of the Treasury. Parliament was dissolved on 29th December. Gladstone was returned unopposed, this time in conjunction with the Liberal lawyer whom he had beaten at the last election. The new Parliament met on 19th February 1835. The elections had given the Liberals a considerable majority. Immediately after the meeting of Parliament Gladstone was promoted to the Under-Secretaryship for the Colonies, where his official chief was Lord Aberdeen. The administration was not long-lived. On 30th March Lord John Russell moved a resolution in favour of an inquiry into the temporalities of the Irish Church, with the intention of applying the surplus to general education without distinction of religious creed. This was carried against ministers by a majority of thirty-three. On 8th April Sir Robert Peel resigned, and the Under-Secretary for the Colonies of course followed his chief into private life.

Released from the labours of office, Gladstone, living in chambers in the Albany, practically divided his time between his parliamentary duties and study. Then, as always, his constant companions were Homer and Dante, and it is recorded that he read the whole of St Augustine, in twenty-two octavo volumes. He used to frequent the services at St James's, Piccadilly, and Margaret Chapel, since better known as All Saints', Margaret Street. On 20th June 1837 King William IV. died, and Parliament, having been prorogued by the young Queen in person, was dissolved on the 17th of the following month. Simply on the strength of his parliamentary reputation Gladstone was nominated, without his consent, for Manchester, and was placed at the bottom of the poll; but, having been at the same time nominated at Newark, was again returned. The year 1838 claims special note in a record of Gladstone's life, because it witnessed the appearance of his famous work on *The State in its Relations with the Church.* He had left Oxford just before the beginning of that Catholic revival which has transfigured both the inner spirit and the outward aspect of the Church of England. But the revival was now in full strength. The *Tracts for the Times* were saturating England with new influences. The movement counted no more enthusiastic or more valuable disciple than Gladstone. Its influence had reached him through his friendships, notably with two Fellows of Merton — Mr James Hope, who became Mr Hope-Scott of Abbotsford, and the Rev. H. E. Manning, afterwards Cardinal Archbishop. *The State in its Relations* was his practical contribution to a controversy in which his deepest convictions were involved. He contended that the Church, as established by law, was to be "maintained for its truth," and that this principle, if good for England, was good also for Ireland.

Literary work.

On 25th July 1839 Gladstone was married at Hawarden to Miss Catherine Glynne, sister, and in her issue heir, of Sir Stephen Glynne, ninth and last baronet of that name. In 1840 he published *Church Principles considered in their Results.*

Parliament was dissolved in June 1841. Gladstone was again returned for Newark. The General Election resulted in a Tory majority of eighty. Sir Robert Peel became Prime Minister, and made the member for Newark Vice-President of the Board of Trade. An inevitable change is from this time to be traced in the topics of Gladstone's parliamentary speaking. Instead of discoursing on the corporate conscience of the State and the endowments of the Church, the importance of Christian education, and the theological unfitness of the Jews to sit in Parliament, he is solving business-like problems about foreign tariffs and the exportation of machinery; waxing eloquent over the regulation of railways, and a graduated tax on corn; subtle on the monetary merits of half-farthings, and great in the mysterious lore of *quassia* and *cocculus indicus.* In 1842 he had a principal hand in the preparation of the Revised Tariff, by which duties were abolished or sensibly diminished in the case of 1200 duty-paying articles. In defending the new scheme he spoke incessantly, and amazed the House by his mastery of detail, his intimate acquaintance with the commercial needs of the country, and his inexhaustible power of exposition. In 1843 Gladstone, succeeding Lord Ripon as President of the Board of Trade, became a member of the Cabinet at the age of thirty-three. He has recorded the fact that "the very first opinion which he ever was called upon to give in Cabinet" was an opinion in favour of withdrawing the Bill providing education for children in factories, to which vehement opposition was offered by the Dissenters on the ground that it was too favourable to the Established Church.

Enters the Cabinet.

At the opening of the session of 1845 the Government, in pursuance of a promise made to Irish members that they would deal with the question of academical education in Ireland, proposed to establish non-sectarian colleges in that country and to make a large addition to the grant to the Roman Catholic College of Maynooth. Gladstone resigned office, in order, as he announced in the debate on the Address, to form "not only an honest, but likewise an independent and an unsuspected judgment," on the plan to be submitted by the Government with respect to Maynooth. His subsequent defence of the proposed grant, on the ground that it would be improper and unjust to exclude the Roman Catholic Church in Ireland from a "more indiscriminating support" which the State might give to various religious beliefs, was regarded by men of less sensitive conscience as only proving that there had been no adequate cause for his resignation.

Maynooth grant: resignation.

Before he resigned he completed a second Revised Tariff, carrying considerably farther the principles on which he had acted in the earlier revision of 1842.

In the autumn of 1845 the failure of the potato crop in Ireland threatened a famine, and convinced Sir Robert Peel that all restrictions on the importation of food must be at once suspended. He was supported by only three members of the Cabinet, and resigned on 5th December. Lord John Russell, who had just announced his conversion to total and immediate repeal of the Corn Laws, declined the task of forming an administration, and on 20th December Sir Robert Peel resumed office. Lord Stanley refused to re-enter the Government, and his place as Secretary of State for the Colonies was offered to and accepted by Gladstone. He did not offer himself for re-election at Newark, and remained outside the House of Commons during the great struggle of the coming year. It was a curious irony of fate which excluded him from Parliament at this crisis, for it seems unquestionable that he was the most advanced Free Trader in Sir Robert Peel's Cabinet. The Corn Bill passed the House of Lords on the 28th June 1846, and on the same day the Government were beaten in the House of Commons on an Irish Coercion Bill. Lord John Russell became Prime Minister, and Gladstone retired for a season into private life. Early in 1847 it was announced that one of the two members for the University of Oxford intended to retire at the General Election, and Gladstone was proposed for the vacant seat. The representation of the university had been pronounced by Canning to be the most coveted prize of public life, and Gladstone himself confessed that he "desired it with an almost passionate fondness." Parliament was dissolved on 23rd July 1847. The nomination at Oxford took place on 29th July, and at the close of the poll Sir Robert Inglis stood at the head, with Gladstone as his colleague.

Free Trade.

The three years 1847, 1848, 1849 were for Gladstone a period of mental growth, of transition, of development. A change was silently proceeding, which was not completed for twenty years. "There have been," he wrote in later days to Bishop Wilberforce, "two great deaths, or transmigrations of spirit, in my political existence—one, very slow, the breaking of ties with my original party." This was now in progress. In the winter of 1850–51 Gladstone spent between three and four months at Naples, where he learned that more than half the Chamber of Deputies, who had followed the party of Opposition, had been banished or imprisoned; that a large number, probably not less than 20,000, of the citizens had been imprisoned on charges of political disaffection, and that in prison they were subjected to the grossest cruelties. Having made careful investigations, Gladstone, on 7th April 1851, addressed an Open Letter to Lord Aberdeen, bringing an elaborate, detailed, and horrible indictment against the rulers of Naples, especially as regards the arrangements of their prisons and the treatment of persons confined in them for political offences. The publication of this letter caused a wide sensation in England and abroad, and profoundly agitated the Court of Naples. In reply to a question in the House of Commons, Lord Palmerston accepted and adopted Gladstone's statement, expressed keen sympathy with the cause which he had espoused, and sent a copy of his Letter to the Queen's representative at every court of Europe. A second Letter and a third followed, and their effect, though for a while retarded, was unmistakably felt in the subsequent revolution which created a free and united Italy.

Naples prisons.

In February 1852 the Whig Government was defeated on a Militia Bill, and Lord John Russell was succeeded by Lord Derby, formerly Lord Stanley, with Mr Disraeli, who now entered office for the first time, as Chancellor of the Exchequer and Leader of the House of Commons. Mr Disraeli introduced and carried a makeshift Budget, and the Government tided over the session, and dissolved Parliament on 1st July 1852. There was some talk of inducing Gladstone to join the Tory Government, and on 29th November Lord Malmesbury dubiously remarked, "I cannot make out Gladstone, who seems to me a dark horse." In the following month the Chancellor of the Exchequer produced his second Budget. The Government redeemed their pledge to do something for the relief of the agricultural interest by reducing the duty on malt. This created a deficit, which they repaired by doubling the duty on inhabited houses. The voices of criticism were heard simultaneously on every side. The debate waxed fast and furious. In defending his proposals Mr Disraeli gave full scope to his most characteristic gifts; he pelted his opponents right and left with sarcasms, taunts, and epigrams. Gladstone delivered an unpremeditated reply, which has ever since been celebrated. Tradition says that he "foamed at the mouth." The speech of the Chancellor of the Exchequer, he said, must be answered "on the moment." It must be "tried by the laws of decency and propriety." He indignantly rebuked his rival's language and demeanour. He tore his financial scheme to ribbons. It was the beginning of a duel which lasted till death removed one of the combatants from the political arena. "Those who had thought it impossible that any impression could be made upon the House after the speech of Mr Disraeli had to acknowledge that a yet greater impression was produced by the unprepared reply of Mr Gladstone." The House divided, and the Government were left in a minority of nineteen. Lord Derby resigned.

Gladstone and Disraeli.

The new Government was a coalition of Whigs and Peelites. Lord Aberdeen became Prime Minister, and Gladstone Chancellor of the Exchequer. Having been returned again for the University of Oxford, he entered on the active duties of a great office for which he was pre-eminently fitted by an unique combination of financial, administrative, and rhetorical gifts. His first Budget was introduced on 18th April 1853. It tended to make life easier and cheaper for large and numerous classes; it promised wholesale remissions of taxation; it lessened the charges on common processes of business, on locomotion, on postal communication, and on several articles of general consumption. The deficiency thus created was to be met by a "succession-duty," or application of the legacy-duty to real property; by an increase of the duty on spirits; and by the extension of the income-tax, at 5d. in the pound, to all incomes between £100 and £150. The speech in which these proposals were introduced held the House spell-bound. Here was an orator who could apply all the resources of a burnished rhetoric to the elucidation of figures; who could sweep the widest horizon of the financial future, and yet stoop to bestow the minutest attention on the microcosm of penny stamps and post-horses. Above all, the Chancellor's mode of handling the income-tax attracted interest and admiration. It was a searching analysis of the financial and moral grounds on which the impost rested, and a historical justification and eulogy of it. Yet, great as had been the services of the tax at a time of national danger, Gladstone could not consent to retain it as a part of the permanent and ordinary finances of the country. It was objectionable on account of its unequal incidence, of the harassing investigation into private affairs which it entailed, and of the frauds to which

Chancellor of the Exchequer.

it inevitably led. Therefore, having served its turn, it was to be extinguished in 1860. The scheme astonished, interested, and attracted the country. The Queen and Prince Albert wrote to congratulate the Chancellor of the Exchequer. Public authorities and private friends joined in the chorus of eulogy. The Budget demonstrated at once its author's absolute mastery over figures and the persuasive force of his expository gift. It established the Chancellor of the Exchequer as the paramount financier of his day, and it was only the first of a long series of similar performances, different, of course, in detail, but alike in their bold outlines and brilliant handling. Looking back on a long life of strenuous exertion, Gladstone declared that the work of preparing his proposals about the succession-duty and carrying them through Parliament was by far the most laborious task which he ever performed.

War between Great Britain and Russia was declared on 27th March 1854, and it thus fell to the lot of the most pacific of ministers, the devotee of retrenchment, and the anxious cultivator of all industrial arts, to prepare a war-budget, and to meet as well as he might the exigencies of a conflict which had so cruelly dislocated all the ingenious devices of financial optimism. No amount of skill in the manipulation of figures, no ingenuity in shifting fiscal burdens, could prevent the addition of forty-one millions to the national debt, or could countervail the appalling mismanagement at the seat of war. Gladstone declared that the state of the army in the Crimea was a "matter for weeping all day and praying all night." As soon as Parliament met in January 1855 J. A. Roebuck, the Radical member for Sheffield, gave notice that he would move for a select committee "to inquire into the condition of our army before Sebastopol, and into the conduct of those departments of the Government whose duty it has been to minister to the wants of that army." On the same day Lord John Russell, without announcing his intention to his colleagues, resigned his office as President of the Council sooner than attempt the defence of the Government. Gladstone, in defending the Government against Roebuck, rebuked in dignified and significant terms the conduct of men who, "hoping to escape from punishment, ran away from duty." On the division on Mr Roebuck's motion the Government was beaten by the unexpected majority of 157.

Lord Palmerston became Prime Minister. The Peelites joined him, and Gladstone resumed office as Chancellor of the Exchequer. A shrewd observer at the time pronounced him indispensable. "Any other Chancellor of the Exchequer would be torn in bits by him." The Government was formed on the understanding that Mr Roebuck's proposed committee was to be resisted. Lord Palmerston soon saw that further resistance was useless; his Peelite colleagues stuck to their text, and, within three weeks after resuming office, Gladstone, Sir James Graham, and Mr Sidney Herbert resigned. Gladstone once said of himself and his Peelite colleagues, during the period of political isolation, that they were like roving icebergs on which men could not land with safety, but with which ships might come into perilous collision. He now applied himself specially to financial criticism, and was perpetually in conflict with the Chancellor of the Exchequer, Sir George Cornewall Lewis.

In 1858 Lord Palmerston was succeeded by Lord Derby at the head of a Conservative administration, and Gladstone accepted the temporary office of High Commissioner Extraordinary to the Ionian Islands. Returning to England for the session of 1859, he found himself involved in the controversy which arose over a mild Reform Bill introduced by the Government. They were defeated on the second reading of the Bill, Gladstone voting with them. A dissolution immediately followed, and Gladstone was again returned unopposed for the University of Oxford. As soon as the new Parliament met a vote of want of confidence in the ministry was moved in the House of Commons. In the critical division which ensued Gladstone voted with the Government, who were left in a minority. Lord Derby resigned. Lord Palmerston became Prime Minister, and asked Gladstone to join him as Chancellor of the Exchequer. To vote confidence in an imperilled ministry, and on its defeat to take office with the rivals who have defeated it, is a manœuvre which invites the reproach of tergiversation. But Gladstone risked the reproach, accepted the office, and had a sharp tussle for his seat. He emerged from the struggle victorious, and entered on his duties with characteristic zeal. The Prince Consort wrote: "Gladstone is now the real leader in the House of Commons, and works with an energy and vigour altogether incredible."

Budget of 1860.

The Budget of 1860 was marked by two distinctive features. It asked the sanction of Parliament for the commercial treaty which Cobden had privately arranged with the Emperor Napoleon, and it proposed to abolish the duty on paper. The French treaty was carried, but the abolition of the paper-duty was defeated in the House of Lords. Gladstone justly regarded the refusal to remit a duty as being in effect an act of taxation, and therefore as an infringement of the rights of the House of Commons. The proposal to abolish the paper-duty was revived in the Budget of 1861, the chief proposals of which, instead of being divided, as in previous years, into several Bills, were included in one. By this device the Lords were obliged to acquiesce in the repeal of the paper-duty, or else to incur the responsibility of rejecting the whole financial scheme for the year. The Budget became law, and Gladstone was triumphant.

During Lord Palmerston's last administration, which lasted from 1859 to 1865, Gladstone was by far the most brilliant and most conspicuous figure in the Cabinet. Except in finance, he was not able to accomplish much, for he was met and thwarted at every turn by his chief's invincible hostility to change; but the more advanced section of the Liberal party began to look upon him as their predestined leader. In 1864, in a debate on a private member's Bill for extending the suffrage, he declared that the burden of proof lay on those "who would exclude forty-nine fiftieths of the working-classes from the franchise." In 1865, in a debate on the condition of the Irish Church Establishment, he declared that the Irish Church, as it then stood, was in a false position, inasmuch as it ministered only to one-eighth or one-ninth of the whole community. But just in proportion as Gladstone advanced in favour with the Radical party he lost the confidence of his own constituents. Parliament was dissolved in July 1865, and the University elected Mr Gathorne Hardy in his place.

Gladstone at once turned his steps towards South Lancashire, where he was returned with two Tories above him. The result of the General Election was to retain Lord Palmerston's Government in power, but on the 18th October the old Prime Minister died. He was succeeded by Lord Russell, and Gladstone, retaining the Chancellorship of the Exchequer, became for the first time Leader of the House of Commons. Lord Russell, backed by Gladstone, persuaded his colleagues to consent to a moderate Reform Bill, and the task of piloting this measure through the House of Commons fell to Gladstone. The speech in which he wound up the debate on the second reading was one of

Leader of House of Commons.

the finest, if not indeed the very finest, which he ever delivered. But it was of no practical avail. The Government were defeated on an amendment in committee, and thereupon resigned. Lord Derby became Prime Minister, with Disraeli as Chancellor of the Exchequer and Leader of the House of Commons. On the 18th March 1867 the Tory Reform Bill, which ended in establishing Household Suffrage in the boroughs, was introduced, and was read a second time without a division. After undergoing extensive alterations in committee at the hands of the Liberals and Radicals, the Bill became law in August. Lord Cranborne (afterwards Lord Salisbury) declared that it had been remodelled at the dictation of Gladstone.

At Christmas 1867 Lord Russell announced his final retirement from active politics, and Gladstone was recognized by acclamation as Leader of the Liberal party. Nominally he was in Opposition; but his party formed the majority of the House of Commons, and could beat the Government whenever they chose to mass their forces. Gladstone seized the opportunity to give effect to convictions which had long been forming in his mind. Early in the session he brought in a Bill abolishing compulsory Church-rates, and this passed into law. On the 16th March, in a debate raised by an Irish member, he declared that in his judgment the Irish Church, as a State Church, must cease to exist. Immediately afterwards he embodied this opinion in a series of resolutions concerning the Irish Church Establishment, and carried them against the Government. Encouraged by this triumph, he brought in a Bill to prevent any fresh appointments in the Irish Church, and this also passed the Commons, though it was defeated in the Lords. Parliament was dissolved on the 11th November. A single issue was placed before the country—Was the Irish Church to be, or not to be, disestablished? The response was an overwhelming affirmative. Gladstone, who had been doubly nominated, was defeated in Lancashire, but was returned for Greenwich. He chose this moment for publishing a *Chapter of Autobiography*, in which he explained and justified his change of opinion with regard to the Irish Church Establishment.

Leader of Liberal party.

On the 2nd December Disraeli, who had succeeded Lord Derby as Premier in the preceding February, announced that he and his colleagues, recognizing their defeat, had resigned without waiting for a formal vote of the new Parliament. On the following day Gladstone was summoned to Windsor, and commanded by the Queen to form an administration. The great task to which the new Prime Minister immediately addressed himself was the disestablishment of the Irish Church. The Queen wrote to Archbishop Tait that the subject of the Irish Church "made her very anxious," but that Mr Gladstone "showed the most conciliatory disposition." "The Government can do nothing that would tend to raise a suspicion of their sincerity in proposing to disestablish the Irish Church, and to withdraw all State endowments from all religious communions in Ireland; but, were these conditions accepted, all other matters connected with the question might, the Queen thinks, become the subject of discussion and negotiation." The disestablishing Bill was drawn on the principle, and piloted on the lines, thus indicated. Gladstone brought it in on the 1st March 1869. Its progress through the House of Commons was easy. In committee in the House of Lords there was some risk of serious conflict, but moderate counsels prevailed, and the Bill became law on the 26th July. In the session of 1870 Gladstone's principal work was the Irish Land Act, of which the object was to protect the tenant against eviction as long as he paid his rent, and to secure to him the value of any improvements which his own industry had made. In the following session Religious Tests in the Universities were abolished, and a Bill to establish Secret Voting was carried through the House of Commons. This was thrown out by the Lords, but became law a year later. The House of Lords threw out a Bill to abolish the purchase of commissions in the army. Gladstone found that purchase existed only by royal sanction, and advised the Queen to issue a royal warrant declaring that, on and after 1st November following, all regulations authorizing the purchase of commissions should be cancelled.

Prime Minister: Irish Church disestablishment.

In 1873 Gladstone set his hand to the third of three great Irish reforms to which he had pledged himself. His scheme for the establishment of a University which should satisfy both Roman Catholics and Protestants met with general disapproval. The Bill was thrown out by three votes, and Gladstone resigned. The Queen sent for Disraeli, who declined to take office in a minority of the House of Commons, so Gladstone was compelled to resume. But he and his colleagues were now, in Disraelitish phrase, "exhausted volcanoes." Election after election went wrong. The Government had lost favour with the public, and was divided against itself. There were resignations and rumours of resignations. When the session of 1873 had come to an end Gladstone took the Chancellorship of the Exchequer, and, as high authorities contended, vacated his seat by doing so. The point was obviously one of vital importance; and we learn from Lord Selborne, who was Lord Chancellor at the time, that Gladstone "was sensible of the difficulty of either taking his seat in the usual manner at the opening of the session, or letting . . . the necessary arrangements for business in the House of Commons be made in the Prime Minister's absence. A dissolution was the only escape." On 23rd January 1874 Gladstone announced the dissolution in an address to his constituents, declaring that the authority of the Government had now "sunk below the point necessary for the due defence and prosecution of the public interest." He promised that, if he were returned to power, he would repeal the income-tax. This bid for popularity failed, the General Election resulting in a Tory majority of forty-six. Gladstone kept his seat for Greenwich, but was only second on the poll. Following the example of Disraeli in 1868, he resigned without meeting Parliament.

Dissolution of 1874.

For some years he had alluded to his impending retirement from public life, saying that he was "strong against going on in politics to the end." He was now sixty-four, and his life had been a continuous experience of exhausting labour. On 12th March 1874 he informed Lord Granville that he could give only occasional attendance in the House of Commons during the current session, and that he must "reserve his entire freedom to divest himself of all the responsibilities of leadership at no distant date." His most important intervention in the debates of 1874 was when he opposed Archbishop Tait's Public Worship Bill. This was read a second time without a division, but in committee Gladstone enjoyed some signal triumphs over his late Solicitor-General, Sir William Harcourt, who had warmly espoused the cause of the Government and the Bill. At the beginning of 1875 Gladstone carried into effect the resolution which he had announced a year before, and formally resigned the leadership of the Liberal party. He was succeeded by Lord Hartington, afterwards Duke of Devonshire. The learned leisure which Gladstone had promised himself when released from official responsibility

Temporary retirement.

was not of long duration. In the autumn of 1875 an insurrection broke out in Bulgaria, and the suppression of it by the Turks was marked by massacres and outrages. Public indignation was aroused by what were known as the "Bulgarian atrocities," and Gladstone flung himself into the agitation against Turkey with characteristic zeal. At public meetings, in the press, and in Parliament he denounced the Turkish Government and its champion, Disraeli, who had now become Lord Beaconsfield. Lord Hartington soon found himself pushed aside from his position of titular leadership. For four years, from 1876 to 1880, Gladstone maintained the strife with a courage, a persistence, and a versatility which raised the enthusiasm of his followers to the highest pitch. The county of Edinburgh, or Midlothian, which he contested against the dominant influence of the Duke of Buccleuch, was the scene of the most astonishing exertions. As the General Election approached the only question submitted to the electors was—Do you approve or condemn Lord Beaconsfield's foreign policy? The answer was given at Easter 1880, when the Liberals were returned by an overwhelming majority over Tories and Home Rulers combined. Gladstone was now member for Midlothian, having retired from Greenwich at the dissolution.

Midlothian Campaign.

When Lord Beaconsfield resigned the Queen sent for Lord Hartington, the titular leader of the Liberals, but he and Lord Granville assured her that no other chief than Gladstone would satisfy the party. Accordingly, on 23rd April he became Prime Minister for the second time. His second administration, of which the main achievement was the extension of the suffrage to the agricultural labourers, was harassed by two controversies, relating to Ireland and Egypt, which proved disastrous to the Liberal party. Gladstone alienated considerable masses of English opinion by his efforts to reform the tenure of Irish land, and provoked the Irish people by his attempts to establish social order and to repress crime. A Bill to provide compensation for tenants who had been evicted by Irish landlords passed the Commons, but was shipwrecked in the Lords, and a ghastly record of outrage and murder stained the following winter. A Coercion Bill and a Land Bill passed in 1881 proved unsuccessful. On the 6th May 1882 the newly-appointed Chief Secretary for Ireland, Lord Frederick Cavendish, and his Under-Secretary, Mr Burke, were stabbed to death in the Phoenix Park at Dublin. A new Crimes Act, courageously administered by Lord Spencer and Sir George Trevelyan, abolished exceptional crime in Ireland, but completed the breach between the British Government and the Irish party in Parliament.

The bombardment of the forts at Alexandria and the occupation of Egypt in 1882 were viewed with great disfavour by the bulk of the Liberal party, and were but little congenial to Gladstone himself. The circumstances of General Gordon's untimely death awoke an outburst of indignation against those who were, or seemed to be, responsible for it. Frequent votes of censure were proposed by the Opposition, and on 8th June 1885 the Government were beaten on the Budget. Gladstone resigned. The Queen offered him the dignity of an earldom, which he declined. He was succeeded by Lord Salisbury.

The General Election took place in the following November. When it was over the Liberal party was just short of the numerical strength which was requisite to defeat the combination of Tories and Parnellites. A startling surprise was at hand. Gladstone had for some time been convinced of the expediency of conceding Home Rule to Ireland in the event of the Irish constituencies giving unequivocal proof that they desired it. His intentions were made known only to a privileged few, and these, curiously, were not his colleagues. The General Election of 1885 showed that Ireland, outside Ulster, was practically unanimous for Home Rule. On 17th December an anonymous paragraph was published, stating that if Mr Gladstone returned to office he was prepared to "deal in a liberal spirit with the demand for Home Rule." It was clear that if Gladstone meant what he appeared to mean, the Parnellites would support him, and the Tories must leave office. The Government seemed to accept the situation. When Parliament met they executed, for form's sake, some confused manœuvres, and then they were beaten on an amendment to the Address in favour of Municipal Allotments. On 1st February 1886 Gladstone became, for the third time, Prime Minister. Several of his former colleagues declined to join him, on the ground of their absolute hostility to the policy of Home Rule; others joined on the express understanding that they were only pledged to consider the policy, and did not fetter their further liberty of action. On the 8th April Gladstone brought in his Bill for establishing Home Rule, and eight days later the Bill for buying out the Irish landlords. Meanwhile two members of his Cabinet, feeling themselves unable to support these measures, resigned. Hostility to the Bills grew apace. Gladstone was implored to withdraw them, or substitute a resolution in favour of Irish autonomy; but he resolved to press at least the Home Rule Bill to a second reading. In the early morning of 8th June the Bill was thrown out by thirty. Gladstone immediately advised the Queen to dissolve Parliament. Her Majesty strongly demurred to a second General Election within seven months; but Gladstone persisted, and she yielded. Parliament was dissolved on 26th June. In spite of Gladstone's skilful appeal to the constituencies to sanction the principle of Home Rule, as distinct from the practical provisions of his late Bill, the General Election resulted in a majority of considerably over 100 against his policy, and Lord Salisbury resumed office. Throughout the existence of the new Parliament Gladstone never relaxed his extraordinary efforts, though now nearer eighty than seventy, on behalf of the cause of self-government for Ireland. The fertility of argumentative resource, the copiousness of rhetoric, and the physical energy which he threw into the enterprise, would have been remarkable at any stage of his public life; continued into his eighty-fifth year they were little less than miraculous. Two incidents of domestic interest, one happy and the other sad, belong to that period of political storm and stress. On 25th July 1889 Gladstone celebrated the fiftieth anniversary of his marriage, and on the 4th July 1891 his eldest son, William Henry, a man of fine character and accomplishments, died, after a lingering illness, in his fifty-second year.

First Home Rule Bill.

The crowning struggle of Gladstone's political career was now approaching its climax. Parliament was dissolved on 28th June 1892. The General Election resulted in a majority of forty for Home Rule, heterogeneously composed of Liberals, Labour Members, and Irish. As soon as the new Parliament met a vote of want of confidence in Lord Salisbury's Government was moved and carried. Lord Salisbury resigned, and on 15th August 1892 Gladstone kissed hands as First Lord of the Treasury. He was the first English statesman that had been four times Prime Minister. Parliament reassembled in January 1893. Gladstone brought in his new Home Rule Bill on the 13th February. It passed the House of Commons, but was thrown out by the House of Lords on the second reading on 8th September 1893. Gladstone's political work was

Second Home Rule Bill.

now, in his own judgment, ended. He made his last speech in the House of Commons on the 1st March 1894, acquiescing in some amendments introduced by the Lords into the Parish Councils Bill; and on the 3rd March he placed his resignation in the Queen's hands. He never set foot again in the House of Commons, though he remained a member of it till the dissolution of 1895. He paid occasional visits to friends in London, Scotland, and the south of France; but the remainder of his life was spent for the most part at Hawarden. He occupied his leisure by writing a rhymed translation of the Odes of Horace, and preparing an elaborately annotated edition of Butler's *Analogy* and *Sermons.* He had also contemplated some addition to the Homeric studies which he had always loved, but this design was never carried into effect, for he was summoned once again from his quiet life of study and devotion to the field of public controversy. The Armenian massacres in 1894 and 1895 revived all his ancient hostility to "the governing Turk." He denounced the massacres and their perpetrators at public meetings held at Chester on 6th August 1895, and at Liverpool on 24th September 1896. In March 1897 he recapitulated the hideous history in an Open Letter to the Duke of Westminster, which in its masterly handling of facts and its resonant eloquence may rank with the best of his writings.

But the end, though not yet apprehended, was at hand. Since his retirement from office Gladstone's physical vigour, up to that time unequalled, had shown signs of impairment. Towards the end of the summer of 1897 he began to suffer from an acute pain, which was attributed to facial neuralgia, and in November he went to Cannes. In February 1898 he returned to England and went to Bournemouth. There he was informed that the pain had its origin in a disease which must soon prove fatal. He received the information with simple thankfulness, and only asked that he might die at home. On 22nd March he returned to Hawarden, and there he died on 19th May 1898. During the night of 25th May his body was conveyed from Hawarden to London, and the coffin was placed on a bier in Westminster Hall. Throughout the 26th and 27th a vast train of people, officially estimated at 250,000, and drawn from every rank and class, moved in unbroken procession past the bier. On the 28th May the coffin, preceded by the two Houses of Parliament and escorted by the chief magnates of the realm, was carried from Westminster Hall to Westminster Abbey. The Heir-Apparent and his son, the Prime Minister and the Leader of the House of Commons, were among those who bore the pall. The body was buried in the north transept of the abbey, where, on the 19th June 1900, Mrs Gladstone's body was laid beside it.

Death.

After a careful survey of Mr Gladstone's life, enlightened by personal observation, it is inevitable to attempt some analysis of his character. First among his moral attributes must be placed his religiousness. From those early days when a fond mother wrote of him as having been "truly converted to God," down to the verge of ninety years, he lived in the habitual contemplation of the unseen world, and regulated his private and public action by reference to a code higher than that of mere prudence or worldly wisdom. A second characteristic, scarcely less prominent than the first, was his love of power. His ambition had nothing in common with the vulgar eagerness for place and pay and social standing. Rather it was a resolute determination to possess that control over the machine of State which should enable him to fulfil without let or hindrance the political mission with which he believed that Providence had charged him. The love of power was supported by a splendid fearlessness. No dangers were too threatening for him to face, no obstacles too formidable, no tasks too laborious, no heights too steep. The love of power and the supporting courage were allied with a marked imperiousness. Of this quality there was no trace in his manner, which was courteous, conciliatory, and even deferential; nor in his speech, which breathed an almost exaggerated humility. But the imperiousness showed itself in the more effectual form of action; in his sudden resolves, his invincible insistence, his recklessness of consequences to himself and his friends, his habitual assumption that the civilized world and all its units must agree with him, his indignant astonishment at the bare thought of dissent or resistance, his incapacity to believe that an overruling Providence would permit him to be frustrated or defeated. He had by nature what he himself called a "vulnerable temper and impetuous moods." But so absolute was his lifelong self-mastery that he was hardly ever betrayed into saying that which, on cooler reflection, needed to be recalled. It was easy enough to see the "vulnerable temper" as it worked within, but it was never suffered to find audible expression. It may seem paradoxical, but it is true, to say that Mr Gladstone was by nature conservative. His natural bias was to respect things as they were. In his eyes, institutions, customs, systems, so long as they had not become actively mischievous, were good because they were old. It is true that he was sometimes forced by conviction or fate or political necessity to be a revolutionist on a large scale; to destroy an established Church; to add two millions of voters to the electorate; to attack the parliamentary union of the kingdoms. But these changes were, in their inception, distasteful to their author. His whole life was spent in unlearning the prejudices in which he was educated. His love of freedom steadily developed, and he applied its principles more and more courageously to the problems of government. But it makes some difference to the future of a democratic state whether its leading men are eagerly on the look-out for something to revolutionize, or approach a constitutional change by the gradual processes of conviction and conversion.

Character.

Great as were his eloquence, his knowledge, and his financial skill, Gladstone was accustomed to say of himself that the only quality in which, so far as he knew, he was distinguished from his fellow-men was his faculty of concentration. Whatever were the matter in hand, he so concentrated himself on it, and absorbed himself in it, that, for the time being, nothing else seemed to exist for him.

A word must be said about physical characteristics. In his prime Gladstone was just six feet high, but his inches diminished as his years increased, and in old age the unusual size of his head and breadth of his shoulders gave him a slightly top-heavy appearance. His features were strongly marked; the nose trenchant and hawk-like, and the mouth severely lined. His flashing eyes were deep-set, and in colour resembled the onyx with its double band of brown and grey. His complexion was of an extreme pallor, and, combined with his jet-black hair, gave in earlier life something of an Italian aspect to his face. His dark eyebrows were singularly flexible, and they perpetually expanded and contracted in harmony with what he was saying. He held himself remarkably upright, and even from his school days at Eton had been remarked for the rapid pace at which he habitually walked. His voice was a baritone, singularly clear and far-reaching. In the Waverley Market at Edinburgh, which is said to hold 20,000 people, he could be heard without difficulty;

and as late as 1895 he said to the present writer: "What difference does it make to me whether I speak to 400 or 4000 people?" His physical vigour in old age earned him the popular nickname of the Grand Old Man.

(G. W. E. R.)

Glaisher, James (1809– ——), English meteorologist and aeronaut, was born in London on 7th April 1809. After serving for a few years on the Ordnance Survey of Ireland, he acted as an assistant at the Cambridge and Greenwich observatories successively, and when the department of meteorology and magnetism was formed at the latter, he was entrusted with its superintendence, which he continued to exercise for thirty-four years, until his retirement from the public service. In 1845 he published his well-known dew-point tables, which have gone through many editions. In 1850 he established the Meteorological Society, acting as its secretary for many years, and in 1866 he assisted in the foundation of the Aeronautical Society of Great Britain. He was appointed a member of the Royal Commission on the Warming and Ventilation of Dwellings in 1875, and for twelve years from 1880 acted as chairman of the executive committee of the Palestine Exploration Fund. But his name is best known in connexion with the series of balloon ascents which he made between 1862 and 1866, mostly in company with Coxwell. Many of these ascents were arranged by a committee of the British Association, of which he was a member, and were strictly scientific in character, the object being to carry out observations on the temperature, humidity, &c., of the atmosphere at high elevations. In one of them, that which took place at Wolverhampton on 5th September 1862, Mr Glaisher and his companion attained what is probably the greatest height ever reached by a balloon carrying passengers. As no automatically recording instruments were available, and Mr Glaisher was unable to read the barometer at the highest point owing to loss of consciousness, the precise altitude can never be known, but it is estimated at about 7 miles from the earth. An authentic account of this and other ascents undertaken by him may be found in the article AERONAUTICS (*Ency. Brit.*, 9th edition, vol. i.), which came from his pen.

Glamorgan, a maritime county of South Wales, bounded on the N.W. by Carmarthen, on the N. by Carmarthen and Brecon, on the E. by Monmouth, from which it is separated by the Rhymney, and on the S. and the S.W. by the Bristol Channel.

Area and Population.—The area of the ancient county is 516,959 acres, or 808 square miles, with a population in 1881 of 511,433, and in 1891 of 687,218, of whom 360,260 were males and 326,958 females; the number of persons per square mile being 851, and of acres to a person 0·75. The area of the administrative county, according to the census returns of 1891, was 505,815 acres, with a population of 467,954, or with the county boroughs of Cardiff and Swansea, 516,966 acres, with a population of 687,218; but in 1895 the acreage of the combined area was slightly altered by transferences in the case of the county borough of Cardiff to and from Monmouth. The area of the registration county is 576,308, with a population in 1891 of 693,072. Within this area the percentage of increase between 1881 and 1891 was 33·70. The excess of births over deaths between 1881 and 1891 was 97,222, but this was much exceeded by the increase of the population, which was 174,689. In 1901 the population of the ancient county was 860,022. The following table gives the number of marriages, births, and deaths, with the number and percentage of illegitimate births, for 1880, 1890, and 1898:—

Year.	Marriages.	Births.	Deaths.	Illegitimate Births.	
				No	Per cent
1880	4088	18,345	11,076	597	3·3
1890	6575	24,245	13,646	680	2·9
1898	6112	29,347	14,732	812	2·8

In 1891 there were in the county 3289 natives of Scotland, 11,256 natives of Ireland, and 5856 foreigners, while 326,481 persons could speak English, 142,346 Welsh, and 177,726 English and Welsh.

Constitution and Government.—The county is divided into five parliamentary divisions, and it also includes the Cardiff district of boroughs (consisting of Cardiff, Cowbridge, and Llantrisant), greater part of the borough of Merthyr Tydfil, and Swansea, comprising Swansea town and Swansea district (consisting of the boroughs of Aberavon, Kenfig, Loughor, and Neath). There are five municipal boroughs:—Aberavon (7553), Cardiff (164,420), Cowbridge (1202), Neath (13,732), and Swansea (94,514). Cardiff and Swansea are county boroughs. The following are urban districts:—Aberdare (43,357), Barry (27,028), Bridgend (6063), Briton Ferry (6961), Caerphilly (15,835), Glyncorrwg (6450), Maesteg (15,013), Margam (9014), Merthyr Tydfil (69,227), Mountain Ash (31,093), Ogmore and Garw (19,912), Oystermouth (4483), Penarth (14,227), Pontypridd (32,319), Porthcawl (1871), and Rhondda (113,735). Glamorganshire is in the South Wales and Chester circuit, and assizes are held at Cardiff and Swansea. The boroughs of Cardiff, Swansea, and Aberavon have separate commissions of the peace, and the former two have also separate courts of quarter sessions. The ancient county—which is partly in the diocese of Llandaff and partly in that of St Davids—contains 140 entire ecclesiastical parishes and districts and part of five others.

Education.—Cardiff is the seat of the University College of South Wales and of a technical school. At Swansea are the Government schools of science and art. In connexion with the University College of Cardiff there is a day training college for schoolmasters and mistresses. At Swansea there is a residential college for mistresses (British and Foreign School Society's) which also takes day students. In Cardiff there are two school board blind schools and one school board deaf school; in Swansea are the Royal Cambrian Institution for the deaf and the Swansea and South Wales Institution for the blind; at Pontypridd is a school board deaf school, and there is also one at Ystradyfodwg. The number of elementary schools in the county on 31st August 1899 was 382, of which 253 were board and 129 voluntary schools, the latter including 100 National Church of England schools, 24 Roman Catholic, and 5 "British and other." The average attendance at board schools was 108,320, and at voluntary schools 16,400. The total school board receipts for the year ended 29th September 1899 were over £513,702. The income under the Technical Instruction Act was over £669, and that under the Agricultural Rates Act over £2467.

Agriculture.—More than half of the total area of the county is under cultivation, and of this about seven-ninths is in permanent pasture, cattle, especially cows for milk-selling, and sheep being largely kept. There are in addition over 121,000 acres of mountain pasture, and about 27,000 acres under woods. Since 1880 the acreage under corn crops has decreased by about a third, there being a considerable decrease even in the acreage under oats, and a decrease of about two-fifths in the acreage under wheat, and only a little less than two-fifths in the acreage under barley. The acreage under green crops has decreased more than a sixth, the decrease being chiefly in that under turnips, which, however, still occupy about three-fourths of the green crop area.

The following table gives the larger main divisions of the cultivated area at intervals from 1880:—

Year.	Total area under Cultivation.	Corn Crops.	Green Crops	Clover.	Permanent Pasture.	Fallow.
1880	272,215	36,685	15,013	26,088	190,514	3911
1885	279,659	31,455	14,606	27,570	203,889	2128
1890	282,774	28,661	14,176	23,195	215,072	1573
1895	279,416	26,191	13,299	21,358	217,149	1266
1900	274,410	25,205	11,851	21,824	214,375	1026

The following table gives particulars regarding the principal live stock for the same years:—

Year.	Total Horses.	Total Cattle.	Cows or Heifers in Milk or in Calf.	Sheep.	Pigs.
1880	14,206	51,972	21,863	253,321	13,020
1885	15,362	57,256	23,957	283,939	17,660
1890	16,125	55,849	25,138	303,507	18,024
1895	17,284	52,203	24,285	292,786	18,892
1900	16,468	56,485	25,697	330,060	16,406

Industries and Trade.—According to the annual report for 1898 of the chief inspector of factories (1900), the total number of persons employed in factories and workshops in 1897 was 54,859, as compared with 53,313 in 1896. Of these 47,358 persons were employed in non-textile factories, there being an increase of 2·2 per cent. between 1895 and 1896, and of 3·3 per cent. between 1896 and 1897. In metal founding and conversion 19,298 persons were employed, in the extraction of metals 3695, in the manufacture of machines, appliances, conveyances, and tools 11,846, in pottery, &c., 1684, in the manufacture of paper, &c., 1916; there is considerable manufacture of chemicals. Workshops employed 7266 persons, of whom 4430 were employed in clothing industries. The fishing industry is of some importance: by lines, draught nets, dredging, trawling, fixed nets, and hand. The principal fish are cod, herring, pollard, whitings, fluke, brill, plaice, soles, turbot, oysters, mussels, limpets, winkles, cockles, shrimps, crabs, and lobsters. The total quantity landed at the ports of Cardiff and Swansea in 1899 was 29,242 cwts., valued at £19,983. The total number of persons employed in mines and quarries in 1899 was 96,017, rather more than the number employed in Lancashire, and exceeded among British counties only by the numbers of Durham and Yorkshire. In the same year 681,910 tons of limestone were raised and 292,137 tons of sandstone. Tin and copper ore are imported from Cornwall for smelting purposes, and most of the iron for the special industries of the county is also imported. There are many large blast-furnaces—at Dowlais, Merthyr Tydfil, Cardiff, Pontypridd, Bridgend, Landore, Port Talbot, and Briton Ferry—the amount of pig iron produced in 1885 being 354,692 tons, in 1890 416,874 tons, in 1895 447,715 tons, and in 1899 578,790 tons. The following table gives particulars regarding the principal minerals in 1890 and 1899:—

Year.	Clay.		Coal.		Iron Ore.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
1890	144,767	£28,804	21,426,415	£11,451,913	21,363	£9613
1899	217,147	£23,364	28,116,941	£10,967,247	6,817	£3068

AUTHORITIES.—*Interesting Tour in the County of Monmouth and Part of Glamorgan by a Gentleman.* 2nd ed. Halesworth, 1808.—*A Book of Glamorganshire Antiquities*, by RICE MERRICK, 1578, ed. Sir T. Phillips. Typis Medio Montano, 1825.—HOMFRAY. *Castles of the Lordship of Glamorgan.* Swansea, 1802.—ROBERTS. *Druidical Remains and Antiquities of the Ancient Britons, principally in Glamorgan.* Swansea, 1842.—NICHOLAS. *The History and Antiquities of Glamorganshire and its Families.* London, 1874.—G. S. CLARK. *The Land of Morgan*, 6 pts. London, 1880; new ed., London, 1883; *Genealogies of Families of the Lordship of Morgan and Glamorgan.* London, 1886; *Cartæ quæ ad Dominium de Glamorgan pertinent*, 2 vols. Dowlais, 1885-90.—THOMAS. *Inscribed Stones of Glamorganshire.* Cardiff, 1893. See also the guides to South Wales.

(T. F. H.)

END OF FOURTH VOLUME.

Printed by BALLANTYNE, HANSON & Co.
Edinburgh & London

A PARTIAL LIST OF THE CONTRIBUTORS

TO

THE NEW VOLUMES

OF

THE ENCYCLOPÆDIA BRITANNICA

WITH THE INITIALS WHICH HAVE BEEN AFFIXED TO THEIR RESPECTIVE ARTICLES.

THE LIST OF CONTRIBUTORS here given is necessarily incomplete, inasmuch as the later Volumes are still in course of preparation, and all the Contributors have not yet been selected. On the other hand, the present List may contain a few names which ultimately will not appear in the final List of Contributors. Death or other cause may prevent certain writers who have undertaken the preparation of Articles from completing the contributions which they were to furnish. A full List, compiled when the final Volume goes to press, will be given later. The present List includes the names of all who have written signed Articles for the Volumes which have so far appeared.

After the few words of description which accompany the names are given the initials of the different authors as they have been affixed to the Articles contributed by them.

The Publishers congratulate themselves that in this List of a thousand names are to be found not only the most famous scholars and writers of Great Britain, but of the whole world.

A

ABBE, Prof. Cleveland, A.M., Ph.D., LL.D.; Meteorologist, U.S. Weather Bureau; author of 'Atmospheric Radiation,' etc.; editor of 'Monthly Weather Review'; Lecturer on Meteorology, Johns Hopkins University. (C. A.)

ABBOTT, Rev. Lyman, D.D.; editor of 'The Outlook' (New York); associate editor of 'The Christian Union' (New York) with Henry Ward Beecher, whom he succeeded as pastor of Plymouth Church, Brooklyn; author of 'Christianity and Social Problems,' 'Life of Christ,' 'Theology of an Evolutionist,' 'Life and Epistles of St Paul.' (L. A.)

ABNEY, Sir William de Wiveleslie, K.C.B., D.Sc., D.C.L., F.R.S.; Principal Assist. Sec., Board of Education, South Kensington, since 1899; President, Royal Astronomical Society, 1893-95; President, Physical Society, 1895-97; author of 'Photography' in Ninth Edition of the 'Ency. Brit.,' 'Instruction in Photography,' 'Treatise on Photography,' 'Colour Vision,' 'Colour-Measurement and Mixture,' 'Thebes and its Five Great Temples,' in part of 'The Pioneers of the Alps.' (W. DE W. A.)

ADAMS, B. B.; associate-editor of the 'Railroad Gazette' (New York). (B. B. A.)

AIRY, Wilfred, B.A., M.I.C.E.; Examiner of Inspectors of Weights and Measures, Board of Trade; author of 'Levelling and Geodesy,' 'Weighing Machines,' etc. (W. AY.)

AKERS, C. E.; author of 'Argentine, Patagonian, and Chilian Sketches,' etc. (C. E. A.)

ALCOCK, Charles William; Secretary Surrey County Cricket Club since 1872; Hon. Sec. Football Association, 1867-90; author of 'Football our Winter Game,' 1867; editor of 'Cricket Newspaper,' 1882-1900, 'Football Annual,' 'Cricketer's Annual' (Lillywhite's), etc. (C. W. A.)

ALEXANDER, Gen. Edward Porter; General of Ordnance; and later Brigadier-General of Artillery and Chief of Artillery in Gen. Longstreet's Corps, Confederate Army. (E. P. A.)

ALEXANDER, W. D., Honolulu; author of 'A Brief History of the Hawaiian People.' (W. D. A.)

ALLBUTT, Thomas Clifford, M.A., M.D., LL.D., D.Sc., F.R.S.; Regius Professor of Physic, Camb., since 1892; Commissioner in Lunacy, 1889-92; author of 'The Ophthalmoscope in Medicine,' 'Goulstonian Lectures (On Visceral Neuroses),' 'On Scrofula,' 'Science and Medical Thought'; editor of 'System of Medicine and Gynæcology,' etc.; inventor of short clinical thermometer. (T. C. A.)

ALLDRIDGE, T. J., F.R.G.S., F.Z.S.; for many years Travelling Commissioner of Sierra Leone; District Commissioner of Sherbro District, Sierra Leone; author of 'The Sherbro and its Hinterland.' (T. J. A.)

ANDERSON, Miss A. M.; Principal Lady Inspector of Factories, Home Office. (A. M. AN.)

ANDERSON, W., F.R.C.S., the late; Comp. of the Order of the Rising Sun (Japan); Professor at Royal Academy; Chairman of Council of the Japan Society; Medical Director, Imperial Naval Medical College, Tokio; author of 'The Pictorial Arts of Japan,' 'Japanese Wood Engravings,' 'Cat. of Chinese and Japanese Pictures in British Museum.' (W. AN.)

ANDERSON, Lt.-Col. W. P.; Chief Engineer and Superintendent of Lights, Department of Marine and Fisheries, Ottawa, Canada. (W. P. A.)

ANDREWS, Hon. Elisha Benjamin, LL.D.; Chancellor of the University of Nebraska; late Superintendent of Schools of the City of Chicago; formerly President of Brown University; author of 'Institutes of General History,' 'Institutes of Economics,' 'History of the United States,' etc. (E. B. A.)

ANSTRUTHER-THOMSON, Major W., F.G.S., F.S.A.; Inspector of Concentration Camps, S.A. (W. A.-T.)

ARCHER, William; dramatic critic of 'World' (London), 1884 onwards; edited and translated Ibsen's 'Prose Dramas'; author of 'Life of Macready,' 'Masks or Faces,' 'The Theatrical World,' 'Study and Stage,' 'America To-day, 1900,' 'Poets of the Younger Generation,' etc. (W. A.)

ARMSTRONG, Edmund Archibald, Barrister-at-Law, Inner Temple. (E. A. AR.)

ARMSTRONG, Henry Edward, Ph.D., LL.D., F.R.S.; Professor of Chemistry at the City and Guilds of London Central Institute, South Kensington; author of 'Carbon,' etc., in Ninth Edition of 'Ency. Brit.,' 'Introduction to the Study of Organic Chemistry.' (H. E. A.)

ARMSTRONG, Sir Walter; Director of the National Gallery of Ireland; author of 'Sir Joshua Reynolds,' 'Thomas Gainsborough,' 'Sir Henry Raeburn,' 'Alfred Stevens,' 'Peter de Wint,' 'Velasquez,' 'Scottish Painters,' 'J. M. W. Turner,' etc., and co-editor of 'Bryan's Dictionary of Painters.' (W. AR.)

ASHWORTH, Philip A., Dr. Juris, of the Inner Temple, Barrister-at-Law; editor of Taswell-Langmead's 'Constitutional History of England,' translator of Gneist's 'History of the English Constitution,' etc. (P. A. A.)

ASKWITH, Rev. Edward Harrison, M.A., B.D.; Chaplain of Trinity College, Cambridge; author of 'Christian Conception of Holiness,' 'Epistle to the Galatians,' etc. (E. H. A.)

ASTON, Major George Grey, R.M.A.; late Professor of Fortification, Royal Naval College, Greenwich. (G. G. A.)

ASTON, William George, B.A., M.A., Hon. D.Lit., C.M.G.; student interpreter in Japan, 1864; interpreter and translator to British Legation at Yedo, 1870; assistant Japanese Secretary, Yedo, 1875-82; acting Consul, Hiogo, 1880-83; Consul-General for Corea, 1884; Japanese Secretary, Tokio, 1886; author of 'A Grammar of the Japanese Spoken Language,' 'A Grammar of the Japanese Written Language,' 'A Translation of the Nihongi, or Annals of Ancient Japan,' 'History of Japanese Literature,' etc. (W. G. AS.)

ATWATER, Wilbur Olin, Ph.D.; Professor of Chemistry, Wesleyan University, U.S.A.; Special Agent of the U.S. Department of Agriculture in charge of Nutrition investigations. (W. O. A.)

AVES, Ernest, M.A.; formerly Sub-Warden of Toynbee Hall; author of papers on sociology and economics. (E. A*.)

AXON, William Edward Armitage, LL.D.; late Dep. Librarian Manchester Free Libraries; author of 'Manchester' in Ninth Edition of 'Ency. Brit.,' 'The Annals of Manchester,' 'Manchester a Hundred Years Ago,' 'Lancashire Gleanings,' 'Stray Chapters in Literature,' 'Folk-lore and Archæology,' etc. (W. E. A. A.)

B

BACON, Edwin Monroe, M.A.; editor of 'Time and the Hour' (Boston, U.S.A.); sometime editor-in-chief of the 'Boston Globe,' the 'Boston Advertiser,' and the 'Boston Post'; author of 'Boston Illustrated,' 'Bacon's Dictionary of Boston,' 'Boston of To-day,' etc. (E. M. B.)

BADEN-POWELL, Maj. Baden F. S.; inventor of man-lifting kites; late President Aëronautical Society; author of 'In Savage Isles and Settled Lands,' many articles on ballooning, etc. (B. F. S. B.-P.)

BAGWELL, Richard, M.A.; author of 'Ireland' in the Ninth Edition of the 'Ency. Brit.,' 'Ireland under the Tudors,' 'A Plea for National Education,' etc. (R. BA.)

BAINES, Jervoise Athelstane, C.S.I.; Hon. Sec. (gold medallist) and Vice-President Royal Statistical Society; Census Commissioner under Government of India, 1889-93; employed at India Office and as secretary to Royal Commission on Opium, 1894-95; author of Official Reports on Provincial Administration, on Indian Census Operations, 1881-91, on Indian Progress, 1894, many papers, ethnographic and statistical, for London societies. (J. A. B.)

BAKER, Henry Frederick, M.A., F.R.S.; Fellow and Lecturer of St John's College, Cambridge; University Lecturer in Mathematics. (H. F. Ba.)

BALCARRES, Lord, M.P., F.S.A., F.S.A.S.; Trustee of National Portrait Gallery, London; Hon. Sec. Society for Protection of Ancient Buildings; Vice-Chairman of National Trust. (B.)

BALDRY, Alfred Lys, artist; author of 'Albert Moore: his Life and Works,' 'The Life and Works of Marcus Stone, R.A.,' 'Sir John Everett Millais,' 'Hubert von Herkomer,' etc. (A. L. B.)

BALDWIN, Hon. Simeon Eben, A.M., LL.D.; Judge of the Supreme Court of Errors of Connecticut; Professor of Constitutional and Mercantile Law, Corporations, and Wills, Yale University; sometime President of the American Bar Association and American Social Science Association; author of 'Baldwin's Connecticut Digest,' 'Cases on R.R. Law,' 'Modern Political Institutions,' etc. (S. E. B.)

BALDWIN, W. H., Jr.; President of the Long Island R.R. Co., U.S.A. (W. H. B.)

BALE, Edwin, R.I.; Art Director, Cassell and Company; Hon. Sec. Artists' Committee for Promoting Art Copyright Bill, etc. (E. Ba.)

BALFOUR, Isaac Bayley, M.D., D.Sc., M.A., F.R.S., F.L.S.; Regius Keeper of Royal Botanic Garden, Edinburgh; Professor of Botany, University of Edinburgh; Transit of Venus Expedition to Rodriguez, 1874; Regius Professor of Botany, University of Glasgow, 1879-84; explored island of Socotra, 1880; Sherardian Professor of Botany, University of Oxford, and Fellow of Magdalen College, 1884-88; author of 'Botany of Rodriguez,' 'Botany of Socotra,' editor of 'Annals of Botany.' (I. B. B.)

BANCROFT, Frederic, Ph.D.; Chief of Bureau of Rolls and Library, U.S. Department of State; author of 'Life of William H. Seward,' etc. (F. Ba.)

BANISTER, G. H., M.I.C.E., M.I.M.E.; late Assistant to Superintendent of the Royal Carriage Department, Woolwich; Whitworth Scholar. (G. H. Ba.)

BARCLAY, Thomas, LL.B., Ph.D.; member of the Institute of International Law; Vice-President of the International Law Association; Examiner in Jurisprudence and International Public and Private Law to the University of Oxford, 1900; member of the Supreme Council of the Congo Free State; Vice-President of the Franco-Scottish Society; President of the British Chamber of Commerce in Paris, 1899-1900; Knight of the Legion of Honour and of the Order of Leopold; author of 'Companies in France,' and other law books, all the articles on International Law in the 'Encyclopedia of the Law of England,' etc. (T. Ba.)

BARING, The Hon. Maurice; Attaché to the British Embassy, Paris, 1899; Third Secretary to the British Embassy, Rome, 1902. (M. Ba.)

BARLOW, Major H. W. W., R.A.; Secretary to Chief Superintendent, Royal Ordnance Factories, Woolwich. (H. W. B.)

BARNES, William Emery, D.D.; Fellow of Peterhouse, Cambridge; Hulsean Professor of Divinity, Cambridge; assist. editor of 'Journal of Theological Studies'; Lecturer in Hebrew at Clare Coll. Camb., 1885-94; in Hebrew and Divinity at Peterhouse, 1889-1901; author of 'The Genuineness of Isaiah xxiv.-xxvii.,' 'Canonical and Uncanonical Gospels, 'The Peshitta Text of Chronicles,' I. II. Chronicles, with Introduction and Notes (Cambridge Bible). Isaiah (Churchman's Bible). (W. E. B.)

BARNETT, Rev. Samuel Augustus, M.A.; Canon of Bristol; Founder and Warden of Toynbee Hall, Whitechapel; President of the Sunday Society; Chairman Whitechapel Board of Guardians, 1894; Chairman of Children's Country Holiday Fund; Chairman Pupil Teachers' Scholarship Fund; author of 'Practicable Socialism' with Mrs Barnett, 'Service of God.' (S. A. B.)

BARRETT, F. N., editor of the 'American Grocer' (New York). (F. N. B.)

BARTLET, Rev. J. Vernon, M.A.; Professor of Church History, Mansfield College, Oxford; author of 'Early Church History,' 'The Apostolic Age,' etc. (J. V. B.)

BARTLEY, George Christopher Trout, M.P.; Assistant-Director of Science Division of Science and Art Department, London, till 1880; established National Penny Bank, 1875; author of 'A Square Mile in the East of London,' 'Schools for the People,' 'Provident Knowledge Papers,' 'The Seven Ages of a Village Pauper,' 'The Parish Net. (G. C. T. B.)

BARWICK, G. F.; Assistant Keeper of Printed Books and Superintendent of Reading-room, British Museum; author of 'International Exhibitions,' 'The Laws Regulating Printing and Publishing in Spain,' and translator of various works of travel, etc. (G. F. B.)

BASSETT, John Spencer, Ph.D.; Professor of History, Trinity College, N.C.; author of 'Constitutional Beginnings of North Carolina,' 'Slavery and Servitude of the Colony of North Carolina,' 'Anti-Slavery Leaders of North Carolina,' 'Slavery in the State of North Carolina.' (J. S. Ba.)

BASTABLE, C. F., M.A., LL.D.; Professor of Political Economy, Dublin University, 1882; author of 'Money' in Ninth Edition of 'Ency. Brit.,' 'Theory of International Trade,' 'Commerce of Nations,' 'Public Finance,' 'Dictionary of Political Economy,' and 'Economic Journal. (C. F. B.)

BATHER, Francis Arthur, M.A., D.Sc., F.G.S.; Natural History Museum, South Kensington; Hon. Member Soc. Linnéenne de Normandie; author of 'Concise Knowledge of Natural History,' 'The Genera and Species of Blastoidea,' 'Echinoderma' (in Lankester's 'Zoology'), 'The Crinoidea of Gottland,' etc. (F. A. B.)

BAUERMAN, H., F.G.S.; Lecturer on Metallurgy, Ordnance College, Woolwich; author of 'Bismuth,' 'Coal,' 'Fuel,' 'Furnace,' etc., in Ninth Edition of 'Ency. Brit.,' 'A Treatise on the Metallurgy of Iron,' 'Text-book of Systematic Mineralogy,' etc. (H. B.)

BEALBY, J. T., B.A.; sometime acting editor of 'Scottish Geographical Magazine'; author of 'A Daughter of the Fen,' and numerous geographical magazine articles; joint author of 'Stanford's Compendium: Europe'; translator of Sven Hedin's 'Through Asia. (J. T. Be.)

BEDDARD, Frank Evers, M.A., F.R.S.; Prosector of Zoological Soc. of England since 1884, and Vice-Sec. since 1898; formerly Lecturer on Biology at Guy's Hospital; has been Examiner in Zoology and Comparative Anatomy, University of London, and of Morphology at Oxford; now Examiner in the University of New Zealand; naturalist to 'Challenger' Expedition Commission, 1882-84; author of 'Worm' in Ninth Edition of 'Ency. Brit.,' 'Animal Coloration,' 'Text-book of Zoogeography,' 'A Monograph of the Oligochæta,' 'Structure and Classification of Birds.' (F. E. B.)

BELL, Charles Frederic Moberly; asst. manager of 'The Times'; formerly correspondent of 'The Times' in Egypt; author of 'Khedives and Pashas,' 'Egyptian Finance,' 'From Pharaoh to Fellah,' etc. (C. F. M. B.)

BELL, Dr Louis, Boston, U.S.A.; author of 'The Elements of Practical Electricity,' 'Power Distribution for Electric Railroads,' 'Electric Power Transmission,' etc. (L. Bl.)

BELL, Malcolm; author of 'Rembrandt,' 'Sir E. Burne-Jones,' etc. (M. Be.)

BELLAIRS, Carlyon; Lieutenant R.N.; writer of articles on naval subjects. (C. W. Be.)

BELLINGER, Hon. Charles Byron; Judge of the U.S. District Court, District of Oregon. (C. B. B*.)

BELTRAMI, Luca; architect; author of 'Storia della facciata di St Maria del Fiore in Firenza,' 'La Basilica Ambrosiana primitiva e la ricostruzione compiuta nel secolo IX,' etc. (L. Bi.)

BÉNÉDITE, Léonce; Conservator, Musée du Luxembourg, Paris; author of 'Alphonse Legros'; editor of 'Bulletin des Musées,' etc. (L. Be.)

BENSON, Arthur Christopher, M.A., F.R.Hist. Soc.; Master at Eton College since 1885; author of 'Memoirs of Arthur Hamilton,' 'Archbishop Laud: a Study,' 'Poems,' 'Lyrics,' 'Essays,' 'Lord Vyet and other Poems,' 'Fasti Etonenses,' 'Life of Archbishop Benson,' 'The Professor, and other Poems.' (A. C. Be.)

BERG, Sigvard Johnson, A.M.I.C.E., Switzerland. (S. J. B.)

BERNARD, Rev. John Henry, D.D.; Fellow of Trin. Coll., Dublin; Archbishop King's Lecturer in Divinity, University of Dublin; member of University Council, 1892; Vice-Warden, Alexandra Coll., Dublin, for higher education of women, 1894; Secretary of Royal Irish Academy, 1899; Commissioner of National Education, Ireland, 1897; part-editor of 'Kant's Critical Philosophy for English Readers,' translator of 'Kant's Kritik of Judgment, joint-author of 'The Literature of the Second Century,' editor of 'The Pilgrimage of St Silvia of Aquitania,' 'The Pastoral Epistles of St Paul,' 'The Works of Bishop Butler, etc. (J. H. Be.)

BERNSTEIN, Eduard; German Socialistic politician and writer; late editor of the 'Social Democrat'; author of 'On the History and Theory of Socialism,' 'The Communistic and Democratic-Socialistic Movements in England during the 17th Century,' etc. (E. Bn.)

BERRY, George Andreas, M.B., F.R.C.S., F.R.S. Edin.; Vice-Pres. Ophthalmological Soc.; author of 'Diseases of the Eye,' 'The Elements of Ophthalmoscopic Diagnosis,' 'Subjective Symptoms in Eye Diseases,' etc. (G. A. Be.)

BESANT, Sir Walter, M.A., F.S.A., the late; Secretary Palestine Exploration Fund, 1868-85; Hon. Sec. Palestine Exp. Fund; First Chairman Society of Authors, 1884-85; Chairman Society of Authors, 1887-1892; author of 'Froissart' in Ninth Edition of 'Ency. Brit.,' 'Studies in Early French Poetry,' 'Rabelais,' Lives of 'Coligny,' 'Whittington,' 'Edward Palmer,' and 'Richard Jefferies,' 'London,' 'Westminster,' 'South London,' many Novels with the late James Rice. Novels alone: 'The Revolt of Man,' 'All Sorts and Conditions of Men,' 'Beyond the Dreams of Avarice,' 'The Orange Girl,' etc. (W. Be.)

BHOWNAGREE, Sir Mancherjee Merwanjee, K.C.I.E., M.P.; State Agent, Bombay, for the territory of Bhavnagar, 1873; author of 'History of the Constitution of the East India Company,' Gujerati translation of 'Her Majesty's Life in the Highlands,' etc. (M. M. Bh.)

'BICKERDYKE, John' (Charles Henry Cook), M.A.; writer on angling and sporting subjects; President of Thames Re-stocking Association, and the Fly-Fishers' Club, 1899-1900; editor of the angling department of the 'Field'; author of 'Angling in Salt Water,' 'The Book of the All Round Angler,' 'Thames Rights and Thames Wrongs,' 'Days in Thule with Rod, Gun, and Camera,' 'Sea-Fishing,' 'Days of My Life in Water, Fresh and Salt,' 'Wild Sports in Ireland,' 'Letters to Young Sea-Fishers,' etc. ('J. B.')

BIDWELL, Shelford, M.A., Sc.D., F.R.S.; barrister; President of Physical Society, England, 1897-99; author of 'Curiosities of Light and Sight,' and numerous memoirs on physical subjects. (S. Bi.)

BINDLOSS, Harold; Secretary Royal Mersey Yacht Club. (H. Bs.)

BINYON, Laurence; assistant in the British Museum, Department of Printed Books, 1893; transferred to Department of Prints and Drawings, 1895; author of 'Lyric Poems,' 'Poems,' 'London Visions,' 'The Praise of Life, 'Porphyrion and other Poems,' 'Western Flanders,' 'Odes,' 'Catalogue of English Drawings in the British Museum.' (L. B.)

BIRD, Christopher John, C.M.G.; Principal Under Secretary of the Colony of Natal, and a Member of the Civil Service Board. (C. J. Bi.)

BIRDWOOD, Sir George Christopher Molesworth, M.D., K.C.I.E., C.S.I., LL.D.; special assistant in Revenue and Statistics Department India Office, 1871-99; author of 'Incense' in Ninth Edition of 'Ency. Brit.,' 'Economic Vegetable Products of the Bombay Presidency,' 'The Industrial Arts of India,' 'Report on Old Records of the India Office,' 'First Letter Book of East India Company,' Appendix on the Aryan Fauna and Flora to Max-Müller's 'Biography of Words,' etc. (G. B.)

BIRKBECK, William John, M.A., F.S.A.; author of 'Russia and the English Church.' (W. J. Bi.)

BIRKINBINE, John, M.E.; President of the Franklin Institute and the Pennsylvania Forestry Association; sometime President American Institute of Mining Engineers, and editor 'Journal of Iron Workers.' (J. Bi*.)

BIRRELL, Augustine, K.C.; Hon. Fellow, Trinity Hall, Cambridge; LL.D. St Andrews (Honorary); Quain Professor of Law, University Coll. London, 1896; M.P. (L.) Fifeshire W., 1889-1900; author of Obiter Dicta, 1884, 1887; Life of Charlotte Brontë, 1885; Res Judicatae, 1892; Men, Women, and Books, 1894; Lectures on the Duties and Liabilities of Trustees, 1896; editor of Boswell's Life of Johnson, 1897; Sir Frank Lockwood, 1898; Collected Essays, 1900. (A. Bi.)

BISHOP, Mrs Isabella L. (Miss Isabella Bird), F.R.G.S., Hon. F.R.S.G.S.; Hon. Member of Oriental Society, Pekin; first lady Fellow of the Royal Geographical Society; author of 'The Englishwoman in America,' 'Six Months in the Sandwich Islands,' 'A Lady's Life in the Rocky Mountains,' 'Unbeaten Tracks in Japan,' 'The Golden Chersonese,' 'Journeys in Persia and Kurdistan,' 'Among the Tibetans,' 'Korea and her Neighbours,' 'The Yangtze Valley and Beyond,' 'Pictures from China,' etc. (I. L. B.)

BLAIR, Andrew A.; chief chemist of the U.S. Geological Survey, Division of Mining and Geology, Tenth Census of the United States; author of 'The Chemical Analysis of Iron,' etc. (A. A. B.)

BLAKE, Rev. John Frederick, M.A., F.R.S.; sometime Professor of Natural Science, University College, Nottingham; author of 'British Fossil Cephalopoda,' 'The Geological

Society of London,' 'Astronomical Myths,' 'Yorkshire Lias,' etc. (J. F. Bl.)

BLAKE, Prof. William Phipps, Ph.B.; Director School of Mines, University of Arizona, and territorial geologist of Arizona; author of 'Geological Reconnaissance of California,' 'Silver Ores and Silver Mines,' etc. (W. P. B.)

BLÖNDAL, Sigfús, of the University Library, Copenhagen. (S. Bl.)

BLOUNT, Bertram, F.C.S., F.I.C.; consulting chemist to the Crown Agents for the Colonies; Hon. President Cement Section of International Assoc. for Testing Materials, Buda-Pesth. (B. Bl.)

BLOWITZ, Henri Georges Stephane Adolphe Opper de; 'The Times' correspondent in Paris; Professor of German at Tours, Limoges, Poitiers, and Marseilles; entered on service of 'The Times,' July 1871; inaugurated constant telegraphic communications and obtained the concession from 9 P.M. to 3 A.M. of a special wire for 'The Times' from 9 May 1874; officer of the Legion of Honour; Doctor of Philosophy; officer of the Institute of France; author of 'Feuilles Volantes,' 'L'Allemagne et la Provence,' 'Le Mariage royal d'Espagne,' 'Une Course à Constantinople.' (de B.)

BLUNT, Capt. Charles Jasper, R.A.; Chief Ordnance Officer, Guernsey; served in the Chitral campaign, etc. (C. J. B.)

BODLEY, John Edward Courtenay, M.A.; private secretary to President of Local Government Board, 1882-85; secretary to Royal Commission on Housing of the Working Classes, 1884-85; author of 'France'; vol. i. 'The Revolution and Modern France,' vol. ii. 'The Parliamentary System,' (French ed. 1901), 'L'Anglomanie et les traditions françaises.' (J. E. C. B.)

BOLTZMANN, Ludwig; Professor of Theoretical Physics, University of Vienna; Hon. Member Royal Academy of Sciences, Berlin; author of 'Lectures on the Theory of Gas,' 'Lectures on Maxwell's Theory of Electricity and Light'; editor of 'Maxwell's Physical Forces.' (L. Bo.)

BONAR, James, M.A., LL.D.; senior Examiner Civil Service Commission, Westminster; junior Examiner in H.M. Civil Service Commission, 1881; senior Examiner, *ibidem*, end of 1895; President of Section F of British Association, 1898; author of 'Malthus and his Work,' 'Ricardo's Letters to Malthus,' 'Philosophy and Political Economy,' 'Catalogue of Adam Smith's Library' (part), 'Ricardo's Letters to Trower.' (J. B*.)

BONNEY, Rev. Thomas George, D.Sc., LL.D., F.R.S.; late Professor of Geology, University Coll. London; Hon. Canon of Manchester; Fellow of St John's Coll. Camb.; Hulsean Lecturer (Camb.), 1884; President Geological Society, 1884-86; Boyle Lecturer, 1890-92; Rede Lecturer (Camb.), 1892; Vice-President Royal Society, 1899; author of 'The Alpine Regions,' 'The Story of our Planet,' 'Charles Lyell and Modern Geology,' 'Ice-Work,' 'Volcanoes,' etc. (T. G. B.)

BOSCO, Augustus; Professor of Statistics, University of Rome. (A. Bo.)

BOULENGER, George A., F.R.S., F.Z.S.; assistant, Dept. of Zoology, Brit. Museum, since 1882; author of numerous works on Zoology. (G. A. B.)

BOURCHIER, James David, M.A.; sometime Scholar of Kings College, Cambridge; Correspondent of 'The Times' at Athens. (J. D. B.)

BOURGET, Paul, poet, critic, and novelist; member of French Academy since 1894; officer of the Legion of Honour, 1895; author of La Vie inquiète, 1874; Edel, 1878; Les Aveux, 1882; Essais de Psychologie, 1883; Nouveaux Essais de Psychologie, 1885; Études et Portraits, 1887; Pastels, 1889; Physiologie de l'Amour moderne, 1890; Sensations d'Italie, 1891; Nouveaux Pastels, 1891; Outre Mer, 1895; L'Irréparable, 1884; Cruelle Enigme, 1885; Un Crime d'Amour, 1886; André Cornélis, 1887; Mensonges, 1887; Le Disciple, 1889; Un cœur de femme, 1890; La Terre Promise, 1892; Cosmopolis, 1892; Un Scrupule, 1894; Un Idylle Tragique, 1896; Voyageuses, 1897; Recommencements, 1897; Complications Sentimentales, 1898; La Duchesse Bleue, 1898; Drames de Famille, 1900; Un Homme d'Affaires, 1900; Le Fantôme. (P. B*.)

BOURNE, Gilbert Charles, M.A., D.Sc., F.L.S.; Fellow and Tutor of New Coll. Oxford; assistant to Linacre Professor of Comparative Anatomy, Oxford, 1887-88; Director, Marine Biological Association, United Kingdom, 1889-1890; assistant to Linacre Professor at Oxford, 1892-1900; University Lecturer in Comparative Anatomy, 1898; author of various memoirs on Comparative Anatomy, an 'Introduction to Study of Comp. Anatomy of Animals,' articles Anthozoa and Ctenophora, in Lankester's 'Zoology,' etc. (G. C. B.)

BOURNE, Henry Eldridge; Professor of History, College for Women, Western Reserve University, U.S. (H. E. B.)

BOWER, Frederick Orpen, Sc.D., F.R.S., F.L.S.; Regius Professor of Botany, University of Glasgow, since 1885; author of 'A Course of Practical Instruction in Botany,' 'Practical Botany for Beginners,' etc. (F. O. B.)

BOWLEY, A. L.; author of 'Elements of Statistics,' 'Wages in the United Kingdom in the Nineteenth Century,' etc. (A. L. Bo.)

BOYD, Charles Walter, B.A. (Edin.); journalist; sometime private secretary in South Africa to Dr Jameson and Mr Cecil Rhodes. (C. W. B*.)

BRABROOK, Edward William, C.B., F.S.A., V.P.S.S., V.P.R.S.L.; V.P. Royal Archæological Institute since 1900; Chief Registrar of Friendly Societies since 1891; President Anthropological Institute, 1895-97; President Folk-Lore Society, 1901; Foreign Associate, Society of Anthropology of Paris, 1901; author of 'Building Societies,' 'Friendly Societies,' 'Savings Banks' in Ninth Edition of 'Ency. Brit.,' 'Provident Societies and Industrial Welfare,' 'History of Royal Society of Literature.' (E. W. B.)

BRADFORD, John R., M.D., D.Sc., F.R.C.P., F.R.S.; member of Senate of University of London; physician to University Coll. Hospital London; Professor of Materia Medica and Therapeutics, University College, London; Professor Supt. of the Brown Institution; author of papers on medical and scientific subjects in Proc. Roy. Soc. and in Transactions of medical societies, etc. (J. R. B.)

BRÆKSTAD, H. L.; Anglo-Norwegian journalist; translator of standard Norwegian works. (H. L. B.)

BRAMWELL, Capt. G. A.; School of Signalling, Aldershot; Deputy-Assistant-Adjutant-General for signalling. (G. A. Br.)

BRANNER, John Casper, Prof., Ph.D., LL.D.; Geologist, Imperial Geolog. Commission, Brazil, 1875-1877; Agent U.S. Department of Agriculture in Brazil, 1882-83; acting President, Stanford University, U.S.A., 1898-99; Fellow of Geolog. Soc. of London and Société Géologique de France; member of various scientific societies of North and South America; author of numerous publications on Brazil. (J. C. Br.)

BRANTLY, William Theophilus; reporter of the Maryland Court of Appeals; ex-secretary of State of Maryland; author of 'Maryland' in Ninth Edition of 'Ency. Brit.,' 'Law of Personal Property.' (W. T. B.)

BRASSEY, Lord, 1st Baron, K.C.B., D.C.L.; Knight of St John of Jerusalem; Commander of Legion of Honour, 1889; President Statistical Society, 1879-80; Civil Lord of Admiralty, 1880-83; Secretary to Admiralty, 1883-85; Chairman of Opium Commission; President of the Institution of Naval Architects, 1893-95; Governor of Victoria, 1895-1900; author of 'Work and Wages,' 'Naval Annual,' 'British Navy,' 'British Seamen,' 'British Work and Foreign Wages,' etc. (Br.)

BRETT, Michael, Barrister, Middle Temple. (M. Bt.)

BRICKDALE, C. Fortescue, Barrister, Lincoln's Inn; author of 'The Law and Practice regarding the Registration of Deeds in the County of Middlesex,' 'Notes on Land Transfer,' 'Registration of Title to Land,' part author of 'The Land Transfer Acts, 1875 and 1897,' etc. (C. F. Br.)

BRIDGE, Vice-Admiral Sir Cyprian Arthur George, K.C.B.; Commander-in-Chief, China station; member of Committee on Heavy Guns, 1878; of War Office Committee on Machine Guns, 1879; of Ordnance Committee, 1881; Director of Naval Intelligence, 1889-94; Commander-in-Chief Australian station, 1895-98; author of 'Signals' in Ninth Edition of 'Ency. Brit.' (C. A. G. B.)

BRINKLEY, Capt. F., R.A.; proprietor and editor of the 'Japan Mail,' Yokohama; edited 'Japan'; translated 'The History of Japan'; compiled 'An Unabridged Japanese and English Dictionary,' etc. (F. By.)

BROADFOOT, Major William, R.E.; author of the Badminton 'Billiards'; edited 'Career of Major George Broadfoot, C.B., in Afghanistan and the Punjaub,' etc. (W. Br.)

BROOME, Lady, widow of the late Sir F. Napier Broome, Governor of West Australia; author of 'Station Life in New Zealand,' etc. (M. A. B.)

BROOMHALL, G. J. S., editor of 'Corn Trade Year-Book,' etc. (G. J. S. B.)

BROWNE, Edward Granville, M.A., M.B.; Fellow of Pembroke College, Cambridge, and Professor of Persian; editor of 'The Episode of the Bab,' etc. (E. G. B.)

BROWNLOW, Rt. Rev. William Robert [the late], D.D., M.A., R.C. Bishop of Clifton; provost, and domestic prelate to Pope Leo XIII.; co-editor of 'English Roma Sotterranea'; author of 'Early Christian Symbolism'; Memoirs of Melise Brownlow, Sir James Marshall, and Mother Rose Columba Adams, O.P.; Lectures on Slavery and Serfdom, on Church History, on Sacerdotalism, on the Catacombs, and other Archæological subjects; translation of 'Cur Deus Homo,' and 'Vitis Mystica.' (✠ W. R. B.)

BRUNTON, Sir Thomas Lauder, M.D., Sc.D., LL.D. (Edin. and Aberd.), F.R.S.; physician to St Bartholomew's Hospital, London; author of 'The Bible and Science,' 'Text-Book of Pharmacology, Therapeutics, and Materia Medica,' 'Disorders of Digestion,' 'Lectures on the Action of Medicines.' (T. L. B.)

BRYAN, George Hartley, Sc.D., F.R.S.; Professor of Pure and Applied Mathematics in the University College of North Wales; Fellow of Peterhouse, 1889-95; gold medal Inst. Naval Architects, 1901. (G. H. Br.)

BRYANT, Hon. Edgar E., LL.D.; Justice of the Circuit Court of Arkansas, 1890-97; author of 'Speeches and Addresses, etc. (E. E. B.)

BRYCE, Rt. Hon. James, P.C., D.C.L., LL.D., F.R.S., M.P.; Regius Professor of Civil Law at Oxford, 1870; Under-Secretary of State for Foreign Affairs, 1886; Chancellor of Duchy of Lancaster (with seat in Cabinet), 1892; President of Board of Trade, 1894; Chairman of Royal Commission on Secondary Education, 1894; member of Senate of London University, 1893; corresponding member of Institute of France, 1891; foreign member of Royal Academies of Turin and Brussels, 1896; corresponding member of Società Romana di Storia Patria, 1885; honorary Fellow of Trinity and Oriel Colleges, Oxford; president of the Alpine Club; author of 'Emperor and Empire,' 'Justinian,' 'Procopius,' 'Theodora,' in Ninth Edition of 'Ency. Brit.,' 'The Holy Roman Empire,' 'The Trade Marks Registration Act,' 'Transcaucasia and Ararat,' 'The American Commonwealth,' 'Impressions of South Africa,' etc. (J. Br.)

BRYDON, J. M., the late; architect; designed various Government Offices, Chelsea Town Hall and Polytechnic, Bath Municipal Buildings, etc. (J. M. By.)

BUCHANAN, John Young, M.A., F.R.S.; chemist and physicist of the 'Challenger' Expedition; later, Lecturer in Geography, University of Cambridge; author of 'Lake,' 'Mediterranean,' in Ninth Edition of 'Ency. Brit.' (J. Y. B.)

BUCKLEY, Rev. James Monroe, D.D., LL.D.; editor of 'The Christian Advocate' (New York); author of 'Travels in three Continents,' 'Faith Healing,' 'Christian Science and Kindred Phenomena,' 'Supposed Miracles,' etc. (J. M. Bu.)

BÜRDE, Lieut. Johannes, late of the German army, 51st Infantry Regiment; author of 'Problems of Applied Tactics, with Solutions,' 'Tactical Problems,' etc. (J. Be.)

BURDETT, Sir Henry, K.C.B.; founder and editor of the 'Hospital'; late superintendent of the Queen's Hospital, Birmingham, and of the Seamen's Hospital, Greenwich; late secretary Share and Loan Department, London Stock Exchange; author of 'Burdett's Official Intelligence of British, American, and Foreign Securities,' 'The National Debt,' 'Local Taxation in England and Wales,' 'The Patriotic Fund,' 'Hospitals and Asylums of the World,' 'The Relative Mortality of Large and Small Hospitals,' 'Burdett's Hospitals and Charities, a Year-book of Philanthropy,' 'Hospitals and the State,' 'Unhealthiness of Public Institutions,' 'A Practical Scheme for Old Age Pensions,' 'The Registration of Nurses,' 'The Nursing Profession, how and where to Train,' 'Housing of the Poor,' etc. (H. Bt.)

BURN, Rev. A. E., B.D.; Examining Chaplain to the Bishop of Lichfield; author of 'The Athanasian Creed,' 'An Introduction to the Creeds and to the Te Deum,' etc. (A. E. B.)

BURNSIDE, Rev. Frederick, M.A.; Hon. Canon St Albans; Rural Dean of Hertford; Hon. editor of the 'Official Year-Book of the Church of England'; compiler of 'The Official Parochial Register of Church Services, etc. (F. Bu.)

BURNSIDE, William, M.A., F.R.S.; Professor of Mathematics, Royal Naval College, Greenwich. (W. Bu.)

BURROUGHS, John, author of 'Wake Robin,' 'Signs and Seasons,' 'Birds and Poets,' 'Fresh Fields,' 'Whitman: A Study,' etc. (J. Bu.)

BURROWS, Rev. Winfrid Oldfield, M.A.; Vicar of Holy Trinity, Leeds; formerly Principal of Leeds Clergy School and Tutor of Christ Church, Oxford. (W. O. B.)

BURTON, Clarence Monroe, LL.D.; author of 'Life of Cadillac, founder of Detroit,' 'Revisited Landmarks of Detroit,' etc. (C. M. B.)

BURTON, William, F.C.S.; author of Cantor Lectures on 'Material and Design in Pottery,' etc. (W. B*.)

BUTLER, Alfred Joshua, M.A.; Fellow of Brasenose College, Oxford; author of 'Tyrol' in Ninth Edition of 'Ency. Brit.' (A. J. B.)

BUTLER, Prof. Nicholas Murray, Ph.D.; Pres. Columbia University, New York; author of 'The Meaning of Education,' etc.; editor of the 'Educational Review' and of the 'Great Educators' series. (N. M. B.)

C

CABLE, George Washington, A.M., D.L.; author of 'New Orleans' in Ninth Edition of 'Ency. Brit,' 'Old Creole Days,' 'The Grandissimes,' 'Dr Sevier, 'John March, Southerner,' etc. (G. W. Ca.)

CAILLARD, Sir Vincent Henry Penalver, K.B.; Assistant Commissioner for England on Montenegrin Frontier Commission, 1879; on Arab Tabia Commission, 1879; attached to Sir Beauchamp Seymour, Naval Demonstration, Dulcigno, 1880; service for Intelligence Department, 1882; attached Headquarters Staff Egyptian Campaign, 1882; appointed President Ottoman Public Debt Council, 1883; and Financial Representative of England, Holland, and Belgium in Constantinople; medal and bronze star, Egyptian campaign; Grand Cordons Medjidie and Osmanie; gold medals of Liakat and Nishan-i-Imtiaz; Grand Cordon of Ordre pour le mérite civile. (V. H. P. C.)

CALLENDAR, Hugh Longbourne, LL.D., F.R.S.; Professor of Physics, Royal Coll. of Science, London; Professor of Physics, M'Gill Coll. Montreal, 1893-98. (H. L. C.)

CAMP, Walter, Newhaven, U.S.A., author of 'Book of College Sports,' 'American Football,' etc. (W. Ca.)

CAMPBELL, J. G. D., M.A.; H.M.'s Inspector of Schools; educational adviser to the King of Siam, 1899-1901. (J. G. D. C.)

CAMPBELL, Rev. Lewis, M.A., LL.D.; emeritus Professor of Greek, University of St Andrews; Hon. Fellow of Balliol Coll. Oxford; Gifford Lecturer, St Andrews, 1894-95; author of 'Plato,' 'Sophocles' in Ninth Edition of 'Ency. Brit.,' 'The Christian Ideal,' part 'Life of James Clerk-Maxwell,' 'Sophocles in English Verse, 'Aeschylus in English Verse,' 'Guide to Greek Tragedy'; edition of 'Plato's Republic' (with late Professor Jowett), 'Life of Benjamin Jowett' (with E. Abbott), 'Religion in Greek Literature,' 'Letters of B. Jowett' (with E. Abbott), 'The Nationalization of the Old English Universities.' (L. C.)

CANA, F. R. (F. R. C.)

CARLYLE, E. I., M.A., F.R.Hist.Soc.; Fellow of Merton College, Oxford; assist. editor to the 'Dictionary of National Biography.' (E. I. C.)

CAROE, William Douglas, M.A., F.S.A.; Architect to Ecclesiastical Commission, to the Dean and Chapter of Canterbury, etc.; Fellow and Member of the Council R.I.B.A.; part author of 'Sefton.' (W. D. C.)

CARSON, Howard A., formerly chief engineer of the Metropolitan (Greater Boston, U.S.A.) Sewerage Commission and now chief engineer of the Boston Transit Commission; in charge of the building of the Boston Subway and the East Boston Tunnel; sometime President of the Boston Society of Civil Engineers. (H. A. C.)

CARTER, Albert Charles Robinson; assistant editor of 'The Year's Art,' 1887; editor, 1894; editor of 'The Year's Music,' 1898; contributor to 'The Art Journal' since 1889; art critic of 'Manchester Courier'; art critic for 'Pall Mall Gazette'; writer of 'The Art Annual, 1900, on War Artists.' (A. C. R. C.)

CARVER, Thomas Gilbert, M.A., K.C.; author of 'On the Law relating to the Carriage of Goods by Sea.' (T. G. C.)

CASE, Thomas, M.A.; Waynflete Professor of Moral and Metaphysical Philosophy, Oxford; Fellow of Magdalen; formerly Fellow and Tutor of B.N.C., and C.C.C.; author of 'Materials for History of Athenian Democracy from Solon to Pericles,' 'Realism in Morals,' 'Physical Realism,' 'St Mary's Clusters.' (T. Ca.)

CASTLE, Egerton, M.A., F.S.A.; author of 'Schools and Masters of Fence,' 'Consequences,' 'English Book-Plates,' 'The Light of Scarthey,' 'The Jerningham Letters,' 'The Pride of Jennico,' 'The Bath Comedy, 'Young April,' 'Marshfield the Observer,' 'The Secret Orchard,' etc. (E. Ca.)

CHADWICK, Capt. French Ensor, in command of U.S. cruiser 'New York,' flagship N. Atlantic Squadron; Chief of Staff of Rear-Admiral Sampson in the Spanish-American War. (F. E. Ch.)

CHALMERS, Mackenzie Dalzell, C.S.I., M.A.; assistant parliamentary counsel to Treasury, England; counsel to Board of Trade; Judge of County Courts, 1884; acting Chief Justice, Gibraltar, 1893; Commissioner of Assize, 1895; member of the Statute Law Committee, and Board of Faculty of Law of Oxford; law member of the Viceroy's Council in India; author of contributions to 'Dictionary of Political Economy and 'Encyclopædia Britannica, 'Digest of the Law of Bills of Exchange,' 'Digest of the Law of Sale,' etc. (M. D. Ch.)

CHAMBERLAIN, Hon. Joshua Lawrence, A.M., LL.D.; Brigadier-General in the U.S. Civil War; Governor of Maine, 1866-71, and President of Bowdoin College, 1871-83; author of 'Maine' in Ninth Edition of 'Ency. Brit.,' 'Maine: Her Place in History,' 'American Ideals,' etc. (J. L. C.)

CHANEY, Henry James, Superintendent Standards Department Board of Trade; Secretary to Royal Commission on Standards, 1867-70; represented Great Britain at International Conference on the Metric System, 1901; author of 'Treatise on Weights and Measures.' (H. J. C.)

CHANNING, Edward, Ph.D.; Professor of History, Harvard University; author of 'History of the United States,' 'Town and County Government in the English Colonies of North America,' 'Narragansett Planters,' etc.; collaborator with the late Dr Justin Winsor on the 'Narrative and Critical History of America.' (E. Ch.)

CHANUTE, Octave, late President American Society of Civil Engineers; honorary member Institution of Civil Engineers, Great Britain; author of 'Kansas City Bridges, 'Progress in Flying Machines,' etc. (O. C.)

CHAPMAN, Alfred, M.I.C.E.; designer and constructor of sugar machinery. (A. Ch.)

CHARLES, Rev. Robert Henry, M.A., D.D.; Professor of Biblical Greek, Trin. Coll. Dublin; author of 'Book of Enoch,' translated from the Ethiopic and edited 'Ethiopic Text of Book of Jubilees, edited from four MSS.,' 'Book of the Secrets of Enoch,' 'Apocalypse of Baruch,' translated from the Syriac and edited 'The Assumption of Moses,' 'The Doctrine of a Future Life,' 'Jowett Lectures for 1898-99.' (R. H. C.)

CHATAWAY, James Vincent, M.L.A., the late; Secretary for Agriculture, Queensland. (J. V. C.)

CHIROL, Valentine; B.Lit. University of Paris; foreign editor of 'The Times'; author of 'The Far Eastern Question,' 'Twixt Greek and Turk,' etc. (V. C.)

CHISHOLM, G. G., M.A., B.Sc.; author of 'The Commerce of the British Empire,' joint-author of 'Europe' in Stanford's 'Compendium of Geography and Travel'; edited Longman's 'Gazetteer of the World.' (G. G. C.)

CHISHOLM, Hugh, B.A.; formerly scholar C.C.C., Oxford; Barrister-at-Law of the Middle Temple; assistant editor of the 'St James's Gazette,' 1892-97; editor, 1897-1900. Contributor to 'Fortnightly Review,' 'National Review,' 'The Times,' 'Standard,' etc.; Joint-editor of the New Volumes of the 'Encyclopædia Britannica.' (H. Ch.)

CHREE, Charles, M.A., Sc.D., LL.D., F.R.S.; Fellow of King's College, Camb.; Superintendent Observatory Department, National Physical Laboratory. (C. Ch.)

CHRISTY, S. B., Ph.B.; Professor of Mining and Metallurgy and Dean of the Faculty of the College of Mining, University of California. (S. B. C.)

CHURCH, Arthur Herbert, M.A., D.Sc., F.R.S., F.S.A.; Professor of Chemistry, Royal Academy of Arts; Professor of Chemistry in the Royal Agricultural Coll. Cirencester; Lecturer, Cooper's Hill; President of Mineralogical Society, 1898-1901; author of 'Guano,' 'Hemp,' 'Irrigation,' in Ninth Edition of 'Ency. Brit.,' 'Precious Stones,' 'English Earthenware,' 'English Porcelain,' 'The Laboratory Guide,' 'Food Grains of India,' 'Food,' 'Josiah Wedgwood,' 'Colour,' etc. (A. H. C.)

CHURCH, Col. George Earl; Member of the Council Roy. Geog. Soc.; President of the Geog. Section, British Association, 1898; author of 'South America, an outline of its Physical Geography,' etc. (G. E. C.)

CIST, Henry Martyn, A.M., Cincinnati, U.S.A.; author of 'Army of the Cumberland,' 'Life of Major-General George H. Thomas'; editor of 20 Annual Reports of the Society of the Army of the Cumberland. (H. M. C.)

CLARK, Charles Hopkins, editor of 'Hartford Courant,' Conn., U.S.A. (C. H. Cl.)

CLARK, George A., B.L.; Secretary to the Leland Stanford Junior University, Secretary of the U.S. Fur Seal Commission, 1896-1898. (G. A. C.)

CLARKE, Colonel Sir George Sydenham, K.C.M.G., F.R.S.; Governor of Victoria, Australia, since 1901; served Egyptian expedition, 1882; Sudan expedition, 1885; Suakin, in Intelligence Department and as Assistant Political Officer; Secretary Colonial Defence Committee; Secretary to Royal Commission on Navy and Army Administration; Superintendent Royal Carriage Factory, 1894-1901; member of Committee on War Office Reorganization, 1900-1901; author of 'Practical Geometry and Engineering Drawing,' 'The Principles of Graphic Statics,' 'Plevna, 'Fortification Past, Present, and Future,' 'The Navy and the Nation,' 'Imperial Defence,' 'Russia's Sea-power,' etc. (G. S. C.)

CLAUSEN, George, A.R.A., R.W.S.; medals: Paris 1889, Chicago 1893, Brussels 1897, Paris 1900. (G. Cl.)

CLAUSON, Captain John Eugene, R.E., B.A. London; Secretary Colonial Defence Committee, War Office, London. (J. E. C.)

CLAYDEN, Peter William, the late; President Inst. Journalists, London; a President International Congress of the Press, Antwerp, 1894; English member International Bureau of Press; Treasurer, Institute of Journalists' Orphan Fund; author of 'Scientific Men and Religious Teachers,' 'England under Lord Beaconsfield,' 'Early Life of Samuel Rogers,' 'Rogers and his Contemporaries,' 'England under the Coalition,' etc. (P. W. C.)

CLERC, F. L., Denver, Colorado, U.S.A. M. Amer. Soc. of Mining Engineers. (F. L. C.)

CLERK, Dugald, M.I.C.E., F.C.S.; Consulting Engineer; Originator of the 'Clerk' type of Gas Engine; author of 'The Theory of the Gas and Oil Engine,' 'Notes on Motive Power Inventions,' etc. (D. Cl.)

CLIFFORD, Hugh Charles, C.M.G.; British Resident, Pahang; nominated by Colonial Office to post of Governor North Borneo and Labuan under Chartered Company, 1900; Resident, Pahang, 1901; Acting Resident, Negri Sembilan, Sept. 1901; author of 'In Court and Kampong,' 'Studies in Brown Humanity,' 'Since the Beginning,' 'In a Corner of Asia,' joint-author with Sir Frank Swettenham of a Dictionary of the Malay Language. (H. Cl.)

CLODD, Edward; author of 'The Childhood of the World,' 'The Childhood of Religions,' 'Jesus of Nazareth,' 'Myths and Dreams,' 'Story of Creation,' 'Story of Primitive Man,' 'Primer of Evolution,' 'Pioneers of Evolution,' 'Tom Tit Tot, an Essay on Savage Philosophy in Folk-Tale,' 'Grant Allen,' 'Story of the Alphabet,' etc. (E. Cl.)

COBHAM, C. Delaval, M.A., B.C.L.; British Commissioner, Larnaca, Cyprus; editor of 'Bibliography of Cyprus,' and 'Excerpta Cypria'; translator of Mariti's 'Travels in Cyprus.' (C. D. C.)

COCKBURN, Hon. Sir John Alexander, K.C.M.G., M.D.; Fellow King's College, London; Mayor of Jamestown, S. Australia; member of House of Assembly, S. Australia; Minister of Education, 1885-87; Premier and Chief Secretary, 1889-90; Chief Secretary, 1892; Minister of Education and Agriculture, 1893-98; one of the representatives of South Australia at the Federal Conferences in 1890, 1891, 1897, and 1898; Agent-General for South Australia to 1901. (J. A. Co.)

COGHLAN, T. A., A.M.I.C.E.; Government Statistician of New South Wales; author of 'The Mining Industry of New South Wales,' 'A Statistical Account of the Seven Colonies of Australasia'; has also written on the Agriculture, Fauna, and Timber Resources of New South Wales. (T. A. C.)

COLCLOUGH, John George, B.A.; late Secretary of the British Chamber of Commerce, Paris; author of 'Ulster,' 'The Law of Contract,' 'Twenty-five Years of Anglo-French Trade,' etc. (J. G. C.)

COLE, Alan S.; Asst. Sec. (Art) Board of Education; Ex. for Art, S. Kensington; author of 'Ancient Needle Point and Pillow Lace,' 'Tapestry and Embroidery,' etc.; and editor 'Studies from the Museums,' various descriptive catalogues of Tapestry, Embroidery, Lace, and Egyptian textiles at S. Kens. Mus., etc. (A. S. C.)

COLLINS, Rev. William Edward, M.A.; Professor of Ecclesiastical History, King's

Coll., London; Examining Chaplain to the Bishop of St Albans; author of 'The English Reformation and its Consequences,' 'The Nature and Force of the Common Law.' 'Unity, Catholic and Papal,' etc. (W. E. Co.)

COLOMB, Sir John Charles Ready, K.C.M.G., M.P.; author of 'Protection of Commerce in War,' 'Imperial Strategy,' 'The Distribution of our War Forces,' 'Colonial Defence and Colonial Opinions,' 'The Defence of Great and Greater Britain,' 'Naval Intelligence and Protection of Commerce,' 'The Use and Application of Marine Forces,' 'Imperial Federation, Naval and Military,' 'British Defence,' etc. (J. C. R. C.)

COLVIN, Sir Auckland, K.C.S.I., K.C.M.G., C.I.E.; Grand Cordons of Osmanieh and Medjidieh; Comptroller-Gen. Egypt; Financial Adviser to Khedive; Financial member of Viceroy's Council, India; Lieut.-Gov. North-West Provinces and Oudh; author of 'John Russell Colvin,' etc. (A. Co.)

COLYAR, H. A. de; of the Middle Temple, Barrister-at-Law; author of 'Law of Guarantees' and 'Principal and Surety.' (H. A. de C.)

COMSTOCK, Brig.-Gen. Cyrus Ballou; U.S.A., retired; Board of Engineers for Fortifications, U.S. Army; chief engineer, Army of the Potomac, 1862-63; President of the Mississippi River Commission; author of 'Primary Triangulation of the U.S. Lake Survey.' (C. B. C.)

CONATY, Right Rev. Bishop Thomas James, S.T.D., J.C.D.; Rector of the Catholic University of America. (✠ T. J. C.)

CONWAY, Sir William Martin, M.A.; Slade Professor of Fine Arts, Cambridge; Professor of Art, Univ. Coll. Liverpool, 1885-88; Hon. Sec. Art Congress, 1888-90; President of the Alpine Club; author of 'Dawn of Art in the Ancient World,' a series of Climbers' Guide-books to the Pennine and Lepontine Alps, etc., 'Climbing and Exploration in the Karakoram-Himalayas,' 'The Alps from End to End,' 'The First Crossing of Spitsbergen,' 'With Ski and Sledge over Arctic Glaciers,' 'The Bolivian Andes.' (W. M. C.)

COOK, Theodore Andrea, M.A., F.S.A.; author of 'Old Touraine,' 'Rouen,' 'A History of the English Turf,' joint-author of 'Ice-Sports.' (T. A. Co.)

COOKE, Charles Wallwyn Radcliffe-, B.A.; author of 'A Treatise on the Agricultural Holdings (England) Act,' 'Four Years in Parliament with Hard Labour,' 'A Book about Cider and Perry'; President, National Association of English Cider-makers. (C. W. R. C.)

COOLIDGE, Rev. William Augustus Brevoort, M.A., F.R.G.S.; Fellow of Magdalen College, Oxford; Professor of English History, St David's College, Lampeter, 1880-81; Corresponding Member of the Swiss Hist. Society, 1891; author of 'Jura,' 'Switzerland' (History, Geography, and Statistics), 'Tell,' 'Valais,' 'Zurich' in Ninth Edition of 'Ency. Brit.'; joint author of 'Guide du Haut Dauphiné,' 'Guide to the Central Alps of the Dauphiny,' 'Guide to the Lepontine Alps,' 'The Mountains of Cogne,' 'The Adula Alps,' 'The Range of the Tödi,' 'Guide to Grindelwald,' 'Guide to Switzerland'; editor of 'Alpine Journal,' 1880-89. (W. A. B. C.)

COPEMAN, Sydney Monckton, M.A., M.D.; Medical Inspector, Local Government Board; Member of the Council Epidemiological Society; author of 'Vaccination: its Natural History and Pathology,' 'Bacteriology of Vaccine Lymph,' etc. (S. M. C.)

CORRADINI, Enrico; late editor of 'La Naziona,' Florence; author of 'La Civia Romanzo,' etc. (E. Co.)

COTTON, James Sutherland, M.A.; Hon. Secretary of the Egypt Exploration Fund; late editor of 'The Academy,' London; Fellow and Lecturer of Queen's Coll. Oxford; author of 'Warren Hastings' in Ninth Edition of 'Ency. Brit.,' 'Decennial Report on the Moral and Material Progress of India,' 'India,' 'Elphinstone,' 'Quinquennial Report on Education in India'; editor of 'Paterson's Practical Statutes,' 'The Official Gazetteer of India.' (J. S. Co.)

COX, General Jacob Dolson, LL.D., the late; Governor of the State of Ohio (1866-67); U.S. Secretary of the Interior (1869-70); Major-General U.S. Volunteers in the Civil War; Brigade-Commander under General Sherman in the Atlanta campaign; author of 'Atlanta: the March to the Sea,' 'Battle of Franklin,' etc. (J. D. Co.)

CRACKANTHORPE, Montague Hughes, K.C., D.C.L.; late member General Council of the Bar and Council of Legal Education; late Chairman Incorporated Council of Law Reporting; Honorary Fellow St John's Coll. Oxford; representative of General Council of Bar at International Congress of Advocates, Brussels, 1897; representative of the same Council at International Congress of the Société de Législation Comparée, Paris, 1900; acting Chairman of the International Commission on Criminal Sentences; author of many legal, social, and political articles. (M. H. C.)

CRAIES, W. F.; Barrister, Inner Temple; edited 'A Collection of Statutes relating to Criminal Law,' 'A Treatise on the construction and effect of Statute Law,' 'The Laws of Insurance,' etc. (W. F. C.)

CRANE, Walter, A.R.W.S.; silver medal, Paris, 1889; silver medal, Society of Arts; gold medal, Munich, 1895; first and present President Arts and Crafts Ex. Society (England), 1888; member of Council of Art, Board of Education, and examiner in Design; Hon. Member Dresden Academy of Fine Arts; appointed British Commissioner for the Turin International Exhibition of Decorative Art, 1902; Director of Design, Manchester Municipal School of Art, from 1893-96 (resigned); Hon. Art Director, Reading College, 1898; Principal of the Royal College of Art, South Kensington, 1898-99 (resigned); author and illustrator of 'Baby's Opera,' 'Baby's Banquet,' 'The Sirens Three,' 'Flora's Feast,' 'Queen Summer,' 'Claims of Decorative Art,' 'Renascence, 1891,' 'Decorative Illustration of Books,' 'Spenser's Fairie Queene,' 'The Shepherd's Calendar,' 'Line and Form,' 'A Masque of Days,' etc. (W. Cr.)

CRAWFORD, Francis Marion; author of many novels, including 'Mr Isaacs,' and 'Saracinesca'; and of 'Ave Roma Immortalis, 'Life of Pope Leo XII.,' 'Constantinople,' etc. (M. Cr.)

CREAK, Capt. Ettrick William, R.N., C.B., F.R.S.; late Superintendent of Compasses, Hydrographic Department, Admiralty, London. (E. W. C.)

CREIGHTON, Charles, M.A., M.D. Aberdeen; author of 'History of Epidemics in Britain,' 'Jenner and Vaccination,' etc. (C. C.)

CREWE, Earl of, P.C., M.A., F.S.A.; President of the Literary Fund; assist. priv. sec. to Sec. for Foreign Affairs, 1883-84; Lord-Lieut. of Ireland, 1892-95; author of 'Stray Verses,' articles on Ireland, etc. (C.)

CRIMP, Santo, M.I.C.E.; the late; author of 'Sewage Disposal Works'; joint author of 'Tables and Diagrams for use in designing sewers and water mains,' etc. (S. Cr.)

CRITCHELL, James Troubridge; London Correspondent of the 'Brisbane Courier,' 'North Queensland Herald,' etc.; author of 'Preliminary Enquiry into the Markets of the European Continent,' 'Guide to Queensland,' etc. (J.T.Cr.)

CROOKES, Sir William, F.R.S.; Past President of the Chemical Society, Great Britain; Past President of the Institution of Electrical Engineers; editor of 'Chemical News,' President of the British Association for the Advancement of Science, 1898; editor of 'Quarterly Journal of Science'; Professor of Chemistry, Training Coll., Chester, 1855; author of 'Assaying' in Ninth Edition of 'Ency. Brit.'; 'Select Methods in Chemical Analysis,' 'Manufacture of Beetroot-Sugar in England,' 'Handbook of Dyeing and Calico-Printing,' 'Dyeing and Tissue Printing,' 'Kerl's Treatise on Metallurgy,' with Ernst Rohrig, 'Wagner's Chemical Technology,' 'Auerbach's Anthracen and its Derivatives,' 'Ville's Artificial Manures,' 'A Solution of the Sewage Question,' 'The Profitable Disposal of Sewage,' 'The Wheat Problem,' etc. (W. C.)

CROSS, Charles Robert, B.Sc.; Professor of Physics and Director of Rogers Laboratory, Massachusetts Institute of Technology; Director of Rumford Committee, American Academy of Arts and Sciences. (C. R. Cr.)

CROZIER, Capt. T. H., R.A.; Professor of Artillery, Ordnance College, Woolwich. (T. H. C.)

CRUMP, Charles George, B.A.; of H.M. Record Office; editor 'The History of the Life of Thomas Ellwood,' 'The Works of Walter Savage Landor,' etc. (C. G. Cr.)

CUNDALL, F.; Sec. and Librarian, Institute of Jamaica; author of 'Studies in Jamaica History,' 'The Story of the Life of Columbus and Discovery of America'; edited 'Bibliotheca Jamaicensis,' etc. (F. Cu.)

CUNNINGHAM, J. T., M.A.; late Fellow of University Coll., Oxford; lecturer for Fisheries, Tech. Instruction Com. of Cornwall; late Asst. Professor of Natural History, Edinburgh; also Naturalist to Marine Biological Assoc. of the U.K.; author of 'Treatise on Common Sole,' 'Marketable Marine Fishes of the British Isles,' 'Sexual Dimorphism,' etc. (J. T. C.)

CURRAN, Rev. J. Milne; author of 'Geology of Sydney and the Blue Mountains,' 'A Contribution to the Geology and Petrography of Bathurst,' etc. (J. M. Cu.)

D

DABNEY, Charles William, Ph.D.; Pres. Univ. of Tennessee; assistant U.S. Secretary Agriculture, 1893-97, etc. (C. W. D.)

DABNEY, Richard Heath, A.M., Ph.D.; Professor of Historical and Economical Science, University of Virginia; author of 'The Causes of the French Revolution,' 'John Randolph: a Character Sketch.' (R. H. D.)

DALBY, W. Ernest, M.A., B.Sc., M.I.C.E., M.I.M.E., Assoc. M.I. Nav. Architects; Professor of Mechanical Engineering and Applied Mathematics, City and Guilds Technical College, Finsbury. (W. E. D.)

DALE, T. F.; author of 'The Game of Polo, part-editor of 'Riding and Polo.' (T. F. D.)

DALL, Hon. William Healey, A.M.; naturalist, U.S. National Museum; author of 'Alaska and its Resources,' 'Tribes of the Extreme North-west,' etc. (W. H. D.)

DALLAS, J. M. M.; late Secretary of the Edinburgh Draughts Club. (J. M. M. D.)

DANNREUTHER, Edward, Professor Royal Coll. Mus.; author of 'Musical Ornamentation,' 'Liszt's Études,' 'Richard Wagner.' (E. Da.)

DARWIN, George Howard, M.A., LL.D., D.Sc., F.R.S.; Plumian Professor of Astronomy and Experimental Philosophy, Cambridge; Fellow of Trin. Coll. Camb.; author of 'Tides,' in Ninth Edition of 'Ency. Brit.' 'Reports to B.A. on Harmonic Analysis of Tidal Observations,' 'Memoirs on the Effects of Tidal Friction on the Earth and on the Moon,' Phil. Trans. Roy. Soc., 'The Tides and Kindred Phenomena in the Solar System,' etc. (G. H. D.)

DARWIN, Leonard, Major, late R.E.; Intelligence Dept. War Office, 1885-90; served on several scientific expeditions, including Transit of Venus of 1874 and 1882; author of 'Bi-metallism.' (L. D.)

DAVENPORT, Cyril James H., F.S.A.; British Museum; silver medal Society of Arts, 1900; binding editor to the Anglo-Saxon Review; author of 'The English Regalia,' 'Royal English Bookbindings,' 'Cantor Lectures on Decorative Bookbindings,' 'English Embroidered Bookbindings,' 'Life of T. Berthelet.' (C. D.)

DAVEY of Fernhurst, Lord, D.C.L., F.R.S.; Lord of Appeal in Ordinary; Solicitor-General, 1886; Lord Justice of Appeal, 1893. (D.)

DAVIDS, T. W. Rhys, LL.D., Ph.D.; Secretary and Librarian Royal Asiatic Society; Professor of Pali and Buddhist Literature, Univ. Coll. London; author of 'Buddhism,' 'Jains,' 'Lamaism,' in Ninth Edition of 'Ency. Brit.,' 'Buddhism,' 'Buddhist Birth Stories,' 'Buddhist Suttas from the Pali,' 'Hibbert Lectures,' 1881, etc. (T. W. R. D.)

DAVIDSON, William Leslie, M.A., LL.D.; Professor of Logic and Metaphysics, Aberdeen University; author of 'English Words Explained,' 'Theism as grounded in Human Nature,' 'A Philosophical Centenary: Reid and Campbell,' 'Christian Ethics.' (W. L. D.)

DAVIES, A. Llewelyn, B.A.; Barrister, Inner Temple; Assistant Reader in Common Law under the Council of Legal Education. (A. Ll. D.)

DAVIES, Henry Walford, Mus. Doc. (Camb.), A.R.C.M. (Lond.); organist and director of the choir, Temple Church, London; formerly organist and choirmaster, St Anne's, Soho; teacher of counterpoint, R.C.M., 1895. (H. W. D.)

DAVIS, John Patterson, Ph.D., A.M.; assistant in History and Economics, University of Michigan, 1894-1895; now Attorney-at-Law, Nampa, Idaho; author of 'The Union Pacific Railway,' etc. (J. P. D.)

DAVIS, William Morris, Professor Physical Geography, Harvard University; author of 'Physical Geography' and numerous scientific publications. (W. M. D.)

DAWKINS, William Boyd, M.A., D.Sc., F.R.S., F.S.A., F.G.S., A.M.I.C.E.; Professor of Geol. and Palæontology in Owens College, Manchester; geologist on Geological Survey of Great Britain, 1861-69; author of 'Cave' in Ninth Edition of 'Ency. Brit.,' 'Cave Hunting,' 'Early Man in Britain,' 'British Pleistocene Mammalia.' (W. B. D.)

DAWSON, George Mercer, LL.D., F.R.S., the late; Director Geological Survey of Canada; Geologist and Naturalist to H.M. North American Boundary Commission, 1873-75; one of

H.M. Behring Sea Commissioners, 1891, and under the Behring Sea Joint Commission Agreement, 1892; author of numerous scientific and technical reports printed by the Canadian Government, and scientific and other papers. (G. M. D.)

DAY, Lewis F.; English Designer and Art Lecturer; Med. Paris Exhibition (1900); Examiner for Art, Board of Education; author of 'Windows—Stained and Painted Glass,' 'The Anatomy of Pattern,' 'The Distribution of Ornamental Design,' 'Nature in Ornament,' etc. (L. F. D.)

DAYOT, Armand; Inspector of Fine Arts, Ministry of Fine Arts, France; author of 'Un siècle d'art,' 'La Révolution Française, d'après des peintures, sculptures, etc.,' 'Les maîtres de la caricature Française au XIXe siècle,' etc. (A. Da.)

DEACON, George Frederick, M.I.M.E.; Member of Council of Institution of Civil Engineers, London; investigated schemes for water-supply of Liverpool; projected the Vyrnwy scheme; carried out part of it in conjunction with the late Thomas Hawksley; President Association of Municipal and County Engineers, 1878; President Engineering Section Sanitary Institute, 1894; President Mechanical Science Section, British Association, Toronto, 1897. (G. F. D.)

DEANS, Richard Storry, LL.B.; Barrister-at-Law, Gray's Inn. (R. S. D.)

DENNING, W. F., F.R.A.S.; Gold Medal, R.A.S.; President Liverpool Ast. Society, 1877-78; author of 'Telescopic Work for Starlight Evenings,' 'The Great Meteoric Shower,' etc. (W. F. D.)

DE VILLIERS, John Abraham J.; British Museum. (J. A. J. de V.)

DE VINNE, Theodore Low, printer and typographist, New York; head of the firm of Theodore L. de Vinne and Co.; author of 'Printers' Price List,' 'Invention of Printing,' 'Historic Types,' etc. (T. L. de V.)

DEWAR, James, M.A., Hon. LL.D. (Glasgow, St Andrews, Edin.), D.Sc. (Victoria), F.R.S., F.R.S.Ed., F.I.C., F.C.S.; Professorial Fellow of Peterhouse, Camb.; Jacksonian Professor of Experimental Philosophy, Cambridge; Fullerian Professor of Chemistry, Royal Institution, London; Vice-President of the Royal Society; a Director of the Davy-Faraday Research Laboratory; President British Association for 1902; co-inventor with Sir Frederick Abel of cordite; late member of the Government Explosives Committee; author of 'Alum,' etc. in Ninth Edition of 'Ency. Brit.,' numerous papers contributed to the proceedings of the Royal Societies of London and Edinburgh, the Royal Institution, the British Association, the Chemical Society, etc. (J. Dr.)

DIBDIN, Charles, F.R.G.S., A.V.I.; Knight of St John of Jerusalem in England; Hon. Corresponding Member of Institutions de Prévoyance, France; Secy. of the Royal National Lifeboat Institution, England; Hon. Secy. of the Civil Service Lifeboat Fund. (C. Di.)

DIBDIN, Lewis Tonna, K.C., D.C.L. (Durham), F.S.A.; author of 'Church Courts,' 'City Livery Companies,' 'Brewer's Endowment and Establishment,' 'Monasticism in England,' 'Hanson's Death Duties.' (L. T. D.)

DICEY, Edward, C.B., B.A.; editor of 'The Observer' (London), 1870-89; author of 'Rome in 1860,' 'Cavour,' 'The Morning Land,' 'England and Egypt,' 'Victor Emmanuel,' 'Bulgaria, the Peasant State,' 'The Story of the Khedivate,' etc. (E. D.)

DICKEY, Rev. Charles A., D.D.; President of the Presbyterian Hospital in Philadelphia; Moderator of the General Assembly of the Presbyterian Church in the U.S., 1900. (C. A. D.)

DICKSON, Henry Newton, B.Sc., F.R.S.E., F.R.G.S.; late Vice-President Royal Meteorological Society; Lecturer in Physical Geography, Oxford; author of 'Meteorology: the Elements of Weather and Climate,' etc. (H. N. D.)

DIXON, Capt. J. Whitly, R.N.; conservator of the river Humber; late Staff Commander of the Medway Fleet Reserve; author of 'Mariner's Compass in an Iron Ship,' etc. (J. W. D.)

DOBSON, George; Petersburg; author of 'Russia's Railway Advance and Central Asia,' etc. (G. D.)

DOBSON, Henry Austin, Principal, H.M. Board of Trade, to 1901; author of 'Hogarth' in Ninth Edition of 'Ency. Brit.'; 'Proverbs in Porcelain,' 'Old-World Idylls,' 'At the Sign of the Lyre,' 'Collected Poems,' 'Thomas Bewick and his Pupils,' Lives of Fielding, Steele, Goldsmith, Horace Walpole, William Hogarth, 'Four Frenchwomen,' 'Eighteenth Century Vignettes,' 'A Paladin of Philanthropy,' etc. (A. D.)

DODD, Lieut.-Col. John Richard, M.B., F.R.C.S., R.A.M.C.; Medical Officer, Royal Arsenal, Woolwich. (J. R. D.)

DOUGLAS, James, LL.D.; member and Vice-President Am. Inst. of Mining Engineers; member Am. Philosoph. Soc., Am. Geolog. Soc., Society of Arts, London, etc.; formerly Professor of Chemistry, Morrin College, Quebec; author of 'Canadian Independence,' 'Imperial Federation and Annexation,' numerous technical articles and reports, etc. (J. Ds.)

DOUGLAS, Robert Kennaway, Keeper of Oriental Printed Books and MSS. at the British Museum; Professor of Chinese, King's Coll. London; appointed China Consular Service, 1858; retired, and appointed assistant in charge of Chinese Library, British Museum, 1865; author of 'Canton,' 'China,' 'Jenghiz Khan,' 'Manchuria,' etc., in Ninth Edition of 'Ency. Brit.,' 'The Language and Literature of China,' 'Confucianism and Taoism,' 'China,' 'A Chinese Manual,' 'The Life of Li Hung-Chang,' 'China.' (R. K. D.)

DOUGLASS, William Tregarthen, M.I.C.E., M.I.M.E., M.I.E.E.; late Consulting Engineer to the Trinity House; Con. Eng. to Govts. of W. Australia, N. S. Wales, Victoria, Cape of Good Hope, etc.; erected the Eddystone, Bishop Rock Lighthouses, etc.; author of 'The New Eddystone Lighthouse,' 'On the More Efficient Lighting of Estuaries and Rivers,' etc. (W. T. D.)

DOWSON, J. Emerson, M.I.C.E., M.I.M.E.; Inventor of the Dowson Gas Plant; part author of 'Tramways,' 'Decimal Coinage,' etc. etc. (J. E. Do.)

DREYER, John Louis Emil, Director Armagh Observatory; assist. Astronomer at Dublin University Observatory, 1878-82; author of 'Observatory,' 'Sextant,' 'Time,' 'Transit Circle,' in Ninth Edition 'Ency. Brit.,' 'Second Armagh Catalogue of 3300 Stars,' 1886, 'New General Catalogue of Nebulæ and Clusters of Stars,' 'Tycho Brahe'; co-editor 'Copernicus: an International Journal of Astronomy,' 1881-84. (J. L. E. D.)

DRIESCH, Hans A. E., Ph.D. Jena; Stazione Zoologica, Naples; author of 'Analytical Theory of Organic Development,' 'Biology,' etc. (H. A. E. D.)

DRIVER, Rev. Samuel Rolles, D.D., D.Litt.; Regius Professor of Hebrew, and Canon of Christ Church, Oxford; member of Old Testament Revision Company; author of 'Isaiah,' 'Notes on the Hebrew Text of the Books of Samuel,' 'An Introduction to the Literature of the Old Testament,' various commentaries; joint-editor of the 'Holy Bible, with various renderings and readings from the best authorities,' 'A Hebrew and English Lexicon of the Old Testament.' (S. R. D.)

DUFF, Rt. Hon. Sir Mountstuart Elphinstone Grant, P.C., M.A., D.L., G.C.S.I., F.R.S.; Under-Secretary of State for India, 1868-74; Under-Secretary for the Colonies, 1880-81; Governor of Madras, 1881-86; Member of Senate University of London, 1891; President Royal Geographical Society, 1889-93; President Royal Historical Society, 1892-99; author of 'Miscellanies, Political and Literary,' 'Memoir of Sir H. S. Maine,' 'Ernest Renan,' 'Memoir of Lord de Tabley,' 'Notes from a Diary.' (M. G. D.)

DUFFIELD, William Bartleet; of the Inner Temple, Barrister-at-Law. (W. B. Du.)

DU FIEF, J.; Secrétaire, Société Royale Belge de Géographie, Bruxelles; author of 'Atlas du Belgique,' 'Les decouvertes maritimes des Portugais au XVe siècle,' 'Les Expeditions Belges au Katenga,' etc. (J. du F.)

DUNCAN, Louis, Ph.D.; sometime President of the American Institute of Electrical Engineers, and Associate Professor of Electricity, Johns Hopkins University, Baltimore. (L. Du.)

DUNCAN, P.; Secretary's Department, Inland Revenue Office, London. (P. D.)

DUNNING, William Archibald, Ph.D.; Professor of History, Columbia University, New York; member of The American Historical Association; author of 'Essays in Reconstruction,' etc.; editor 'Political Science Quarterly.' (W. A. D.)

DUTT, Romesh Chunder, C.I.E.; Lecturer Indian History, Univ. Coll. London; Fellow of the Calcutta Univ.; Divisional Commissioner, 1894 and 1895, being the only native of India who attained that position in the last century; author of a series of historical and social novels in Bengali, and a translation of the Rig Veda and other Sanscrit religious works into that language; in English, 'Civilization in Ancient India,' 'Lays of Ancient India,' 'Maha-bharata,' condensed into English verse, 'Ramayana,' condensed into English verse, 'England and India, 1785-1885'; 'Famines in India.' (R. C. D.)

DYER, Sir William Turner Thiselton-, M.A., B.Sc., LL.D., Ph.D., K.C.M.G., C.M.G., C.I.E., F.R.S.; Director, Royal Gardens, Kew; Fellow, University of London, 1887-90; V.P.R.S. 1896-97; joint-author of 'Biology' in Ninth Edition of 'Ency. Brit.,' 'Flora of Middlesex,' edited English edition of Sachs' 'Text-book of Botany,' 'Flora Capensis,' etc. (W. T. T.-D.)

E

EARDLEY-WILMOT, Rear-Admiral Sydney M., R.N.; author of 'The British Navy, Past and Present,' 'The Next Naval War,' 'Our Flags: Their Origin, Use, and Traditions,' 'The Development of Navies during the Last Half Century,' etc. (S. M. E.-W.)

EATON, Fred. A.; Secretary to the Royal Academy, London; edited Thausing's 'Albert Dürer: His Life and Works.' (F. A. E.)

EDGINGTON, Charles, M.A.; President Oxford University Speed Skating Club; holder since 1898 of the world's speed record for the hour (19 m. 348 yds.). (C. E.)

EDGEWORTH, Francis Ysidro, M.A.; D.C.L.; Professor of Political Economy, Oxford, Fellow of All Souls' Coll. Oxford; Fellow of King's Coll. London; editor of the 'Economic Journal'; author of 'Mathematical Psychics,' etc. (F. Y. E.)

EDWARDS, William Seymour, Attorney and Counsellor-at-law, U.S.A.; author of 'Coals and Cokes in West Virginia.' (W. S. E.)

EGERTON, H. E.; author of 'A Short History of British Colonial Policy,' 'Sir Stamford Raffles,' 'Essays on Christ's Hospital,' etc. (H. E. Eg.)

ELIOT, Charles William, LL.D., D.C.L.; President of Harvard University; author of 'American Contributions to Civilization,' 'Educational Reform,' etc. (C. W. E.)

ELIOT, Whately, M.I.C.E.; conducted survey of the coast of New Zealand; late Engineer to Peterhead Harbour Board; Resident Engineer Eastham section of the Manchester Ship Canal; Superintendent Civil Engineer, Keyham Dockyard Extension, etc. (W. E.)

ELLINGTON, E. B., M.I.C.E.; Member of the Council M.E.; Member of the Société des Ingénieurs Civils de France; Chief Engineer London and Liverpool Hydraulic Power Companies, etc.; inventor of numerous improvements in hydraulic machinery. (E. B. E.)

ERNST, Gen. Oswald Herbert; Brigadier-General U.S.A.; member of the U.S. Isthmian Canal Commission; Engineer in charge of Western River Improvements, 1878-86, and of Harbour Improvements on Texas Coast, 1886-89; Superintendent U.S. Military Academy, 1893-98; author of 'Manual of Practical Military Engineering,' etc. (O. H. E.)

EVANS, Hon. Henry Clay; U.S. Commissioner of Pensions, Washington. (H. C. E.)

EVERETT, Commander Allan F., R.N.; Signal School, H.M.S. 'Victory,' Portsmouth. (A. F. E.)

EVERETT, Joseph David, M.A., D.C.L., D.Sc., F.R.S.; late Professor of Natural Philosophy, Queen's Coll. Belfast; Assist. to Professor of Mathematics, Glasgow, 1864-67; author of 'Centimètre-Gramme-Second System of Units,' English edition of 'Deschanel's Physics,' 'Elementary Text-Book of Physics,' 'Outlines of Natural Philosophy.' (J. D. E.)

EWART, James Cossar, M.D., F.R.S.; Regius Professor of Natural History, Edinburgh; Professor Natural History, Aberdeen, 1878-82; member Fishery Board for Scotland; author of 'The Locomotor System of the Echinoderms' (with the late G. J. Romanes), 'On the Progress of Fish Culture in America,' 'On Whitebait,' 'On the Preservation of Fish,' 'The Development of the Limbs of the Horse.' (J. C. E.)

EWING, James Alfred, M.A., B.Sc., F.R.S., M.I.C.E.; Professor of Mechanism and Applied Mechanics, Cambridge; Fellow of King's College, Cambridge; Professor of Mechanical Engineering at the Imperial University, Tokyo, Japan, 1878-83; author of 'Pneumatic Despatch,' 'Seismometer,' 'Sewerage,' 'Siemens,' 'Steam Engine,' 'Strength of Materials' in Ninth Edition of 'Ency. Brit.,' 'Treatise on Earthquake Measurement,' 'Magnetic Induction in Iron and other Metals,' 'The Steam Engine and other Heat Engines,' etc. (J. A. E.)

EXETER, Bishop of, Right Rev. Herbert Edward Ryle, D.D., B.A.; Warburton Lecturer 1899-1903; Fellow King's College, Cambridge, 1881; Divinity Lecturer at

Emmanuel College, Cambridge, 1881-84; at King's College, 1882-86; Principal of St David's College, Lampeter, 1886-88; Professorial Fellow of King's College, Cambridge, 1888; examining chaplain to late Bishop of St Asaph, 1887-89, and to Bishop of Ripon, 1889; Hon. Canon of Ripon, 1895; Chaplain to the Queen, 1898-1901; Hulsean Professor of Divinity, Cambridge University, 1887-1901, and President of Queens' College, Cambridge, 1896-1901; author of 'The Canon of the Old Testament,' 'The Early Narratives of Genesis,' 'Commentary on Ezra and Nehemiah,' 'Philo and Holy Scripture,' etc. (H. E. E.)

F

FAIRBAIRN, Andrew Martin, M.A., D.D., LL.D.; Principal Mansfield Coll. Oxford; Principal of Airedale Coll. 1877-1886; Chairman of Congregational Union of England and Wales, 1883; Member of Royal Commission on Secondary Education, 1894-95; author of 'Arminius,' 'Independents,' in Ninth Edition of 'Ency. Brit.,' 'Studies in the Life of Christ,' 'The City of God,' 'Religion in History and in Modern Life,' 'Catholicism, Roman and Anglican,' 'The Philosophy of the Christian Religion,' etc. (A. M. F.)

FAIRBROTHER, William Henry, M.A., Lecturer in Philosophy, Lincoln College, Oxford; author of 'Philosophy of Thomas Hill Green.' (W. H. F*.)

FAIRLIE, John A., Ph.D.; Asst. Prof. of Administrative Law, Univ. of Michigan; author of 'Municipal Government.' (J. A. Fa.)

FARRAR, Very Rev. Frederic William, D.D., F.R.S.; Dean of Canterbury; Hulsean Lecturer at Cambridge; Bampton Lecturer at Oxford; Chaplain to the Speaker of the House of Commons, 1890-95; author of 'Jesus Christ' in Ninth Edition of 'Ency. Brit.,' 'The Life of Christ,' 'The Life of St Paul,' 'The Early Days of Christianity,' 'Darkness and Dawn,' 'The Bible, its Meaning and Supremacy,' etc. (F. W. F.)

FAUNCE, W. H. P., A.M., D.D.; President of Brown University, Providence, R.I. (W. H. P. F.)

FAUR, G., of the Egyptian Hall, London. (G. Fa.)

FERGUSON, J.; editor of the 'Ceylon Observer,' 'Tropical Agriculturist,' etc.; author of 'Handbook to Ceylon,' manuals on Coffee, Tea, Gold, Gems, etc. (J. F.)

FERRERO, Baron Augusto; editor of 'La Tribuna,' Rome; author of 'Nostalgie d'Amore'; edited 'From Florence to Rome: A Political Diary of 1870-71,' etc. (A. Fe.)

FFOULKES, Miss C. Jocelyn; translator of Morelli's 'Italian Painters,' etc. (C. J. F*.)

FIDLER, H.; Civil Engineer, head of Technical Staff Department of Civil Engineer-in-Chief, Admiralty; editor of 'A Manual of Construction,' etc. (H. F.)

FIELD, Capt. A. Mostyn, R.N.; F.R.A.S., F.R.G.S., F.R.Met.S.; has worked for the Hydrographic Survey in various parts of the world. (A. M. F*.)

FILON, Pierre Marie Augustin; agrégé ès lettres; French Critic; tutor to the late Prince Imperial; literary editor of the 'Revue Bleue'; author of 'Le Mariage de Londres,' 'Histoire de la Littérature Anglais,' 'English Profiles,' and works on the French and English drama. (A. Fi.)

FISHER, Alexander; English teacher and specialist in the art of enamelling; author of technical articles in the 'Magazine of Art,' the 'Studio,' etc. (A. Fi*.)

FISHER, George Park, D.D., LL.D.; Professor of Ecclesiastical History, Yale; author of 'The Reformation,' 'History of the Christian Church,' 'The Colonial Era,' etc. (G. P. F.)

FISKE, John, LL.D., the late; author of 'Discovery of America,' 'American Revolution,' 'The Mississippi Valley in the Civil War,' 'Cosmic Philosophy,' etc. (J. Fi.)

FITCH, Charles H., in charge of the Indian Territory Section, U.S. Geological Survey. (C. H. F.)

FITCH, Sir Joshua Girling, M.A., LL.D.; Chief Inspector of Training Colleges, retired 1894; H.M. Inspector of Schools, 1863; Chevalier of the Legion of Honour; Governor of St Paul's School, London, and Girton College, Cambridge; author of 'Lectures on Teaching,' The Arnolds and their Influence on English Education,' 'Educational Aims and Methods.' (J. G. F.)

FITZGERALD, Vice-Adml. Charles Cooper Penrose; Superintendent, Pembroke Dockyard; second in command of the China Station, 1898-1899; author of 'Boat Sailing,' 'Life of Sir George Tryon.' (C. C. P. F.)

FITZGERALD, J. D.; Barrister-at-Law of N.S.W., Journalist, and Alderman of the Corporation of Sydney. (J. D. F.)

FITZMAURICE-KELLY, James; corresponding member of the Spanish Academy; author of 'A History of Spanish Literature,' 'The Life of Miguel de Cervantes Saavedra,' etc. (J. F.-K.)

FLANNERY, Sir Fortescue, M.Inst.C.E., M. Inst. Marine Engineers; Consulting Engineer; sometime President of the Institution of Marine Engineers. (F. F*.)

FLEMING, C. J. N., B.A.; Scottish International Football Player; member of Committee of Scottish Rugby Football Union. (C. J. N. F.)

FLEMING, John Ambrose, M.A., D.Sc., F.R.S.; Pender Professor of Electrical Engineering, Univ. College, London; Fellow of Univ. Coll. London; author of 'Treatise on the Alternate Current Transformer,' 'Electric Lamps and Electric Lighting,' 'Magnets and Electric Currents,' 'A Handbook for the Electrical Laboratory and Testing Room.' (J. A. F.)

FOOTE, Arthur De Wint; Superintendent of North Star Mining Company, California; Member of the American Society of Civil Engineers. (A. De W. F.)

FORBES, Dr H. O., LL.D., F.R.G.S.; Director of Museums, Liverpool; author of 'A Naturalist's Wanderings in the Eastern Archipelago,' etc. (H. O. F.)

FORD, Worthington Chauncey, Public Library, Boston, U.S.A.; Chief of Bureau of Statistics, U.S. Department of State, 1885-89, and of Bureau of Statistics, U.S. Treasury Department, 1893-98; author of 'American Citizen's Manual,' etc. (W. C. F.)

FORD, W. J., M.A.; author of 'A Cricketer on Cricket.' (W. J. F.)

FORTIER, Alcée, Litt.D.; Professor of Romance Language, Tulane University, New Orleans; sometime President of the Modern Language Association of America, and of the American Folk-Lore Society; President of the Louisiana Historical Society since 1894; author of 'Louisiana Studies,' 'Louisiana Folk Tales,' etc. (A. Fo.)

FOSTER, Clement Le Neve, B.A., D.Sc., F.R.S.; Professor of Mining at Royal School of Mines, London; Examiner in Mining for the Board of Education; Geological Survey of Great Britain, 1860-65; H.M. Inspector of Mines, 1873-1901; author of 'Mining' in Ninth Edition of 'Ency. Brit.,' 'Ore and Stone Mining,' etc. (C. L. N. F.)

FOSTER, Hon. John Watson, LL.D.; ex-U.S. Minister to Mexico, Russia, and Spain; U.S. Secretary of State 1892-93, and Agent of the United States in the Behring Sea Arbitration. (J. W. Fo.)

FOSTER, Sir Michael, D.C.L., D.Sc., LL.D., K.C.B., F.R.S., M.P.; Professor of Physiology, Cambridge; secretary R.S.; President British Ass., 1899; author of 'Physiology' in Ninth Edition of 'Ency. Brit.,' 'Text-Book of Physiology,' 'Lectures on History of Physiology'; joint-editor of 'Scientific Memoirs of Thomas Henry Huxley,' etc. (M. F.)

FOWLER, G. H., Ph.D. Leipsic; late Hon. Secretary, Marine Biological Association, Plymouth; edited 'The Hydromedusa,' and 'The Leptomedusa,' Marshall's 'The Frog,' Erichson's 'Scientific Progress in Entomology.' (G. H. Fo.)

FOX, Francis, M.I.C.E.; author of 'On the Results of Trials of Varieties of Iron Permanent Way,' and various papers on 'Ventilation, Tunnelling,' etc. (F. Fo.)

FOX, Major Charles James; head of London Salvage Corps. (C. J. F.)

FRANKLIN, Fabian, Ph.D.; editor of 'Baltimore News,' Baltimore, U.S.A.; formerly Professor of Mathematics, Johns Hopkins University. (F. Fr.)

FRANTZ, Henri; art critic, 'Gazette des Beaux Arts,' Paris. (H. Fr.)

FREAM, William, LL.D., F.G.S. F.L.S., F.S.S.; Lecturer on Agricultural Entomology, Edin. Univ.; author of 'Elements of Agriculture,' 'Soils and their Properties,' 'The Complete Grazier,' etc. (W. Fr.)

FREEMANTLE, Commander S., R.N.; part author of 'Nautical Terms and Phrases in French and English,' etc. (S. Fr.)

FRERE, Rev. Walter Howard, M.A.; Superior of the Community of the Resurrection; author of 'A New History of the Book of Common Prayer,' 'Notes on the Early History of the Use of Incense'; editor 'Bibliotheca Musico-Liturgica,' 'The Marian Reaction,' etc. (W. H. F.)

FRY, Rt. Hon. Sir Edward, B.A., D.C.L., LL.D., F.R.S., F.S.A., F.L.S.; Judge of High Court, Chancery Division, 1877-83; Lord Justice of Appeal, 1883-92; Fellow University of London and Univ. Coll. London; Hon. Fellow of Balliol Coll. Oxford; presided over the Royal Commission on the Irish Land Acts, 1897-98; author of 'Quakers' in Ninth Edition of 'Ency. Brit.,' 'The Specific Performance of Contracts,' 'British Mosses,' 'James Hack Tuke,' etc. (E. F.)

FULTON, Robert Burwell, A.M., LL.D.; Chancellor of the University of Mississippi; author of 'Mississippi, State' in Ninth Edition of 'Ency. Brit.' (R. B. F.)

G

GADOW, Hans Friedrich, Ph.D., Hon. M.A. Cambridge, F.R.S.; Strickland Curator and Lecturer on Zoology, Cambridge; British Museum, Natural History Department, 1880-82; author of 'In Northern Spain,' 'A Classification of Vertebrata,' 'Aves in Bronn's Animal Kingdom,' 'Amphibia and Reptiles,' and papers in Royal Society Philosophical Transactions and other scientific periodicals. (H. F. G.)

GALLWEY, Lt.-Col. Henry Lionel, C.M.G., D.S.O.; Deputy Commissioner and Consul, Niger Coast Protectorate; Acting Consul-General, 1896-98, Oil Rivers Protectorate; in command of a Haussa company during operations in Benin country, including capture of Benin City, 1897, etc. (H. L. G.)

GAMBLE, F. W., editor of 'Junior Course of Practical Zoology,' 'Flatworms and Mesozoa,' etc. (F. W. Ga.)

GANNETT, Henry; Chief Geographer U.S. Geological Survey; Chief Geographer 10th, 11th, and 12th U.S. Censuses; author of 'Idaho,' etc., in Ninth Edition of 'Ency. Brit.,' 'Dictionary of Altitudes,' 'Statistical Atlas of the U.S.,' etc. (H. G*.)

GARCKE, Emile, M.I.E.E., F.S.S.; Manager of the Brush Electrical Engineering Co.; Chairman Elect. Sect. London Chamber of Commerce, 1884-88; Member of Council, Tramways and Light Railways Assoc.; author of 'Manual of Electrical Undertakings,' joint-author of 'Factory Accounts.' (E. Ga.)

GARDNER, Ernest Arthur; Yates Professor of Archæology, University College, London; Director of British School of Archæology at Athens, 1887-95; author of 'Handbook of Greek Sculpture,' 'Journal of Hellenic Studies,' many articles on Greek art, archæology, and excavations, from 1882; joint-editor of the 'Journal of Hellenic Studies' since 1897. (E. Gr.)

GARDNER, J. Starkie, English Iron Worker and Expert; author of 'English Enamels,' 'Ironwork,' 'Armour in England,' etc. (J. S. G.)

GARDNER, Percy, Litt.D., F.S.A.; Linc. and Merton Professor of Classical Archæology, Oxford University; Corresp. Member of the Academy of Sciences, Göttingen; Member of the Archæological Institutes of Germany, Austria, America, Greece, etc.; Assistant at British Museum, 1871; Fellow of Christ's College, Cambridge, 1872; Disney Professor of Archæology, Cambridge, 1880; editor of 'Journal of Hellenic Studies'; author of 'Corinth,' 'Ephesus,' in Ninth Edition of 'Ency. Brit.,' 'The Parthian Coinage,' 'Samos and Samian Coins,' 'Types of Greek Coins,' 'Numismatic Commentary on Pausanias,' 'New Chapters in Greek History,' 'Manual of Greek Antiquities' (with Mr. Jevons), 'Sculptured Tombs of Hellas,' etc. (P. G.)

GARNETT, Richard, LL.D., C.B.; Assistant in Library of British Museum, 1851; Superintendent of Reading Room, 1875; Keeper of Printed Books, 1890-1899; edited the British Museum Catalogue from 1881 to 1890; author of 'Alexander VI.,' 'Anthology,' 'Augustan History,' 'Byzantine Historians,' 'Chateaubriand,' 'Hazlitt,' 'Leigh Hunt,' etc., in Ninth Edition of 'Ency. Brit.,' 'Relics of Shelley,' 'Life of Carlyle,' 'Life of Emerson,' 'Twilight of the Gods,' 'Life of Milton,' 'Age of Dryden,' 'William Blake,' 'A History of Italian Literature,' 'Life of Edward Gibbon Wakefield.' (R. G.)

GARNETT, William, M.A., Hon. D.C.L. Durham; Sec. Technical Education Board, London Co. Council; Whitworth Scholar (first); Demonstrator in Physics, Cambridge; Prof. of Math., Physics and Mechanics, University Coll., Nottingham; Principal, Durham Coll. of Science, Newcastle-upon-Tyne; author of 'Dynamics,' 'Energy,' 'Evaporation,' 'Hydrometer' in the Ninth Edition of 'Ency. Brit.,' 'Elementary Dynamics,' 'Elementary Mechanics,' etc. (W. G.)

GARSTANG, Walter, M.A., F.Z.S.; late Fellow of Lincoln Coll., Oxford; Naturalist in charge of Fishery Investigations, Marine Biol.

Assoc.; delegate of H.M. Gov. to Internat. Conf. on Exploration of the Sea, Christiania, 1901; medallist of the Société Centrale d'Agriculture et de Pêche, Paris; author of numerous memoirs on Marine Biology, etc. etc. (W. GA.)

GATES, Lewis Edwards, A.B.; Assistant Professor of English, Harvard University; author of 'Selections from Jeffrey,' 'Selections from Newman,' 'Three Studies in Literature.' (L. E. G.)

GEDDIE, John; on the editorial staff of the 'Scotsman,' Edinburgh; author of 'The Water of Leith,' etc. (J. GE.)

GEIKIE, Sir Archibald, Hon. D.C.L., D.Sc., LL.D., F.R.S., F.G.S.; correspondent of Institute of France, of the Lincei, Rome, of the Academies of Berlin, Vienna, Belgium, Stockholm, Turin, Munich, Christiania, Göttingen, Kais. Leopold, Carol., Philadelphia, New York, National Academy of Sciences of United States, etc.; Director Geological Survey of Scotland, 1867; first Murchison Professor of Geology and Mineralogy, Edinburgh, 1871-82; Foreign Sec. Royal Society, 1890-94; President Geological Society, 1891-92; President British Association, 1892; Director-General Geological Survey of United Kingdom, and Director Museum of Practical Geology, London, 1882-1901; author of 'Geography' (Physical), 'Geology,' 'Hutton, James,' 'Murchison,' 'Scotland' (geology), 'Vesuvius,' in Ninth Edition of 'Ency. Brit.,' 'Memoir of Edward Forbes' (with G. Wilson), 'Geological Map of Scotland' (with Murchison), 'The Scenery of Scotland viewed in connexion with its Physical Geology,' 'Text-book of Geology,' 'New Geological Map of Scotland,' 'The Ancient Volcanoes of Britain,' etc. (A. GE.)

GIANNINI, Torquato C., State Advocate, San Marino; author of 'Laws and Decrees of the Republic of San Marino,' etc. (T. G*.)

GIBBONS, H.E. Cardinal James, Archbishop of Baltimore, U.S.; author of 'The Faith of Our Fathers,' 'Our Christian Heritage,' 'The Ambassador of Christ.' (✠J. G.)

GIBBS, George; Consulting Engineer to the Baldwin Locomotive Works, and the Westinghouse Electric Manufacturing Co.; formerly Mechanical Engineer for the Chicago, Milwaukee, and St Paul R.R. Co.; Member Am. Soc. Mech. Engineers, and Am. Soc. Civ. Engineers. (G. GI.)

GIBSON, George Alexander, M.D., D.Sc. Edin., F.R.C.P. Edin., F.R.S. Edin.; Hon. Member Norwich Med. Chir. Soc.; Fellow and Member of many societies in England and Scotland; Physician to Royal Infirmary of Edinburgh; Lecturer on Medicine in School of Medicine of Royal Colleges; editor of the 'Edinburgh Med. Journ.' since 1896; Secretary, Royal Coll. of Physicians, Edin., 1884-94; Member of Council of the College since 1894; author of 'Physical Diagnosis' (part), 'Cheyne-Stokes Respiration,' 'Diseases of the Heart and Aorta'; editor of 'Text-Book of Medicine,' 1901. (G. A. G.)

GIFFEN, Sir Robert, K.C.B., F.R.S.; assistant editor of 'Economist,' London, 1868-76; Chief of Statistical Department, Board of Trade, 1876-82; Assistant Secretary Board of Trade, and afterwards Controller-General of Commercial, Labour, and Statistical Departments, 1882-97; President of Statistical Society, 1882-84; author of 'American Railways as Investments,' 'Stock Exchange Securities,' 'Essays in Finance,' 'The Progress of the Working Classes in the Last Half-Century,' 'The Growth of Capital,' 'The Case against Bimetallism,' etc. (R. GN.)

GILBERT, Grove Karl, A.M.; Geologist U.S. Geological Survey; author of 'Geology of the Henry Mountains,' 'Lake Bonneville,' etc. (G. K. G.)

GILES, Peter, M.A.; Fellow of Emmanuel College, Cambridge, and University Reader in Comparative Philology; late Secretary of the Cambridge Philological Society; author of 'A Short Manual of Comparative Philology,' etc. (P. GI.)

GILLESPIE, A. L.; F.R.C.P. Edin., F.R.S.E.; author of 'Natural History of Edinburgh,' 'Manual of Modern Gastric Methods,' etc. (A. L. G.)

GILMAN, Daniel Coit, LL.D.; President Carnegie Inst., Washington; President Johns Hopkins University, 1876-1901; author of 'Life of James Monroe,' 'University Problems,' etc. (D. C. G.)

GINSBURG, Benedict William, M.A., LL.D.; Secretary of the Royal Statistical Society of Great Britain; author of 'Legal Duties of Ship Masters,' etc. (B. W. G.)

GLEICHEN, Count, Albert Edward Wilfred, C.M.G., D.S.O., C.V.O.; Major Grenadier Guards; Director of Intelligence and Civil Service, Sudan Provinces; D.A.A.G., S. Africa, 1900; Nile Expedition, 1884-85; Intelligence Department, War Office, 1886-88; Mission to Abyssinia, 1897; D.A.A.G. in Intelligence Division War Office, 1898-99; served S. Africa, 1899-1900; author of 'With the Camel Corps up the Nile,' 'Armies of Europe' (translation), 'With the Mission to Menelik.' (G*.)

GOODRICH, Edwin Stephen, M.A.; Fellow of Merton College, Oxford, and Aldrichian Demonstrator of Anatomy, University Museum, Oxford. (E. S. G.)

GOODRICH, J. E., D.D.; Prof. of Latin, University of Vermont; author of 'Vermont' in Ninth Edition of 'Ency. Brit.' (J. E. G.)

GORDON, Home Seton Charles Montagu; writes for 'Victoria History Counties of England,' 'Morning Post' (London), 'The Artist,' 'Outlook,' 'County Gentleman,' 'Badminton Magazine,' etc. (H. S. C. M. G.)

GORDON, Gen. Sir John James Hood, K.C.B., Indian Staff Corps; member of the Council of India. (J. J. H. G.)

GORST, John Lowndes, C.B.; Financial Adviser to the Egyptian Government; Controller of Direct Taxes to Egyptian Government, 1890; Under-Secretary of State for Finance, 1892; Adviser to the Ministry of the Interior, 1894; Grand Cordon Order Medjidieh, 1897. (J. L. G.)

GOSCH, C. A.; attaché to the Danish Legation in Great Britain; author of 'Denmark and Germany since 1815,' 'The Nationality of Schleswig,' editor of 'Danish Arctic Expeditions 1605-1620,' etc. (C. A. G.)

GOSSE, Edmund, Hon. M.A. Trin. Coll. Camb.; Hon. LL.D. St Andrews; Knight of the Royal Norwegian Order of St Olaf, First Class; Asst. Librarian, British Museum, 1867-75; Translator to Board of Trade; Clark Lecturer in English Literature, Trin. Coll. Camb., 1884-90; author of 'Cowley,' 'Denmark,' 'Holberg,' 'Holland' (literature), 'Norway' (literature), 'Oehlenschlager,' 'Pastoral,' 'Sweden' (literature) in Ninth Edition of 'Ency. Brit.,' 'Collected Poems,' 'Northern Studies,' 'Life of Gray,' 'Life of Congreve,' 'History of Eighteenth Century Literature,' 'The Jacobean Poets,' 'History of Modern English Literature,' 'Life and Letters of Dr John Donne,' etc. (E. G.)

GOUGH, James A. H., B.A. Lond.; late Secretary of the Thames Conservancy. (J. H. GO.)

GOULD, Prof. Elgin R. L., Ph.D.; Pres. City and Suburban Homes Company, New York; formerly Lecturer at Johns Hopkins and Chicago Universities; Cor. Secretary Am. Statistical Soc.; Member International Statistical Soc., British Economic Soc., and Cor. Member Société de Statistique, Paris; author of 'Housing of Working People,' etc. (E. R. L. G.)

GOW, William, M.A. Glasgow, Ph.D. Heidelberg; Lecturer at University Coll. Liverpool, on Marine Insurance; author of 'Marine Insurance,' a hand-book, 'A British Imperial Customs Union,' etc. (W. GO.)

GRACE, John Hilton, M.A.; Fellow of Peterhouse, Cambridge. (J. H. GR.)

GRAHAM, P. Anderson; author of 'Rural Exodus.' (P. A. G.)

GREEN, Joseph Reynolds, Sc.D., F.R.S., F.L.S.; Professor of Botany, Pharmaceutical Society of Great Britain; Fellow of Downing Coll. Cambridge; Demonstrator of Physiology, Cambridge, 1885-87; author of 'A Manual of Botany,' 'The Soluble Ferments and Fermentation,' etc. (J. R. GR.)

GREENE, General Francis Vinton; Major-General U.S. Volunteers in the Spanish-American War; President New York State Canal Commission; author of 'The Russian Army and its Campaigns in Turkey,' 'Life of Major-General Nathaniel Greene,' 'The Mississippi Campaigns of the Civil War,' etc. (F. V. G.)

GREENE, Thomas L.; Manager of the Audit Company of New York; author of 'Corporation Finance,' etc. (T. L. G.)

GREENHILL, Alfred George, M.A., F.R.S.; Prof. of Math., Ordnance Coll. Woolwich; author of 'Hydromechanics' in Ninth Edition of 'Ency. Brit.,' 'Differential and Integral Calculus with Applications,' 'A Chapter in the Integral Calculus,' 'Applications of Elliptic Functions,' 'Hydrostatics.' (A. G. G.)

GREENOUGH, John, B.A.; banker and financier, New York. (J. GH.)

GREENWOOD, Frederick; originator and first editor of 'Pall Mall Gazette' and the 'St James's Gazette'; author of 'Louis Napoleon Bonaparte,' 'Life of Napoleon the Third,' 'The Lover's Lexicon,' 'Imagination in Dreams,' etc. (F. G.)

GREENWOOD, Thomas; author of 'Public Libraries,' 'The Library Year-book,' etc. (T. GD.)

GREGO, Joseph, English Art Critic and Writer; author of 'A History of Parliamentary Elections,' 'A History of Dancing,' 'Thomas Rowlandson,' 'James Gillray,' etc. (J. GO*.)

GRIERSON, Colonel James Moncrieff, R.A., M.V.O.; served as D.A.Q.M.G., Indian Contingent, Egypt, 1882; as D.A.A. and Q.M.G., Suakin, 1885; as D.A.Q.M.G., Hazara Expedition; as A.A.G., Army Headquarters, S. Africa, 1900; as D.A.G., China, 1900-1901, on F.M. Count Waldersee's staff; Military Attaché, Embassy, Berlin, 1896-1900; Chief Staff Officer, 2nd Army Corps, 1901; Knight of Grace of St John of Jerusalem; Commander of 2nd Class of Prussian Royal Crown (with star), Red Eagle, and Saxon Albrecht orders; author of 'Armed Strengths of Armies of Russia, Germany, and Japan,' 'Staff Duties in the Field,' 'Handbook of the Russian Army.' (J. M. GR.)

GRIFFITH, Francis Llewelyn, M.A.; Reader in Egyptology, Oxford University; editor of 'Archæological Survey of Egypt,' 'The Royal Tombs of the First Dynasty,' etc. (F. LL. G.)

GRIFFITHS, John G.; Fellow of the Inst. of Chartered Accountants, and President of same, 1897-99. (J. G. GR.)

GRIFFITHS, Major Arthur George Frederick; H.M. Inspector of Prisons, 1878-96; formerly editor of 'Army and Navy Gazette'; editor of the 'Fortnightly Review,' 1884, the 'World,' 1895; author of 'Prison Discipline' in Ninth Edition of 'Ency. Brit.,' 'Memorials of Millbank,' 'Secrets of the Prison House,' 'Mysteries of Police and Crime.' (A. G.)

GRUEBER, H. A., F.S.A.; Assistant Keeper of Coins and Medals, British Museum; editor of 'Medallic Illustrations of the History of Great Britain and Ireland,' 'Roman Medallions in the British Museum,' etc. (H. A. G.)

GULLAND, George Lovell, M.A., M.D., F.R.C.P. Edin.; Fellow and late President of Royal Med. Soc., Edin. (G. L. G.)

GUNTHER, Albert Charles Lewis Gotthilf, M.A., M.D., Ph.D., F.R.S.; Keeper of Zoological Department British Museum; author of 'Flying Fish,' 'Ichthyology,' 'Lizard,' 'Mackerel,' etc., in Ninth Edition of 'Ency. Brit.,' 'Catalogues of Colubrine Snakes, Batrachia salientia, and Fishes in the British Museum,' 'Reptiles of British India,' 'Fishes of Zanzibar,' 'Reports on the "Challenger" Fishes,' etc. (A. GU.)

H

HADCOCK, A. G., late R.A.; manager of Gun Dept., Elswick; part-author 'Modern Artillery,' etc. (A. G. H.)

HADLEY, Arthur Twining, LL.D.; Pres. Yale University; joint-editor of the New Volumes of the 'Ency. Brit.'; part-author of 'Railway' in Ninth Edition of 'Ency. Brit.,' author of 'Railroad Transportation,' 'Economics,' etc. (A. T. H.)

HALDANE, John Scott, M.A., M.D., F.R.S.; University Lecturer in Physiology, Oxford; Fellow New College, Oxford; Metropolitan Gas Referee, Board of Trade; author of 'Essays in Philosophical Criticism,' (joint-author) 'Blue-book on the Causes of Death in Colliery Explosions,' a series of papers in scientific journals and blue-books on the physiology of respiration, and on the air of the mines, dwelling-houses, etc. (J. S. H.)

HALE, Rev. Edward Everett, S.T.D.; author of 'Everett' in Ninth Edition of 'Ency. Brit.,' 'Man without a Country,' 'Life of James Russell Lowell,' etc. (E. E. H.)

HALE, George E., Sc.D.; Professor of Astrophysics in the University of Chicago and Director of the Yerkes Observatory, Williams Bay, Wis.; editor of the 'Astrophysical Journal.' (G. E. H.)

HALSEY, F. A.; asst.-editor of the 'American Machinist'; Member of the Am. Assoc. of Mech. Engineers, and designer of Compressed Air Machinery; author of 'Slide Valve Gears,' 'Locomotive Link Motion,' 'Premium Plan of Paying for Labour,' etc. (F. A. H)

HAMILTON, David James, M.B. Edin., F.R.C.S. Edin.; Professor of Pathology, Aberdeen; author of 'Text-Book of Pathology,' etc. (D. J. H.)

HAMILTON, Sir Edward Walter, K.C.B., K.C.V.O.; Assist. Sec. H.M. Treasury; author of 'National Debt,' etc. (E. W. H*.)

HAMILTON, Adml. Sir Richard Vesey, G.C.B.; served in Arctic Expedition, 1850-51, and 1852-1854 in search of Sir John Franklin; in China, 1857, etc. (R. V. H.)

HAMMOND, John Hays, A.M.; consulting engineer of the Consolidated Gold Fields of South Africa, British South Africa Company, etc. (J. H. H*.)

HARMER, Sidney Frederic, D.Sc. (Camb.), B.Sc. (Lond.), F.R.S., F.Z.S., F.G.S.; Fellow since 1886 and assistant tutor since 1890 of King's College, Cambridge; superintendent of University Museum of Zoology; author of papers on Zoological subjects; joint-editor of the 'Cambridge Natural History.' (S. F. H.)

HARMON, Hon. Judson, LL.D.; ex-U.S. Attorney-General; sometime President of the Ohio Bar Association. (J. Ha.)

HARMSWORTH, Alfred Charles; principal proprietor of the 'Daily Mail,' the 'Evening News,' etc. (A. C. H*.)

HARPER, William Rainey, D.D., LL.D., Ph.D.; Pres. University of Chicago. (W. R. H.)

HARRIS, Hon. Addison C., U.S. Minister to Austria; author of 'Indiana' in Ninth Edition of 'Ency. Brit.' (A. C. H.)

HARRIS, James Rendel, M.A., Litt.D., LL.D.; Univ. Lecturer in Palæography, Camb., late Prof. at Johns Hopkins University; author of 'The Teaching of the Apostles and the Sibylline Books,' 'Fragments of Philo,' 'The Origin of the Leicester Codex,' 'A Study of Codex Bezae,' 'The Apology of Aristides,' 'Life of Francis William Crossley'; editor 'The Gospel of the Twelve Apostles,' etc. (J. R. Ha.)

HARRIS, Thomas, M.D., F.R.C.P. Ed.; Hon. Physician of Manchester Royal Infirmary, and Lecturer on Diseases of the Respiratory Organs, Owens College, Manchester; author of numerous articles on diseases of the respiratory organs. (T. H*.)

HARRISON, Charles Custis, LL.D.; Provost of the University of Pennsylvania. (C. C. H*.)

HARRISON, Frederic, M.A.; President of London Positivist Committee; Fellow and Tutor of Wadham Coll., 1854-56; Hon. Fellow, 1899; member of Royal Commission of Trades Unions, 1867-69; Secretary Royal Commission for Digesting the Law, 1869-70; Professor of Jurisprudence and International Law to Inns of Court, 1877-89; Rede's Lecturer, Cambridge, 1900; Vice-President Royal Historical Soc., author of 'Social Statics—Comte's Positive Polity,' 'The Choice of Books,' 'Oliver Cromwell,' 'Victorian Literature,' 'William the Silent,' 'The Millenary of King Alfred.' (F. H*.)

HART, Charles Henry, Director of the Pennsylvania Academy of Fine Arts, Philadelphia; author of 'Philadelphia' in Ninth Edition of 'Ency. Brit.,' 'Portraits of Great Americans,' 'Turner, the Dream Painter,' 'William Morris,' etc. (C. H. H*.)

HART, Maj.-Gen. Sir Reginald Clare, R.E., K.C.B., V.C.; commanding Quetta district in India; assistant Garrison Instructor, 1874-78; Garrison Instructor, 1885-88; Director Military Education in India, 1888-96; Afghan War, 1879; Ashantee Expedition, 1881; Egyptian War, 1882; commanded 1st Brigade Tirah Campaign, 1897-98; author of 'Reflections on the Art of War,' 'Sanitation and Health.' (R. C. H.)

HASSERT, Dr K., traveller; intimately acquainted with the Balkan States and author of numerous works of travel, etc. (K. H.)

HASTINGS, Charles S., Ph.D.; Professor of Physics, Sheffield Scientific School, Yale University. (C. S. H.)

HASTINGS, E. J., Miss; contributor to 'The Times' Gazetteer. (E. J. H.)

HAWKINS, Charles Cæsar, M.A., M.I.E.E.; author of 'The Dynamo,' and of many papers, such as 'Armature Reaction,' 'The Theory of Commutation,' etc. (C. C. H.)

HAXTON, H. R., author of 'The Advertiser's Manual,' 'An Evening with "Punch,"' etc. (H. R. H*.)

HEADLAM, James Wycliffe, M.A.; late Fellow of King's Coll., Cambridge; author of 'Bismarck,' etc. (J. W. He.)

HEADLAM, Walter George; Fellow of King's College, Cambridge. (W. G. H.)

HEAWOOD, Edward, M.A., Librarian to R.G.S.; aided in settlement of Santal Colony in Bengal Duars, 1890-92; author of 'Geography of Africa,' etc. etc. (E. He.)

HEHNER, Otto; Past President of the Society of Public Analysts; Public Analyst for Nottinghamshire, the Isle of Wight, etc.; Chairman of the London Section of the Society of Chemical Industry, etc.; author of works on Butter-analysis, Alcohol Tables, etc. (O. H*.)

HEINEMANN, Mrs William ['Kassandra Vivaria']; authoress of 'Via Lucis,' 'The Garden of Olives,' etc. (M. He.)

HELE-SHAW, H. S., LL.D., F.R.S., M.I.C.E., M.I.M.E., Assoc. Inst. N.A.; Senior Whitworth Scholar, 1876; Harrison Professor of Engineering in Univ. Coll., Liverpool. (H. S. H.-S.)

HELMUTH, William Tod, M.D., LL.D., the late; Professor of Surgery and Dean of the Homœopathic and Medical College and Hospital, New York, and President of the Collins State Homœopathic Hospital; sometime President of the American Institute of Homœopathy and the New York State Homœopathic Medical Society; author of 'Treatise on Diphtheria,' 'System of Surgery,' etc. (W. T. H.)

HEMMING, Major Edward Hughes, R.E., H.M. War Office. (E. H. H.)

HENDERSON, Col. George Frances Robert, C.B.; Director of Military Intelligence, South Africa; for many years Director of Military Art and History at the Staff College; author of 'A Tactical Study of Fredericksburg,' 'Life of Stonewall Jackson,' etc. (G. F. R. H.)

HENDERSON, T. F.; on editorial staff of the Ninth Edition of the 'Ency. Brit.' (T. F. H.)

HENRICI, Olaus F. M. E., Ph.D., LL.D., F.R.S.; Professor of Mechanics and Mathematics, City and Guilds of London Central Technical Coll., author of 'Geometry' (pure and projective), 'Projection,' in Ninth Edition of 'Ency. Brit.,' 'Skeleton Structures, especially in their Application to the Building of Steel and Iron Bridges,' 'Congruent Figures,' etc. (O. H.)

HENRY, Hon. William Wirt, M.A.; late Pres. of the Virginia Hist. Soc. and of the Am. Hist. Ass.; author and editor of the 'Life, Correspondence, and Speeches of Patrick Henry.' (W. W. H*.)

HENSON, Herbert Hensley, B.D.; Canon of Westminster; author of 'Light and Leaven,' 'Apostolic Christianity,' editor 'Church Problems,' etc. (H. H. H*.)

HERBERTSON, Dr A. J.; of the School of Geography, Ashmolean Buildings, Oxford. (A. J. He.)

HERDMAN, William Abbott, D.Sc., F.R.S.; Prof. of Natural History, Univ. Coll. Liverpool; assist. to Sir Wyville Thomson in 'Challenger' Expedition office; Demonstrator of Zoology in Edinburgh, 1880; President Zoological Section Brit. Ass., 1895; has (along with others) established a Marine Biological Station at Port Erin, Isle of Man; author of 'Tunicata' in Ninth Edition of 'Ency. Brit.,' 'Report upon the Tunicata collected during the voyage of the "Challenger,"' 'The Fauna of Liverpool Bay,' 'Oysters and Disease,' etc. (W. A. He.)

HERR, E. M., General Manager Westinghouse Air Brake Company, Pittsburg. (E. M. He.)

HERVEY, Arthur; musical critic of the 'Morning Post'; author of 'Masters of French Music,' etc. (A. He.)

HEWINS, William Albert Samuel, M.A.; Director, London School of Economics and Political Science, 1895; Tooke Professor of Economic Science and Statistics at King's Coll. London, 1897; Member of the Senate of the University of London; Hon. Fellow R. Hist. Soc.; Examiner in Political Economy in the University of London, and in the Historical Tripos, Cambridge; Lecturer at Univ. College, Bristol, 1890; author of 'English Trade and Finance in the 17th Century,' etc. (W. A. S. H.)

HIBBERT, Walter, A.M.I.C.E., F.I.C., F.C.S.; Lecturer on Electro-Technology, Polytechnic, Regent Street; author of 'Notes on Secondary Batteries,' etc. (W. Ht.)

HIGGINSON, Col. Thomas Wentworth, LL.D.; author of 'Atlantic Essays,' 'Cheerful Yesterdays,' 'History of the United States,' 'Biography of Wendell Phillips,' etc. (T. W. H.)

HIGGS, HENRY, LL.B., F.S.S.; clerk in H.M. Treasury; Sec. to the British Economic Association and joint-editor of the 'Economic Journal'; Life Governor of University College, London; ex-Member of Council of Royal Stat. Soc.; Pres. of sections of Political Economy and Statistics, Brit. Ass., Dover, 1899; author of 'The Physiocrats,' and many articles. (H. H*.)

HILL, E. P., M.I.C.E.; partner in Messrs. G. H. Hill and Sons, engineers to the Corporation of Manchester, etc. (E. P. H*.)

HILL, Leonard Erskine, M.B., F.R.S.; Lecturer on Physiology, London Hospital; Demonstrator of Physiology, Oxford University; Assistant Professor of Physiology, University College, London; Hunterian Professor Royal College of Surgeons, author of 'The Physiology and Pathology of the Cerebral Circulation,' 'Manual of Physiology.' (L. E. H.)

HILL, Maurice, B.A.; Barrister, Inner Temple. (M. H*.)

HILL, Robert Thomas, U.S. Geological Survey; formerly Professor of Geology, University of Texas; author of 'Texas' in Ninth Edition of 'Ency. Brit.,' 'Cuba, Porto Rico, and other Islands of the West Indies.' (R. T. H.)

HILLIER, Alfred Peter, M.D., B.A., C.M.; one of the Reform Prisoners at Pretoria, 1896; author of 'South African Studies,' etc. (A. P. H.)

HIME, Lieut.-Col. H. W. L.; Gold Medal Roy. Artillery Inst., and Roy. United Service Inst.; Secretary Roy. Artillery Inst., 1880-86; author of 'Outlines of Quaternions,' 'Stray Military Papers,' 'Lucian, the Syrian Satirist,' etc. (H. W. L. H.)

HINTON, A. Horsley, editor of 'The Amateur Photographer'; author of 'A Handbook of Illustration,' 'Practical Pictorial Photography,' etc. (A. H. H.)

HIPKINS, Alfred James, F.S.A.; member of Council and Hon. Curator of R. C. of Music; engaged in Messrs Broadwood's pianoforte business since 1840; Member of Committee of the Inventions and Music Exhibition, 1885, of the Vienna Exhibition, 1892, and of the Paris Exhibition, 1900; author of 'Harp,' 'Lyre,' 'Pianoforte,' in Ninth Edition of 'Ency. Brit.,' 'Musical Instruments,' 'A Description and History of the Pianoforte,' etc. (A. J. H.)

'HOBBES, John Oliver' (Pearl Mary Teresa Craigie); author of 'Some Emotions and a Moral,' 'A Study in Temptations,' 'The Gods, Some Mortals, and Lord Wickenham,' 'School for Saints,' 'Robert Orange,' 'The Serious Wooing,' 'The Ambassador,' 'The Wisdom of the Wise,' etc. (P. M. T. C.)

HOBSON, Ernest W., D.Sc., F.R.S.; Fellow of Christ's Coll. Cambridge; University Lecturer in Mathematics. (E. W. H.)

HODGE, Frederick Webb, Bureau of American Ethnology, Smithsonian Institution; managing editor 'American Anthropologist.' (F. W. H.)

HODGES, Major Harry F., Corps of Engineers, U.S. Army. (H. F. H.)

HODGKINSON, W. R. E., F.R.S. Edin., F.C.S., F.R.G.S., Ph.D. Würzburg; Professor of Chemistry and Physics, Ordnance Coll., Woolwich; late Professor of Chemistry and Physics, R.M.A., Woolwich; edited Valentine's 'Practical Chemistry,' etc. (W. R. E. H.)

HOFFER, Leopold; chess editor of the 'Standard' (*London*); author of 'Chess,' etc. (L. H.)

HOFMAN, Heinrich O., E.M., Ph.D.; Professor of Metallurgy, Massachusetts Institute of Technology. (H. O. H.)

HOGARTH, David George, M.A., Fellow of Magdalen College, Oxford; explored Asia Minor, 1887, 1890, 1891, 1894; excavated at Paphos in Cyprus, 1888; appointed by Egypt Exploration Fund, 1893; Special Correspondent for 'The Times' in Crete and Thessaly, 1897; Director, British School at Athens, 1897-1900; Director, Cretan Exploration Fund, 1899; author of 'A Wandering Scholar in the Levant,' 'Philip and Alexander of Macedon,' 'The Nearer East,' etc. (D. G. H.)

HOLDEN, Prof. Edward Singleton, Sc.D., LL.D.; Director of the Lick Observatory, 1887-97; Member National Academy of Sciences; Associate Royal Astronomical Society of London, Astronomical Society of France, etc.; author of 'Astronomy for Students,' 'Life of Sir Wm. Herschel,' 'Nebula of Orion,' etc. (E. S. H.)

HOLDICH, Col. Sir Thomas Hungerford, R.E. (retired), K.C.I.E., C.B.; Abyssinia, 1867; Afghan War, 1878-80; also served on political duty with Afghan Boundary Commission, 1884-86; Supt. Frontier Surveys, India, 1892-98; Asmar Boundary Commission, 1894; Pamir Commission, 1895; as H.M. Commissioner for Perso-Beluch Boundary in 1896; author of 'Kandahar,' in Ninth Edition of 'Ency. Brit.,' 'The Indian Borderland,' various papers on military surveying, etc. (T. H. H*.)

HOLLAND, Hon. Sydney, LL.D.; President of the Life Saving Society of England; Chairman of the London Hospital; Knight of Grace of the Order of St John of Jerusalem. (S. H*.)

HOLLINGSHEAD, John, staff of 'Household Words,' under Charles Dickens; staff of 'Cornhill Magazine, under W. M. Thackeray, 'Good Words,' under Dr Norman Macleod, 'Daily News,' etc.; founded Gaiety Theatre, 1868; Theatrical Licensing Reform, 1866 and 1892; Copyright Reform, 1874; author of 'Plain English,' 'Underground London,' 'Ragged London,' 'According to My Lights,' etc. (J. Hd.)

HOLROYD, Charles, F.R. Soc. Painter Etchers; Keeper National Gallery of British Art (Tate Gallery); assistant to Professor Legros, Slade School of Art, for four years; author of 'Michael Angelo and His Works,' 'Etchings,' etc. (C. Hd.)

HOOPER, Franklin H., A.B.; associate-editor of the New Volumes of the 'Encyclopædia Britannica'; assistant editor of 'The Century Dictionary.' (F. H. H.)

HOOPER, Wynnard, M.A., author of 'Population,' 'Statistics,' 'Suicide,' in the Ninth Edition of the 'Ency. Brit.' (W. Ho.)

HOPKINSON, S. D. (S. D. H.)

HOSE, C., LL.D., D.Sc.; Resident in the Boram District, Sarawak; author of 'A Descriptive Account of the Mammals of Borneo,' etc. (C. H.)

HOUGHTON, A. E., B.A., L.C.L.; Correspondent of the 'Standard' in Spain; author of 'Restoration of the Bourbons in Spain.' (A. E. H.)

HOUSMAN, Laurence, author of 'The Writings of William Blake,' 'Arthur Boyd Houghton,' 'Green Arras,' etc.; illustrated 'Goblin Market,' 'The End of Elfintown,' 'The Were Wolf,' '"Jump to Glory" Jane,' 'The Sensitive Plant.' (L. Ho.)

HOUTUM-SCHINDLER, Gen. Sir A., C.I.E.; general in the Persian army; has resided, as Persian official, and travelled for many years in Persia; author of 'Eastern Persian Irak,' etc. (A. H.-S.)

HOWE, Henry Marion, A.M.; Professor of Metallurgy, Columbia University, New York; Past President Am. Institute of Mining Engineers; President Jury of Mines and Mining, World's Columbian Exposition; Bessemer Medallist, British Iron and Steel Inst., and Gold Medallist, Franklin Inst. of Philadelphia, 1895; author of 'Metallurgy of Steel,' 'Copper Smelting,' etc. (H. M. H.)

HOWELL, Hon. Clark; editor of 'The Constitution,' Atlanta, Georgia. (C. Ho.)

HOWELL, William H., Ph.D., M.D.; Dean of the Medical Faculty and Professor of Physiology, Johns Hopkins University. (W. H. H.)

HUBBARD, Wilfranc. (W. Hd.)

HUDSON, James Fairchild, editor of the 'Pittsburg Dispatch'; author of 'Railways of the Republic,' etc. (J. F. H.)

HUGHES, Rev. Hugh Price, M.A.; Pres. Wesleyan Conference, 1898-99; editor of 'Methodist Times'; Past Pres. of National Council of Evangelical Free Churches; author of 'Social Christianity,' 'Ethical Christianity,' etc. (H. P. H.)

HUGHES, Rupert, A.M.; formerly assistant editor of the 'Criterion,' New York; author of 'American Composers,' 'Gyges Ring,' etc. (R. Hu.)

HULL, Commander Thomas A., R.N., F.R.G.S.; employed in the search for Sir John Franklin, survey of Palestine, Corfu, etc.; late Superintendent of Admiralty charts; author of 'Practical Nautical Surveying'; editor and reviser 'The Pilot's Handbook for the English Channel,' and 'The Practice of Navigation and Nautical Astronomy,' etc. (T. A. H.)

HUMMEL, J. J., F.I.C.; Professor of Dyeing, Yorkshire Coll., Leeds; author of 'The Dyeing of Textile Fabrics.' (J. J. H.)

HUNT, Rev. William, M.A.; examiner in History, 1877 to 1880, Oxford; author of 'The English Church, 597 to 1066,' 'The Church of England in the Middle Ages'; editor with E. A. Freeman of 'Historic Towns,' etc. (W. Hu.)

HUNT, Hon. William H., Governor of Porto Rico; sometime Justice of the Supreme Court of Montana. (W. H. H*.)

HUNTER, Sir Robert, M.A.; Solicitor to the Post Office; author of 'The Preservation of Open Spaces and of Footpaths and Other Rights of Way.' (R. H*.)

HUNTER, Walter, M.I.C.E., M.I.M.E.; engineering director of the Grand Junction Water Works Co., and joint engineer of the Staines Reservoir Joint Committee. (W. H*.)

HUTCHINSON, Horatio Gordon, B.A.; amateur golf champion, 1886-87; author of 'Golf' in Badminton Library, 'Creatures of Circumstance,' 'The Book of Golf and Golfers,' 1899. (H. G. H.)

HUTTON, Rev. Arthur Wollaston, M.A.; Rector of Spridlington, 1873-76; received into Roman Catholic Church by Dr Newman, 1876; resumed clerical functions in the Church of England, 1898; author of 'Our Position as Catholics in the Church of England,' 'The Anglican Ministry,' 'Cardinal Manning'; edited Arthur Young's 'Tour in Ireland,' 1892, Maitland's 'Essays on the Reformation,' Newman's 'Lives of the English Saints,' etc. (A. W. Hu.)

I

IDE, Hon. Henry Clay, Member of U.S. Philippine Commission; formerly U.S. Commissioner to Samoa, and later Chief Justice of Samoa. (H. C. I.)

ILBERT, Sir Courtenay Peregrine, K.C.S.I., C.I.E.; Clerk of the House of Commons; formerly Parl. Counsel to the Treasury, 1899-1902; Legal Member of Council of Governor-General of India, 1882-86; Assistant Parl. Counsel to the Treasury, 1886-99; Member of Statute Law Committee; author of 'The Government of India,' 'Legislative Method and Forms.' (C. P. I.)

INAMA-STERNEGG, Karl Theodor von; Professor of Political Science, Vienna; President of the Austrian Royal Statistical Central Commission; author of 'Outlines of Germanic Philology,' 'Economy,' etc. (K. T. I.-S.)

IRVINE, William Fergusson; Hon. Sec. Record Society of Lanc. and Chesh., author of 'Notes on the Ancient Parish of Bidston'; editor 'Liverpool in King Charles II.'s Time,' etc. (W. F. I.)

J

JACKS, Rev. L. P. (L. P. J.)

JACKSON, Lieut.-Col. Louis, R.E.; late instructor in Fortification, R.M.A., Woolwich; instructor in Fortification and Military Engineering, School of Military Engineering, Chatham; Assoc. Memb. of Ordnance Committee, etc. (L. J.)

JACOB, Francis, M.I.E.E., F.P.S. Lond.; chief electrician to Messrs Siemens Bros. and Co. (F. Ja.)

JAMES, Edmund Janes, A.M., Ph.D.; President North-Western University; late Professor of Public Administration and Director of the Extension Division, University of Chicago; past Pres. Am. Acad. of Political and Social Science; author of 'Our Legal Tender Decisions,' 'The Education of Business Men,' etc. (E. J. J.)

JAMES, Lionel; War Correspondent of 'The Times' in South Africa. (L. J*.)

JAMIESON, George, C.M.G.; Director of the Pekin Syndicate and Yangtse Valley Company; Consul and Judge of Supreme Court, Shanghai, 1891; Consul-Gen., 1897-99; author of various papers on the Revenue and Statistics of China; prize essay on Bimetallism. (G. J.)

JEBB, Sir Richard Claverhouse, Litt.D., D.C.L., LL.D., M.P.; Regius Professor of Greek, Camb.; Hon. Professor Ancient History, Roy. Acad., since 1898; Fellow and Lecturer of Trinity College, 1863; Public Orator of the University, 1869; Professor of Greek, University of Glasgow, 1875-89; Lecturer at Johns Hopkins University, Baltimore, 1892; Member of Royal Commission on Secondary Education, 1894; of Royal Commission on Irish University Education, 1901; Member of Consulting Committee of Board of Education, 1900; Fellow of London University, 1897; Member of London University Commission, 1898; Bampton Lecturer, 1899; author of 'Aristophanes,' 'Demosthenes,' 'Euripides,' etc., in Ninth Edition of 'Ency. Brit.,' 'Sophocles,' 'Electra' in Catena Classicorum, 'Ajax,' 'Characters of Theophrastus,' 'Attic Orators,' 'Modern Greece,' 1880; 'Bentley,' 'Sophocles,' with Critical Notes, Commentary, and Translation; 'Humanism in Education,' etc. (R. C. J.)

JEFFERSON, Joseph, LL.D.; actor; author of 'Autobiography,' etc. (J. J*.)

JEKELFALUSSY, Józef von Jekel-und Margitfalva, Dr. Juris, the late; Director-General of the Royal Hungarian Statistical Bureau; Member of the Royal Hungarian Academy of Sciences; edited 'The Millennium of Hungary and its People,' etc. (J. Je.)

JENKS, Jeremiah Whipple, Ph.D.; Professor of Political Science, Cornell University; Member of the U.S. Committee to investigate Trusts; author of 'Henry C. Carey,' 'Road Legislation for the American State,' and numerous magazine contributions in Germany, England, and the United States. (J. W. J.)

JENKYNS, Sir Henry, the late, K.C.B.; Parliamentary Counsel to Treasury. (H. Je.)

JERVIS-SMITH, Rev. Frederick J., M.A., F.R.S.; University Lecturer in Mechanics; Millard Lecturer, Trinity College, Oxford; Member of Com. on Explosions, Home Office, 1895-96; received Medal French Exhibition for Dynamometer; silver medal Inventions Exhibitions for Integrator. (F. J. J.-S.)

JEUNE, Rt. Hon. Sir Francis Henry, K.C.B., K.B.; appointed a Judge of the High Court, 1891; President of Probate, Divorce, and Admiralty Division; Judge-Advocate-Gen., 1892. (F. H. J.)

JEUNE, Lady; contributor to leading reviews and magazines; author of 'Lesser Questions,' etc. (M. J.)

JOHNSTON, Sir Harry Hamilton, G.C.M.G., K.C.B.; Special Commissioner, Commander-in-Chief and Consul-General for Uganda Protectorate; explored Portuguese West Africa and River Congo, 1882-83; commanded Scientific Expedition of Royal Society to Mt. Kilimanjaro, 1884; H.M. Vice-Consul in Cameroons, 1885; Acting Consul in Niger Coast Protectorate, 1887; Consul for province of Mozambique, 1888; expedition to Lakes Nyasa and Tanganyika (founding of the British Central Africa Protectorate), 1889; author of 'River Congo,' 'Kilimanjaro,' 'History of a Slave,' 'Life of Livingstone,' 'British Central Africa,' etc. (H. H. J.)

JORDAN, David Starr, Ph.D., LL.D.; President of Leland Stanford Junior University; sometime Assistant to the U.S. Fish Commission, and Professor of Zoology, and President of Indiana University; Commissioner and Expert for the United States to investigate the Fur Seal Question, 1896-97; author of 'Vertebrate Animals of Northern U.S.,' 'Fisheries of North and Middle America,' 'Factors of Organic Evolution,' etc. (D. S. J.)

JORDAN, Richard; Draughts Champion of Scotland, 1896, and of the World since 1896. (R. J.)

JUDSON, Harry Pratt, A.M., LL.D.; Professor of Political Science, and Dean of the Faculties of Arts, Science, and Literature, University of Chicago; author of 'Europe in the Nineteenth Century,' 'Growth of the American Nation,' etc. (H. P. J.)

K

KAN, C. M.; Professor of Geography, University of Amsterdam; author of 'Holland' in Ninth Edition of the 'Ency. Brit.,' 'A History of Discoveries in the Indian Archipelago,' editor 'The International Colonial Review,' etc. (C. M. K.)

KARAGEORGEVITCH, Bojidar, Prince; artist and art critic. (B. K.)

KEANE, Augustus Henry, F.R.G.S.; Emeritus Professor of Hindustani, Univ. Coll. London; late Vice-President Anthrop. Institute; author of 'Kirghiz,' 'Soudan,' 'Somali,' 'Yoruba,' etc., in Ninth Edition of 'Ency. Brit.' Stanford's 'Asia,' 'Africa,' 'Ethnology,' 'Man, Past and Present,' etc. (A. H. K.)

KELSEY, C. H., President of the Title Guaranty and Trust Company, New York. (C. H. K.)

KELTIE, John Scott, F.S.S., F.S.A. (Scot.), LL.D. St Andrews; Secr. Royal Geog. Soc.; Knight of Swedish Order of North Star, 1898; Hon. Memb. Geographical Societies of Paris, Berlin, Rome, Brussels, Amsterdam, Geneva, Lisbon, Buda-Pest, Philadelphia, etc.; for several years sub-editor of 'Nature'; inspector of geographical education, R.G.S., 1884; Librarian R.G.S., 1885; President Geographical Section, Brit. Ass., 1897; author of 'Finland,' 'Sir John Franklin,' etc., in Ninth Edition of 'Ency. Brit.,' 'History of Scottish Highlands and Clans,' 'Applied Geography,' 'The Partition of Africa'; editor of 'Statesman's Year Book' since 1880; editor of the 'Geographical Journal'; joint-editor of 'World's Great Explorers' Series, and 'The Systematic Atlas.' (J. S. K.)

KEMPE, Harry Robert, A.M.I.C.E., M.I.E.E.; principal technical officer, Postal Telegraph Dept., England; author of 'Handbook of Electrical Testing,' 'The Electrical Engineer's Pocket Book,' 'The Engineer's Year Book,' etc. etc. (H. R. K.)

KENNEDY, Sir Charles Malcolm, K.C.M.G., C.B.; Head of Commercial Department, Foreign Office, 1872-93; Lecturer on International Law, Univ. Coll. Bristol; Commissioner in the Levant, 1870-71; at Paris, 1872-86; Plenipotentiary, Treaty of the Hague, 1882; author of 'Kennedy's Ethnological and Linguistic Essays' (editor), 'Diplomacy and International Law.' (C. M. K*.)

KENNEDY, Hon. Sir William Rann; Judge of the King's Bench Division of the High Court of Justice; Fellow, and afterwards Hon. Fellow of Pembroke Coll. Camb. (W. R. K.)

KEYNES, John Neville, M.A., D.Sc.; University Lecturer in Moral Science, Cambridge, 1884; Member of the Council of the Senate of the University of Cambridge; author of 'Studies and Exercises in Formal Logic,' 'Scope and Method of Political Economy.' (J. N. K.)

KHNOPFF, Fernand: chevalier de l'ordre de Leopold, de St Michel de Bavière; Vice-Pres. de Cercle artistique et littéraire de Bruxelles, etc. (F. K*.)

KIDD, Benjamin; formerly of Inland Revenue Department; author of 'Social Evolution,' 1894 (translations: German, 1895; Swedish, 1895; French, 1896; Russian, 1897; Italian, 1898; Czech, 1900; Danish, 1900); The Control of the Tropics, 1898. (B. K*.)

KIRK, Edward C., D.D.S.; Dean of the Department of Dentistry, and Professor of Clinical Dentistry, University of Pennsylvania; Member of the National Dental Association and the American Academy of Dental Science; editor of 'The American Text-book of Operative Dentistry,' and of 'The Dental Cosmos' Magazine. (E. C. K.)

KNIGHT, Major John G. D., Corps of Engineers, U.S.A., A.M.; Commandant U.S. Engineer School; in charge of U.S. Engineer Depot, 1895-1901, of Torpedo Defence, E. entrance N.Y. Harbour, 1898-1901; on Board of U.S. Torpedo System, 1896-1901. (J. G. D. K.)

KNOTT, Cargill Gilston, D.Sc.; Lecturer on Applied Mathematics, Edinburgh University; Assistant to Professor of Natural Philosophy, Edinburgh University, 1879-83; Prof. of Physics, Imperial University, Japan, 1883-91; conducted Magnetic Survey of Japan, 1887; awarded Keith Prize (Roy. Soc. Edin.) for work on magnetic strains, 1897; author of 'Ice,' 'Pneumatics,' in Ninth Edition of 'Ency. Brit.,' 'Physics,' etc. (C. G. K.)

KNOWLING, Richard John, D.D.; Professor of New Testament Exegesis in King's College, London, 1894; Fellow, 1899; Examiner for Hall-Houghton Prizes at Oxford, 1897, and in Theology at Durham, 1895-96; Select Preacher at Cambridge, 1895; author of 'Witness of the Epistles,' 'Acts of the Apostles,' etc. (R. J. K*.)

KOREN, John; author of 'Economic Aspects of the Liquor Problem,' etc. (J. K.)

KRAUS, Professor Dr F. X., the late; Professor of Ecclesiastical History at the University of Freiburg in Bresigau. (F. X. K.)

KROPOTKIN, Prince Peter Alexeivitch; Gold Medal of Russian Geographical Society, 1864; crossed North Manchuria from Transbaikalia to the Amur, 1864; Secretary to Physical Geography Section of Geographical Society; author of 'Lithuanians,' 'Nijni-Novgorod,' 'Nova Zembla,' 'Poland,' 'Siberia,' 'Tomsk,' 'Warsaw,' etc., in Ninth Edition of 'Ency. Brit.,' 'General Sketch of the Orography of East Siberia,' 'In Russian and French Prisons,' 'Recent Science in Nineteenth Century,' 'The State, its Part in History,' 'Memoirs of a Revolutionist.' (P. A. K.)

L

LABBE, Alphonse, Docteur ès sciences; chief of the Laboratory of Zoology, University of Paris; author of 'La Cytologie expérimentale,' 'Recherches zoologiques et biologiques sur les parasites du sang des vertèbres,' etc. (A. L*.)

LAMB, Horace, M.A., LL.D., F.R.S.; Chairman of Convocation, and of the General Board of Studies, Victoria University; Professor of Mathematics, Owens Coll., Victoria Univ., Manchester; member of Council of the Royal Society, 1894-96; President of the Manchester Literary and Philosophical Society, 1899-1901; Fellow and Assistant Tutor, Trinity Coll., Camb., 1872-75; Professor of Mathematics, University of Adelaide, 1875-85; author of 'Motion of Fluids,' 'Hydrodynamics,' 'Infinitesimal Calculus.' (H. Lb.)

LANE-POOLE, Stanley, M.A., Litt.D.; Professor of Arabic at Trin. Coll. Dublin; employed in Coin Department of British Museum, 1874-92; sent by Government on archæological missions to Egypt, 1883, and Russia, 1886; employed by Egyptian Government on archæological research at Cairo, 1895-97; corr. member of the Imperial Russian Archæological Society; lecturer at the Royal Institution, 1900; author of 'Catalogue of the Oriental and Indian Coins in the British Museum,' 'Lord Stratford de Redcliffe,' 'E. W. Lane,' 'Saladin,' 'Historics of the Moors in Spain,' 'Turkey,' 'The Barbary Corsairs,' 'The Mahommedan Dynasties,' 'The Mogul Emperors,' 'Egypt in the Middle Ages,' 'Egypt,' 'The Art of the Saracens of Egypt,' 'Cairo,' etc., edited 'Lane's Arabic Lexicon,' 'Arabian Society in the Middle Ages,' 'Life of General Chesney.' (S. L.-P.)

LANESSAN, J. M. A. de; Agr. de la faculté de Médicine; French Minister of Marine; formerly Governor-General of Indo-China; author of 'La Tunisie,' 'L'expansion coloniale de la France,' 'L'Indo-Chine française,' 'Du Protoplasme végétal,' 'La Matière, la Vie et les êtres vivants.' (J. M. A. de L.)

LANG, Andrew, M.A., LL.D.; Hon. Fellow of Merton Coll., Oxford; author of 'Apparitions,' 'Ballad,' 'Family,' 'Molière,' in Ninth Edition of 'Ency. Brit.,' 'Oxford,' 'Helen of Troy,' 'Custom and Myth,' 'Myth, Ritual, and Religion,' 'Life, Letters, and Diaries of Sir Stafford Northcote,' 'Pickle the Spy,' 'The Book of Dreams and Ghosts,' Translations of 'Odyssey' (with Professor Butcher), and 'Iliad' (with Myers and Walter Leaf); 'The World's Desire' (with Rider Haggard), 'The Making of Religion,' 'The Companions of Pickle,' 'A History of Scotland from the Roman Occupation,' 'Prince Charles Edward,' 'Magic and Religion,' 'The Mystery of Mary Stuart,' etc. (A. L.)

LANG, W. H., M.B., D.Sc.; lecturer in botany, Queen Margaret's Coll., Glasgow; author of 'Memoirs on Morphology,' 'The Development of the Higher Cryptogams,' etc. (W. H. L.)

LANKESTER, Edwin Ray, M.A., LL.D., F.R.S.; Hon. Fellow of Exeter Coll., Oxford; Correspondent of the Institute of France; Director of the Natural History Department of the British Museum; Fullerian Professor of Physiology and Comparative Anatomy in the Royal Institution of London, 1898-1900; Fellow and Lecturer, Exeter Coll., 1872; Professor of Zoology and Compar. Anat. Univ. Coll., London, 1874-90; Regius Professor Natural History, Edinburgh, 1882; Linacre Professor of Comparative Anatomy, Oxford, 1891-1898; Royal Medallist Royal Society, 1885; Vice-President Royal Society, 1896; Founder (1884), President (1892) Marine Biological Association (Plymouth Laboratory); Correspondent of the Institute of France; Corr. Mem. Imp. Acad. Sciences, St Petersburg; For. Mem. Royal Bohemian Society of Sciences, of the New York Academy of Sciences, of the Academy of the Lincei of Rome, of the Royal Belgian Academy, and of the Academy of Sciences of Philadelphia; editor since 1869 of 'Quarterly Journal of Microscopical Science'; author of 'Hydrozoa,' 'Mollusca,' 'Mussel,' 'Polyzoa,' 'Protozoa,' 'Vertebrata,' 'Zoology,' in Ninth Edition of 'Ency. Brit.,' 'A Monograph of Cephalaspidian Fishes,' 'Comparative Longevity,' 'Developmental History of the Mollusca,' 'Degeneration,' 'The Advancement of Science,' 'Zoological Articles'; joint-editor of 'Scientific Memoirs of Thomas Henry Huxley.' (E. R. L.)

LARMOR, Joseph, M.A., D.Sc., Sec. R.S.; Fellow of St John's Coll., Camb.; University Lecturer in Mathematics; Professor of Natural Philosophy, Queen's Coll., Galway, and in the Queen's University in Ireland, 1880-1885, and formerly Fellow of the Royal University; Examiner in Mathematics and Natural Philosophy in the Univ. of London; lately President of the Cambridge Philosophical Society; Treasurer of the London Mathematical Society; author of 'Æther and Matter,' and various Memoirs on Mathematics and Physics. (J. L*.)

LAUGHTON, John Knox, M.A.; Professor Modern History, King's Coll., London; Secretary of the Navy Records Society; served in Baltic during the Russian War, 1854-55; in China, 1856-59; afterwards in Mediterranean and Channel; Mathematical and Naval Instructor, Royal Naval College, Portsmouth, 1866-73; also at Greenwich, and lecturer on Meteorology, 1873-85; Pres. R. Met. Soc. 1882-1884; Honorary Fellow, Caius College, Cambridge, 1895; author of 'Farragut,' 'Fitzroy,' in Ninth Edition of 'Ency. Brit.,' 'Physical Geography in its Relation to the Prevailing Winds and Currents,' 'Studies in Naval History,' 'Nelson and his Companions in Arms,' 'Life of Henry Reeve,' 'Sea Fights and Adventures,' 'Letters and Despatches of Lord Nelson,' 'Defeat of the Spanish Armada.' (J. K. L.)

LAWRENCE, Rt. Rev. William, D.D., S.T.D.; Bishop of Massachusetts; sometime Professor of Homiletics and Pastoral Theology, and Dean Episcopal Theological School, Cambridge, U.S.A.; author of 'Life of Amos A. Lawrence,' 'Proportional Representation in the House of Clerical and Lay Delegates,' 'Visions and Service.' (W. L.)

LAYARD, George S.; English art writer; author of 'Charles Keene,' 'Mrs Lynn Linton,' 'Portraits of Cruikshank by Himself,' 'Tennyson and his Pre-Raphaelite Illustrators,' etc. (G. S. L.)

LECLÈRE, Léon; Professor of Universal History and History of Philosophy, University of Brussels. (L. L.)

LEE, Sidney, B.A., Litt.D.; editor of Dictionary of National Biography and Supplement; Clark Lecturer in English Literature, Trin. Coll., Cambridge, 1901; author of 'Stratford-on-Avon from the Earliest Times to the Death of Shakespeare,' 'Lord Herbert of Cherbury's Autobiography, with a continuation of his Life,' 'A Life of William Shakespeare.' (S. L.)

LEE-WARNER, Sir William, K.C.S.I., M.A.; Secretary in the Political and Secret Departments of the India Office; Fellow of the University of Bombay; entered Indian Civil Service, 1869; political agent at Kolhapur; Under-Secretary in Foreign Office of India; Secretary to the Government of Bombay in Political and Judicial Departments; Chief Commissioner of Coorg and Resident in Mysore; additional member of the Viceroy's Council; served on Education Commission, the Financial Commission, etc.; author of 'The Protected Princes of India,' 'The Citizen of India.' (W. L.-W.)

LEGGE, J. G.; Chief Inspector of Reformatory and Industrial Schools, Home Office. (J. G. L.)

LEGGE, Robin H.; editor of 'Music in the Nineteenth Century.' (R. H. L.)

LEONARD, Rt. Rev. Abiel, A.M., S.T.D.; Bishop of the Diocese of Salt Lake. (A. Le.)

LEVEY, George Collins, C.M.G.; London Correspondent of 'Melbourne Age'; editor and proprietor of 'Melbourne Herald,' 1863-68; editor and contributor to 'Melbourne Age,' 1869-81; Secretary to Commissioners for Victoria at the Exhibitions in London, Paris, Vienna, Philadelphia, Melbourne, 1873, 1876, 1878, 1880-81; Executive Commissioner, Amsterdam, 1883; Secretary Royal Commission, Hobart Exhibition, 1894-95; Secretary Colonial Adelaide Exhibition, 1887; Committee of Royal Commission to Paris Exhibition, 1900; member of Board of Advice to Agent-General of Victoria; author of 'Handbook to Australasia,' 'Australian Encyclopædia.' (G. C. L.)

LEWES, Vivian B., F.I.C., F.C.S.; Professor of Chemistry, Royal Naval College; Chief Superintending Gas Examiner to the Corporation of the City of London. (V. B. L.)

LEWIS, Charlton T., Ph.D.; President N.Y. Prison Association, N.J. State Charities Aid Association; Chairman of Commission to revise Penal Laws of New Jersey; Lecturer on Life Insurance, Harvard and Columbia Universities, and on Principles of Insurance, Cornell University; author of 'History of Germany,' Essays, Addresses, etc. (C. T. L.)

LEYLAND, John; writer on naval questions. (J. Ld.)

LIAS, Rev. John James, M.A.; Professor of Modern Literature, St David's Coll., Lampeter, 1871-1880; examining chaplain to Bishop of Llandaff, 1887-98; Chancellor of Llandaff Cathedral; author of 'Science in Relation to Miracles,' 'The Nicene Creed,' 'A Plea for Rationality in Ceremonial,' etc. (J. J. L*.)

LIDDELL, F. F., M.A.; Fellow of All Souls College, Oxford; Barrister, Lincoln's Inn; editor of 'Manual of Military Laws.' (F. F. L.)

LIGHTFOOT, T. B., M.I.C.E., M.I.M.E.; author of 'The Mechanical Refrigeration of Air,' 'Preservation of Foods by Cold,' etc. (T. B. L.)

LILLIE, Arthur; champion Grand National Croquet Club, 1872; author of 'Croquet,' 'Croquet Up to Date,' etc. (A. Li.)

LITTLEJOHN, Henry Harvey, M.B., B.Sc., F.R.C.S. Ed.; Lecturer in Medical Jurisprudence, School of Medicine of the Royal College of Physicians and Surgeons of Edinburgh. (H. H. L.)

LLOYD, Lt.-Col. E. M., R.E.; author of 'Vauban, Montalembert, Carnot: Engineer Studies,' etc. (E. M. L.)

LLOYD, Henry Demarest, author of 'Wealth against Commonwealth,' 'Labor Copartnership,' etc. (H. D. L*.)

LOCH, Charles Stewart, B.A.; Secretary to the Council of the London Charity Organization Society since 1875; Member Royal Commission on Aged Poor, 1893-95; Dunkin Trust Lecturer, Manchester College, Oxford, 1896; Vice-President Royal Statistical Society, 1894, 1895, 1897, 1901; author of 'Charity Organization,' 'Old Age Pensions and Pauperism.' (C. S. L.)

LOCOCK, Col. Herbert, C.B.; retired Colonel of Royal Engineers; Assist. Director of Works at Headquarters, 1881-86; Depy. Inspector-General of Fortifications at Headquarters, 1887-96. (H. Lo.)

LODGE, Oliver Joseph, F.R.S., D.Sc., LL.D.; Principal of the University of Birmingham; Professor of Physics, University Coll., Liverpool, 1881-1900; author of 'Elementary Mechanics,' 'Modern Views of Electricity,' 'Pioneers of Science,' 'Signalling without Wires,' etc. (O. J. L.)

LORD, J. K., Professor of the Latin Language and Literature, Dartmouth College, N.H.; author of 'New Hampshire' in Ninth Edition of 'Ency. Brit.' (J. K. L*.)

LOUIS, Prof. Henry, The Durham College of Science, Newcastle-upon-Tyne, England; author of 'A Handbook of Gold Milling,' etc. (H. L*.)

LOUIS, Paul; French statistician; staff of the 'Revue Blanche.' (P. L.)

LOVE, Augustus E. H., M.A., F.R.S.; Sedleian Professor of Natural Philosophy, Oxford, since 1899; Fellow of St John's Coll., Camb.; University Lecturer in Mathematics. (A. E. H. L.)

LOW, A. P.; of the Geological Survey of Canada; author of 'Report on the Exploration in the Labrador Peninsula,' etc. (A. P. Lo.)

LOW, Hon. Seth, LL.D.; Mayor of New York City; formerly President of Columbia University; Mayor of Brooklyn, 1881-85; President of the Archæological Institution of America. (S. L*.)

LOW, Sidney James, M.A., L.C.C.; Lecturer on History, King's College, 1883-86; editor of the 'St James's Gazette,' 1888-97; co-editor of the 'Dictionary of English History'; author of contributions to 'Nineteenth Century,' 'Fortnightly Review,' 'National Review,' etc. (S. J. L.)

LOWE, Major F. M., R.A.; Senior Experimental Officer, Shoeburyness, 1884; Asst. Inspector, Army Inspection Dept., 1888; Gunnery Instructor, Brit. N. America, 1893; Gunnery Instructor, Coast Defence School, and Asst. Superintendent of Experiments at Shoeburyness. (F. M. L*.)

LUGARD, Brig.-Gen. Sir Frederick John Dealtry, K.C.M.G., C.B., D.S.O.; High Commissioner of Northern Nigeria; served Afghan War, 1879-1880; Soudan Campaign, 1885; Burma Campaign, 1886-1887; commanded expedition against slave traders on Lake Nyassa, 1888; employed by British East African Company; in command of Exploration of the Sabakhi, and Administrator of Uganda, 1889-92; employed by Royal Niger Company, 1894-95; West Charterland, 1896-97; H.M. Commissioner Hinterland of Nigeria and Lagos, 1897-99; Commandant of West African Frontier Force, 1897-99; author of 'Our East African Empire.' (F. D. L.)

LUMMIS, Charles Fletcher, editor of the 'Land of Sunshine' magazine, Los Angeles, California; author of 'The Right Hand of the Continent' (California), and numerous publications dealing with the western and south-western States; formerly editor of the Los Angeles 'Daily Times.' (C. F. L.)

LUNGE, George, Ph.D.; Professor of Technical Chemistry at the Polytechnic, Zürich; author of 'Acid and Alkali Manufacture,' etc. (G. L.)

LUSHINGTON, Sir Franklin, M.A., the late; Chief Police Magistrate for London; author of 'Wagers of Battle.' (F. L*.)

LYALL, Sir Alfred Comyn, K.C.B., G.C.I.E., Hon. D.C.L. Oxford, and LL.D. Cambridge; Member of Council of Secretary of State for India since 1888; Lieut.-Gov. North-West Provinces, India, 1882-87; author of 'British Dominion in India,' 'Asiatic Studies,' 'Life of Warren Hastings.' (A. C. L.)

LYDEKKER, Richard, B.A., F.R.S., F.G.S., F.Z.S.; Geological Survey of India, 1874-82; author of 'Geology of Kashmir,' 'Catalogues of Fossil Mammals, Reptiles, and Birds in British Museum,' 'Phases of Animal Life,' 'Royal Natural History,' 'A Manual of Palæontology' (with late Professor A. Nicholson), 'The Great and Small Game of Europe, N. and W. Asia, and America,' 'Descriptions of South American Fossil Animals.' (R. L*.)

LYNES, G. B., A.M.; sub-editor of the New Volumes of 'Ency. Brit.'; formerly literary editor of the 'Baltimore News,' and instructor in History and Acting Librarian, Union College, Schenectady, N.Y.; author of 'A Course in Modern European History,' etc. (G. B. L.)

LYONS, H. G.; Major R.E.; Director of the Survey Department, Egypt; editor of 'A Handbook of Travellers in Egypt;' author of 'Report on the Island and Temples of Philæ,' etc. (H. G. L.)

M

MACALISTER, Alexander, M.A., M.D., D.Sc., LL.D., F.R.S., F.S.A.; Member of Senate of Royal University of Ireland; Professor of Anatomy, Cambridge University, since 1883; Fellow of St John's College; Professor of Zoology, University of Dublin, 1869; Professor of Anatomy and Chirurgery, Dublin, 1877; author of 'Phrenology,' 'Physiognomy,' 'Stigmatization,' in Ninth Edition of 'Ency. Brit.,' 'Introduction to Animal Morphology,' 'Morphology of Vertebrate Animals,' 'Text-Book of Human Anatomy,' etc. (A. Ma.)

MacALISTER, Donald, M.A., M.D., B.Sc., F.R.C.P., Fellow and Senior Tutor of St John's Coll., Camb.; University Lecturer in Medicine; Physician to Addenbrooke's Hospital; Univ. Memb. and Business Chairman General Medical Council; Chairman of British Pharmacopœia Committee; Examiner in Medicine, Univ. Birmingham, and R. Coll. Physicians, London; Hon. President International Congress of Hygiene, Madrid, 1898; Lecturer in Natural Philosophy, St Bartholomew's Hospital, 1879; Goulstonian Lecturer, Royal College of Physicians, 1887; first Croonian Professor, 1888; Thomson Lecturer, Aberdeen, 1889; Examiner Victoria Univ. 1896-98; author of 'Ziegler's Pathological Anatomy,' 'Nature of Fever,' 'Advanced Study and Research in Cambridge,' 'The Practitioner' (with editorial committee), 'The British Pharmacopœia,' etc. (D. M*.)

MACAULAY, W. H., M.A.; Fellow and Lecturer of King's Coll., Cambridge; late University Lecturer in Applied Mechanics, Cambridge. (W. H. M.)

MacCOLL, D. S., M.A.; painter; art critic of the 'Saturday Review.' (D. S. M.)

MacCORMAC, Sir William, Bt., the late; President of the Royal College of Surgeons, 1896-1901; Serjeant-Surgeon to King Edward VII. (W. MacC.)

MACDONELL, John, C.B., LL.D.; Master of the Supreme Court; author of 'The Law of Master and Servant,' etc. (J. M†.)

MACFARLANE, J.; formerly assistant, British Museum. (J. M'F.)

MACGREGOR, Sir William, K.C.M.G., C.B., M.D. Aberdeen, B.Sc. Camb., LL.D. Aberdeen; Governor of Lagos; Resident Surgeon and Resident Physician Glasgow Royal Infirmary, and Royal Lunatic Asylum, Aberdeen; Assistant Government Medical Officer, Seychelles, 1873; Surgeon Civil Hospital, Port Louis, Mauritius, 1874; Chief Medical Officer, Fiji, 1875; late Receiver-General and Administrator of the Government, and Acting High Commissioner and Consul-General for the Western Pacific; Administrator of British New Guinea, 1888; Lieut.-Governor, 1895. (W. M'G.)

MACKAY, Rev. G. F. (G. F. M*.)

MACKAY, T.; author of 'Methods of Social Reform.' (T. M*.)

M'KENDRICK, John Gray, M.D., LL.D. (Hon. Aberdeen), F.R.S., F.R.S. Edin., F.R.C.P.; Professor of Physiology Glasgow University; Examiner in Physiology University of London, Victoria University, and University of Birmingham; formerly Examiner in Univ. of Oxford and Camb.; Fullerian Professor of Physiology at Royal Inst. of Great Britain; one of the lecturers in connexion with the Gilchrist Trust; has served on the Council of the Royal Society; member of Council of Royal Society of Edinburgh; President of Physiological Section of British Association; author of 'Narcotics,' 'Sleep,' 'Smell,' 'Stammering,' 'Stereoscope,' 'Taste,' 'Touch,' 'Voice,' 'Vascular System,' in Ninth Edition of 'Ency. Brit.,' 'Animal Physiology,' 'A Text-Book of Physiology,' 'Life in Motion, or Muscle Nerve,' 'Physiology,' 'Life of Helmholtz,' etc. (J. G. M.)

M'LAUGHLIN, Andrew Cunningham, A.M., LL.B.; Professor of American History, University of Michigan; author of 'History of Higher Education in Michigan,' 'Civil Government in Michigan,' 'Lewis Cass,' etc. (A. C. M.)

MACMAHON, Major Percy Alexander, R.A., Sc.D., F.R.S.; Professor of Artillery, Woolwich; President of London Mathematical Society, 1894-96; accompanied Government Expedition to observe eclipse of sun, Norway, 1896; author of numerous papers on Pure Mathematics, etc. (P. A. M.)

McMASTER, John Bach, Ph.D., Litt.D.; Professor American History, University of Pennsylvania; author of 'A History of the People of the United States.' (J. B. McM.)

McMILLAN, Walter G., F.C.S., M.I.M.M.; Sec. Inst. Elect. Engineers; late lecturer on Metallurgy, Mason Coll., Birmingham; author of 'A Treatise on Electro-Metallurgy,' part author of 'Metals,' translator of 'Electric Smelting and Refining.' (W. G. M.)

MACMORRAN, Alexander, K.C., A.M.I.C.E.; became editor of 'Justice of the Peace,' 1879, and has so continued; author of editions of 'Lumley's Public Health,' works on 'The Public Health (London) Act, 1891,' the 'Local Government Act, 1888,' the 'Local Government Act, 1894,' the 'London Government Act, 1899,' 'Poor Law Orders,' 'Poor Law Statutes,' etc. (A. M'M.)

MAC MUNN, Charles Alexander, M.A. M.D., F.C.S., F.R.M.S.; Hon. Pathologist and Physician, Wolverhampton General Hospital; author of 'The Spectroscope in Medicine,' 'Outlines of Clinical Chemistry,' etc. (C. A. MacM.)

M'CORMICK, William Symington, M.A.; Professor of English Literature at University College, Dundee; author of 'Lectures on Literature,' joint-editor of the Globe 'Chaucer,' etc. (W. S. M.)

McCRADY, Edward, President of the Historical Society of South Carolina; author of 'History of South Carolina under the Proprietary Government,' and 'History of South Carolina under the Royal Government.' (E. McC.)

M'VEY, Frank L., Ph.D.; Assistant Professor of Political Science, University of Minnesota. (F. L. M.)

MacWILLIAM, Robert, Professor at Gill Coll., Somerset East, Cape Colony. (R. M'W.)

MAGNUS, Sir Philip; Superintendent of Technological Examinations and Secretary of Examinations Department, City and Guilds of London Institute; organising Director and Secretary of City and Guilds of London Institute, 1880-88; member Royal Commission on Technical Instruction, 1881-84; is Member of the Senate and Fellow of the London University; Vice-President and Fellow of College of Preceptors; Member of the Mathematical and Physical Societies; author of 'Technical Education' in Ninth Edition of 'Ency. Brit.,' 'Lessons in Elementary Mechanics,' 'Hydrostatics and Pneumatics,' 'Industrial Education.' (P. M*.)

MAITLAND, Frederic William, LL.D., D.C.L. (Oxford, Glasgow, Cracow); Professor of English Law, Cambridge; Reader of English Law at Cambridge, 1884; Corresponding Member of Roy. Prussian Academy; author of 'Justice and Police,' 'Bracton's Note-Book,' 'History of English Law' (with Sir F. Pollock), 'Domesday Book and Beyond,' 'Township and Borough,' 'Canon Law in England,' etc. (F. W. M.)

MAITLAND, J. A. Fuller, M.A., F.S.A.; musical critic of 'The Times'; author of 'Life of Robert Schumann,' 'Masters of German Music,' 'The Musician's Pilgrimage,' Spitta's 'Life of Bach' (joint-translation with Mrs C. Bell); edited the Appendix to Grove's 'Dictionary of Music and Musicians,' 'English County Songs' (with Miss L. E. Broadwood), 'The Fitzwilliam Virginal Book' (with W. B. Squire). (J. A. F. M.)

MANSON, Edward; Barrister, Middle Temple; author of 'Law of Trading Companies,' 'The Law of Debentures and Debenture Stock,' 'Practical Guide to Company Law,' etc. (E. Ma.)

MANSON, James Alexander; sub-editor of the New Volumes of the 'Ency. Brit.'; dramatic critic, 'Weekly Dispatch,' 1890-92; literary editor of the 'Daily Chronicle,' 1891; author of 'In Memoriam edition of Burns's Poetical Works,' 'Valour for Victoria,' 'Sir Edwin Landseer' (Makers of British Art Series), etc. (J. A. M.)

MARKBY, Sir William, K.C.I.E., D.C.L.; Fellow of All Souls College, Oxford, and of Balliol College; judge of High Court, Calcutta, 1866-78; Reader in Indian Law, Oxford, 1878-1900; author of 'Lectures on Indian Law,' 'Elements of Law considered with Reference to General Principles of Jurisprudence.' (W. Ma.)

MARKHAM, Sir Clements Robert, K.C.B., F.R.S.; President of the Royal Geographical Society, of the International Geographical Congress, 1894-99, and of the Hakluyt Society, and of the Geographical, Elizabethan, and Royal Society Clubs; entered the Navy in 1844; served in the Arctic Expedition of 1850-51; geographer to the Abyssinian Expedition; Assistant Secretary in the India Office, 1867-77; author of 'Geography' (historical), 'Peru,' 'Polar Regions,' in Ninth Edition of 'Ency. Brit.'; 'Life of the Great Lord Fairfax,' 'The Fighting Veres,' 'History of Peru,' 'History of Persia,' 'History of the Abyssinian Expedition,' Lives of Columbus, John Davis, and Major Rennell, 'The Paladins of Edwin the Great'; edited volumes for the Hakluyt Society, the Navy Records Society, the Roxburghe Club, etc. (C. R. M.)

MARSHALL, George M., Ph.B.; Professor of English Language and Literature, University of Utah. (G. M. M.)

MARTEL, Major C. P., R.A.; Sec. to the Ordnance Committee; late Professor of Artillery, Ordnance Coll. (C. P. M.)

MARTIN, T. C.; editor of 'Electrical World and Engineer,' New York. (T. C. M.)

MARTIN, Capt. W. R., R.N.; author of 'A Treatise on Navigation and Nautical Astronomy,' etc. (W. R. M*.)

MARZIALS, Frank Thomas; Accountant-General of the Army since 1898; entered War Office during Crimean war; author of 'Lives of Dickens and Victor Hugo, collaborating also in the 'Life of Thackeray,' 'Life of Gambetta,' etc. (F. T. M.)

MASKELYNE, J. Nevil; of the Egyptian Hall, London; author of 'Sharps and Flats.' (J. N. M.)

MASON, Otis Tufton, A.M., Ph.D.; Curator Ethnology, U.S. Nat. Museum, Washington; author of 'The Hupa Indians,' 'Woman's Share in Primitive Culture,' 'Cradles of the North American Indians,' 'The Antiquities of Guadeloupe,' etc. (O. T. M.)

MATHEWS, George Ballard, M.A., F.R.S.; late Professor of Mathematics, University Coll. of Wales; formerly Fellow of St John's Coll., Cambridge; author of 'A Treatise on Bessel Functions' (part), 'Theory of Numbers,' etc. (G. B. M.)

MATTHEWS, Brander, LL.B., D.C.L., A.M.; Professor of English, Columbia University; author of 'French Dramatists of the Nineteenth Century,' 'Introduction to the Study of American Literature,' 'Aspects of Fiction and Other Ventures in Criticism,' etc. (B. M.)

MATTHEWS, George Edward, A.B.; editor of 'The Buffalo Express,' Buffalo, N.Y. (G. E. M.)

MAURICE, Maj.-Gen. Sir John Frederick, K.C.B.; commanded Woolwich District, 1895-1901; Ashanti Campaign, 1873-74; South Africa, 1879; Zulu Campaign, 1880; Egyptian Expedition, 1882; Intelligence Dept. War Office; Sudan, 1884; A.Q.M.G.; Nile, 1885; Professor of Military History, Staff College, Aldershot, 1892-93; commanding R.A., Colchester, 1893-95; Maj.-Gen., Dec. 1895; author of 'War,' in Ninth Edition of 'Ency. Brit.,' 'Life of Frederick Denison Maurice,' 'Hostilities without Declaration of War,' 'Balance of Military Power in Europe,' 'War,' 'National Defences.' (J. F. M*.)

MAUS, Octave; editor of 'L'Art Moderne,' Brussels. (O. M*.)

MAXWELL, William H., A.M.I.C.E.; Borough and Waterworks Engineer, Tunbridge Wells Corporation; author of 'The Removal and Disposal of Town Refuse,' 'Destructors and Steam Production,' etc. (W. H. Ma.)

MAYO-SMITH, Richmond, Ph.D., the late; Professor of Political Economy, Columbia University, New York; author of 'Emigration and Immigration,' 'Sociology and Statistics,' etc. (R. M.-S.)

MEAD, Hon. Elwood; in charge of Irrigation Investigations, U.S. Department of Agriculture. (E. M*.)

MEAKIN, Budgett, author of 'The Moorish Empire,' etc. (B. M*.)

MEISSAS, Gaston; memb. Société de Géographie; author of 'Marseilles,' and (part) of 'Paris,' in the Ninth Edition of the 'Ency. Brit.,' 'Grands Voyageurs de notre Siècle,' etc. (G. Me.)

MERCATELLI, Luigi, late war correspondent in Abyssinia of 'La Tribuna.' (L. Me.)

MERRIFIELD, Webster, LL.D.; President and Professor of Political Economy, State University of North Dakota. (W. Ms.)

MERRILL, Hon. Frederick James Hamilton, Ph.D.; Director of N.Y. State Museum, Albany, N.Y., N.Y. State Geologist; Fellow Am. Ass. Adv. Science and Geol. Soc. of America; Member Am. Inst. Mining Engineers, Am. Soc. of Naturalists, Nat. Geol. Soc., etc. (F. J. H. M.)

MIDDLETON, R. E., M.I.C.E., M.I.M.E.; Fellow of the Sanitary Inst., Fellow of Surveyors' Inst., etc.; late Engineer-in-Charge of Surveying of Forth Bridge; Instructor in Surveying, Central Tech. Coll., S. Kensington; Lecturer on Waterworks, Engineering and Sewage, Univ. Coll., London; part author of 'A Treatise on Surveying,' etc. (R. E. M.)

MIJATOVICH, Chedomille; Senator of the kingdom of Servia since 1875; Envoy Extraordinary and Minister Plenipotentiary of the King of Servia to the Court of St James, 1895-1900; transferred to Constantinople, 1900; Minister of Finance and Commerce of Servia, 1873; Minister of Foreign Affairs and Finance, 1880; Servian Minister to the Court of St James, 1884; Servian Plenipotentiary for the conclusion of peace with Bulgaria, 1886; Member of Royal Servian Academy of Science; corresponding member of South Slavonic Academy; hon. member of Royal Hist. Soc. London; author of several publications in Servian on Political Economy, Finances, History of Commerce, and History of Servia in Fifteenth Century; novels—'Rayko of Rassina,' 'Ikoniya, the Mother of the Vezier, etc.,' 'Constantine the last Emperor of the Greeks,' 'Ancestors of the House of Orange.' (C. Mi.)

MILL, Hugh Robert, D.Sc. (Edin.), LL.D. (St Andrews), F.R.S.G.S., F.R.G.S., F.R.Met.Soc.; Director of British Rainfall Organization, and editor of 'Symons' Meteorological Magazine' since 1901; Hon. Corresponding Member of the Geographical Societies of Paris, Berlin, Amsterdam, Budapest, Brisbane, and Philadelphia; Recorder of Section E, British Association, 1893-99; President, Section E, 1901; British Delegate to International Conference on the Exploration of the Sea, at Christiania, 1901; author of 'Rainband,' 'Rain-gauge,' 'Thermometer,' 'Whirlpool,' in Ninth Edition of 'Ency. Brit.,' 'Realm of Nature,' 'The Clyde Sea Area,' 'The English Lakes,' 'Hints on the Choice of Geographical Books,' 'New Lands,' 'The International Geography,' etc. (H. R. M.)

MILLINGEN, Alexander Van, M.A.; Robert College, Constantinople; author of 'Byzantine Constantinople,' etc. (A. van M.)

MILMAN, Sir Archibald John Scott, K.C.B., the late; Clerk of the House of Commons 1900, retired 1902; entered service of House of Commons in 1857; promoted Second Clerk Assistant, 1870; Clerk Assistant, 1886-1900. (A. J. S. M.)

MILNE, John, F.R.S., F.G.S.; twenty years employed by Japanese Govt. as geologist and mining engineer; established the Seismic Survey of Japan; designer of seismographs and instruments to record vibrations on railways, etc.; author of 'Earthquakes,' 'Seismology,' 'Crystallography,' etc. (J. Mi.)

MILTON, James Tayler, M.I.C.E.; Chief Engineer Surveyor, Lloyd's Register of Shipping; Member of Inst. of Naval Architects and of the Iron and Steel Inst., etc. (J. T. Mi.)

MINCHIN, E. A., M.A., F.Z.S.; Jodrell Professor of Zoology and Comparative Anatomy, Univ. Coll., London; late Fellow of Merton Coll., Oxford; late Lecturer Comp. Anatomy, Oxford; late Lecturer in Biology, Guy's Hospital; author of 'Sponges,' etc. (E. A. M.)

MITCHELL, Hugh; of Gibraltar; Barrister-at-Law, Inner Temple. (H. M*.)

MITCHELL, Peter Chalmers, D.Sc., M.A., F.Z.S.; Lecturer on Biology at the London Hospital Medical College; University Demonstrator in Comparative Anatomy, and assistant to Linacre Professor at Oxford, 1888-91; Lecturer on Biology at Charing Cross Hospital, 1892-94; at London Hospital, 1894; examiner in Biology to the R.C.P. 1892-96; author of 'Outlines of Biology,' 'The Biological Problem of To-day' (translated), 'Thomas Henry Huxley,' etc. (P. C. M.)

MONCKTON, Lionel; composer, and musical critic to the 'Daily Telegraph.' (L. M.)

MONCRIEFF, Sir Colin Campbell Scott, K.C.M.G., C.S.I., LL.D.; Under-Secretary for Scotland; Irrigation Depart. N.W. Provinces; Chief Engineer, Burmah; Under-Secretary of State Public Works, Memshy, Cairo, 1883-92; author of 'Irrigation in Southern Europe.' (C. S. M.)

MONKHOUSE, William Cosmo, the late Assistant Secretary (Finance) Board of Trade; served on several Departmental Committees and Committee on the Mercantile Marine Fund, 1894-96; author of 'The Christ upon the Hill,' 'A Question of Honour,' 'The Earlier English Water-Colour Painters,' 'The Italian Pre-Raphaelites,' 'British Contemporary Artists,' etc. (C. Mo.)

MONTAGU, Sir Samuel; head of the banking firm of Samuel Montagu and Co., London; member of Gold and Silver Commission, 1887-90; author of magazine articles on Finance, Decimal Currency, Weights and Measures, etc. (S. M.)

MOORE, A. W., M.A.; Speaker of the House of Keys, Isle of Man. (A. W. M.)

MOORE, Hon. John Bassett, LL.D.; Professor International Law and Diplomacy, Columbia University, New York; author 'Extradition and Inter-State Rendition,' 'International Arbitrations,' etc. (J. B. M*.)

MORENO, Dr Francesco P.; donor and director of the La Plata Museum, Buenos Aires; repr. in Great Britain of the Argentine in connexion with Chilian Argentine Boundary Dispute; author of 'La Plata,' etc. (F. P. M.)

MORFILL, William Richard, M.A.; Professor of Russian and the other Slavonic languages, Oxford; Curator of the Taylor Institution, Oxford; author of 'Russia' (History and Literature) in Ninth Edition of 'Ency. Brit.' (W. R. M.)

MORSE, John Torrey, Jr.; sometime Lecturer on History, Harvard University; author of biographies of Alexander Hamilton, Abraham Lincoln, John Quincy Adams, Thomas Jefferson, etc., and of 'The Life and Letters of Oliver Wendell Holmes.' (J. T. Mo.)

MORTON, Hon. Julius Sterling (the late); sometime U.S. Secretary of Agriculture and President of Nebraska State Historical Society. (J. S. M*.)

MOSCA, Gaetano; Professor of Constitutional Law, Turin, Italy. (G. Mo.)

MOSCHINI, V.; Mayor of Padua. (V. Mo.)

MOTT, Frederick Walker, M.D., B.S. Lond., F.R.C.P., F.R.S.; Physician to Out-Patients, Charing Cross Hospital; Pathologist to the London County Asylums; Croonian Lecturer, Royal College of Physicians, 1900. (F. W. Mo.)

MUIR, John, A.M., LL.D.; U.S. Explorer and Naturalist; discoverer of the Muir glacier, Alaska; author of 'The Mountains of California' and of numerous articles on the natural history of the Pacific Coast, Alaska, etc.; Editor 'Picturesque California.' (J. Mu*.)

MUIR, Robert, M.A., M.D., C.M.; Professor of Pathology, University of Glasgow; Examiner in Pathology, Oxford; senior assistant to the Prof. of Pathology, Edinburgh, and Pathologist to Edinburgh Royal Infirmary, 1892; Lecturer on Pathological Bacteriology, Edinburgh, 1894; Professor of Pathology, St Andrews, 1898-99; author of 'Manual of Bacteriology' (with Dr J. Ritchie), 'Scientific Papers,' etc. (R. M*.)

MUNRO, Wilfred H.; A.M., Professor of European History, Brown University, R.I. (W. H. Mu.)

MURPHY, Shirley Forster, M.D., M.R.C.S.; Medical Officer of Health, Administrative County of London; Corresp. Mem. Soc. Sweden, and of Roy. Soc. Hygiene, Italy; author of 'Infectious Disease and its Prevention,' editor of 'Our Homes and How to make them Healthy,' etc. (S. F. M.)

MURRAY, Sir George Herbert, K.C.B.; Secretary to the Post Office since 1899; entered Foreign Office, 1873; transferred to Treasury, 1880; private secretary to Mr Gladstone and Earl of Rosebery when Prime Minister; Chairman Board of Inland Revenue, 1897-99. (G. H. M.)

MUTHER, Dr Richard, Professor of Art History, University of Breslau; author of 'The History of Modern Painting,' 'The Oldest German Picture Bibles,' 'Gothic and Early Renaissance Illustrations of German Books,' 'A Century of French Painting,' etc. (R. Mr.)

MYRES, J. L.; Student and tutor of Christ Church, Oxford; author of 'A Catalogue of the Cyprus Museum.' (J. L. M.)

N

NAIRNE, Rev. Alexander, M.A.; Professor of Hebrew and Old Testament Exegesis in King's Coll., Lond.; Fellow of Jesus Coll., Cambridge, 1887-93; Vice-Principal of Clergy Training School, 1887-89. (A. N*.)

NANSEN, Fridtjof, D.Sc., LL.D., D.C.L., Ph.D.; went to Greenland Sea, 1882; curator in Natural History Museum, Bergen; went across Greenland, 1888-89; curator Museum of Comparative Anatomy, Christiania University; made his North Pole Expedition, in which he reached the highest latitude until then attained (86 deg. 175 m.), 1893-96; Prof. of Zoology, Christiania University; author of 'Across Greenland,' 'Eskimo Life,' 'Farthest North,' 'The Norwegian North Polar Expedition,' 'Scientific Results,' etc. (F. N.)

NASH, James Okey, M.A., of the Community of the Resurrection. (J. O. N.)

NATHAN, Major F. L., R.A.; Superintendent of the Royal Gunpowder Factory, Waltham Abbey. (F. L. N.)

NATHAN, Major Matthew, C.M.G., R.E.; Governor of Gold Coast; served in Nile Expedition, 1885; Lushai Expedition, 1889; Sec. Col. Defence Com. 1895-1900; administered Government Sierra Leone, 1899. (M. N.)

NELSON, William Rockhill, Editor-in-Chief of the 'Kansas City Star,' Kansas City, Mo. (W. R. N.)

NEWCOMB, Prof. Simon, Ph.D., LL.D., D.Sc., D. Nat. Phil.; Superintendent U.S. Nautical Almanac; Foreign Mem. Royal Society, London; Assoc. Institute of France, etc.; author of 'Moon' in Ninth Edition of 'Ency. Brit.,' 'Popular Astronomy,' etc.; editor of 'American Journal of Mathematics.' (S. N.)

NEWELL, Frederick Haynes; Hydrographer of the U.S. Geol. Survey; author of 'Agriculture by Irrigation,' 'Hydrography of the United States,' etc. (F. H. N.)

NEWSOM, George Ernest, M.A.; Vice-Principal of King's College, London. (G. E. N.)

NEWTON, Henry G., M.A., LL.B.; Referee in Bankruptcy, New Haven, Conn. (H. G. N.)

NISBET, C. (C. N)

NORTON, Charles Eliot, LL.D.; Professor of the History of Art, Harvard; Dante scholar and translator; author of 'Church Buildings in the Middle Ages'; editor of 'Letters of James Russell Lowell,' 'Correspondence of Carlyle and Emerson,' 'Writings of George William Curtis,' etc. (C. E. N.)

NORTON, Professor Richard N.; American School of Archæology, Rome. (R. N. N.)

NOTTER, Col. J. Lane, M.A., M.D., R.A.M.C., F.C.S.; late Prof. of Military Hygiene, Netley; author of 'The Theory and Practice of Hygiene,' etc. (J. L. N.)

O

O'DONOGHUE, Freeman M., F.S.A.; Assistant Keeper of Prints, British Museum; author of 'Catalogue of the Collection of Playing Cards bequeathed to the British Museum by Lady Charlotte Schneber,' 'A Descriptive and Classified Catalogue of the Portraits of Queen Elizabeth,' etc. (F. M. O'D.)

O'NEILL, Æneas; Assistant Correspondent of 'The Times,' Vienna. (Æ. O'N.)

ORDE-BROWNE, Capt. C., the late; author of 'Armour and its Attack by Artillery,' 'Short Notes on Field Batteries,' 'Ammunition for Rifled Ordnance,' etc. (C. O.-B.)

OWEN, Capt. C. R. B., R.A.; late Professor of Artillery, Ordnance College; Assist. Superintendent, Roy. Carriage Dept., Woolwich Arsenal. (C. R. B. O.)

OWEN, Edmund, M.B. Lond., F.R.C.S.; Senior Surgeon to St Mary's Hospital, London, and Consulting Surgeon to the Children's Hospital, Great Ormond Street; Member of the Council, and late Member of the Court of Examiners of Royal College of Surgeons; Examiner in Surgery at the Universities of Cambridge and of London; Knight of Grace of the Order of St John of Jerusalem; Corresponding Member of the Imperial Medical Military Academy of St Petersburg, of the Canadian Medical Association, and of the Association of American Orthopædic Surgeons; Hon. Surgeon to the Royal Society of Musicians; late President of the Medical Society of London; author of 'A Manual of Anatomy for Senior Students,' 'The Surgical Diseases of Children.' (E. O*.)

P

PAGET, Sir John R., Bart., LL.B., K.C.; Gilbart Lecturer on Banking. (J. R. P*.)

PAGET, Stephen, F.R.C.S.; Surgeon to West London Hospital; Surgeon to Throat and Ear Department, Middlesex Hospital; author of 'The Surgery of the Chest,' 'John Hunter,' 'Ambroise Paré and his Times,' Experiments on Animals,' 'Memoirs and Letters of Sir James Paget.' (S. P.)

PALGRAVE, Robert Harry Inglis, F.R.S.; editor of 'Economist,' 1877-83; author of 'The Local Taxation of Great Britain and Ireland,' 'Notes on Banking in Great Britain and Ireland, Sweden, Denmark, and Hamburg,' 'An Analysis of the Transactions of the Bank of England for the years 1844-72,' 'Bank Rate in England, France, and Germany, 1844-1878'; editor of 'Dictionary of Political Economy.' (R. H. I. P.)

PAPILLON, Rev. Thomas Leslie, M.A.; late Fellow of Merton Coll. and of New Coll., Oxford; author of 'A Manual of Comparative Philology'; editor Dean Bradley's 'Aids to Writing Latin Prose,' etc. (T. L. P.)

PARKIN, George Robert, LL.D., C.M.G.; Principal of Upper Canada College, Toronto, Canada; author of 'Imperial Federation,' 'Round the Empire,' 'The Great Dominion,' 'Life and Letters of Edward Thring.' (G. R. P.)

PARSONS, William Barclay; Chief Engineer of the Underground Railway, New York City. (W. B. P.)

PASCO, Hon. Samuel; Member of the Nicaragua Canal Commission, United States Senator from the State of Florida, 1887-99. (S. Pa.)

PATON, Diarmid Noël, M.D., B.Sc., F.R.C.P. Ed.; Superintendent of Research Laboratory of Royal College of Physicians, Edinburgh, 1889; Lecturer on Physiology, School of Medicine of Royal Colleges, Edinburgh, 1886; Biological Fellow of Edinburgh University, 1884; Member of the Royal Commission on Salmon Fisheries; author of many papers on Physiological subjects. (D. N. P.)

PAUL, Alfred Wallis, C.I.E., B.A.; late Scholar of Wadham College, Oxford; Indian Civil Service (retired): Political Officer Sikkim Expedition; British Commissioner under Anglo-Chinese Convention of 1890; Deputy Commissioner of Darjeeling. (A. W. P.)

PEACH, Capt. E., Indian Staff Corps; author of 'Tactics—Savage Warfare,' etc. (E. P.)

PEARSON, Karl, M.A., LL.B., F.R.S.; Professor of Applied Mathematics and Mechanics, University College, London; Gresham Professor of Geometry, 1892-94; Darwin Medal Royal Society, 1898; author of 'Grammar of Science,' 'Enlarged Grammar of Science,' 'The Chances of Death, and other Studies in Evolution,' 'The Ethic of Freethought,' 'Die Fronica, a History of the Mediæval Portraits of Christ,' etc. (K. P.)

PELSENUR, PAUL, D.Sc. (Brussels); cor. member of the Royal Belgian Academy of Science; member of the Belgian Committee of Mariculture; Professor in the Normal School, Ghent; lecturer, Brussels University; author of 'Introduction à l'Étude des Mollusques,' 'Report on the Pteropoda,' 'The Anatomy of the Deep-Sea Mollusca,' etc. (P. P.)

PEMBREY, Marcus Seymour, M.A., M.D.; Lecturer in Physiology, Guy's Hospital Medical School. (M. S. P.)

PENDEREL-BRODHURST, James George Joseph; editor of 'Land,' 1881-83, assistant editor of 'St James's Gazette,' 1888-93, editor of 'St James's Budget,' 1889-98; author of 'The Life and Times of King Edward VII.,' part author of 'The Royal River and Abbeys and Churches of England and Wales.' (J. G. J. P.-B.)

PENNELL, Joseph, artist; author of 'A Canterbury Pilgrimage,' 'An Italian Pilgrimage,' 'Two Pilgrims' Progress,' 'Our Sentimental Journey through France and Italy,' 'Pen Drawing and Pen Draughtsmen,' 'Our Journey to the Hebrides,' 'The Stream of Pleasure,' 'The Jew at Home,' 'Play in Provence, 'Modern Illustration,' 'The Illustration of Books, 'The Work of Charles Keene,' 'Lithography and Lithographers.' (J. P*.)

PERSHING, James H., A.B.; Lecturer on International Law in the University of Denver, and Professor of Medical Jurisprudence in Gross Medical College, Denver. (J. H. Pe.)

PETERSON, Frederick, Ph.D., M.D.; President New York Neurological Society and President of the Board of Managers of Craig Colony for Epileptics, Chief of Clinic, Department of Neurology, Columbia University. (F. P*.)

PETRIE, William Matthew Flinders, D.C.L., Litt.D., LL.D., Ph.D.; Edwards Professor of Egyptology, University Coll. London; surveying British remains, 1875-80; excavating in Egypt, 1880-1901; author of 'Pyramid,' 'Weights and Measures,' in Ninth Edition of 'Ency. Brit.,' 'Stonehenge,' 'Pyramids and Temples of Gizeh,' 'Season in Egypt,' 'Racial Portraits,' 'Historical Scarabs,' 'Ten Years' Digging,' 'History of Egypt,' 'Tel el Amarna,' 'Egyptian Tales,' 'Decorative Art,' 'Six Temples at Thebes,' 'Religion and Conscience in Ancient Egypt,' 'Syria and Egypt,' 'Royal Tombs of the First Dynasty,' 'Royal Tombs of the Earliest Dynasties,' etc. (W. M. F. P.)

PFEIL, Count Joachim Von, one of the founders of German East Africa; sometime resident in Bismarck Archipelago; author of 'The Founding of the Boer States,' 'Studies and Observations in the South Seas,' etc. (J. von P.)

PHELAN, Hon. James Duval; Mayor of San Francisco, 1896-1901. (J. D. P.)

PHILLIMORE, George Grenville, M.A., B.C.L.; Barrister-at-Law of the Middle Temple. (G. G. P*.)

PHILLIMORE, Sir Walter George Frank, Bt., D.C.L., LL.D.; Judge of the King's Bench Div.; author of 'Book of Church Law,' 2nd ed. of 'Phillimore's Ecclesiastical Law, 3rd ed. of vol. iv. of 'Phillimore's International Law.' (W. G. F. P.)

PHILLIPS, R. W., M.A., D.Sc., F.L.S.; Professor of Botany in the University Coll. of North Wales; author of 'Memoirs on the Physiology of Plants,' 'Morphology of the Algæ,' etc. (R. W. P.)

PHILLPOTTS, Col. A. H. C., R.A. (A. H. C. P.)

PINCHOT, Gifford, B.A.; Forester of the U.S. Department of Agriculture, Special Lecturer in the Forest School, Yale Univ.; author of 'The White Pine.' (G. P.)

PITMAN, Charles Murray; stroke of the Oxford Eight, 1893-95. Author of articles on Rowing. (C. M. P.)

PITT, Walter, M.I.C.E., M.I.M.E.; Member of the Committee of International Maritime Conference (London), etc. (W. P*.)

POLLEN, John Hungerford, M.A.; Examiner for Art, South Kensington; Fellow of Merton Coll., Oxford; Professor of Fine Arts in Catholic University of Dublin; Cantor Lecturer, Society of Arts, 1885; author of 'Carving,' 'Filigree,' 'Furniture,' in Ninth Edition of 'Ency. Brit.,' 'Ancient and Modern Furniture and Woodwork,' 'Ancient and Modern Gold- and Silver-smiths' Work, 'The Trojan Column,' etc. (J. H. P.)

POLLOCK, Sir Frederick, Bt., LL.D., D.C.L.; Corpus Professor of Jurisprudence, Oxford; editor of the Law Reports from 1895; Fellow Trin. Coll., Camb. 1868; Corresponding member Institute of France, 1894; Professor of Jurisprudence, University Coll., London, 1882-83; Professor of Common Law in the Inns of Court, 1884-90; member Royal Labour Commission, 1891-94; author of 'Sword,' 'Tort' in Ninth Edition of 'Ency. Brit.,' 'Principles of Contract,' 'The Law of Torts,' 'Digest of the Law of Partnership,' 'The Land Laws,' 'History of English Law,' 'Spinoza, Life and Philosophy,' 'A First Book of Jurisprudence,' 'The Etchingham Letters,' 1899 (with E. Fuller Maitland). (F. Po.)

POORE, George Vivian, M.D.; Professor of Medicine and Clinical Medicine, University College, London; medical attendant to late Prince Leopold, Duke of Albany, 1870-71; and Prince of Wales, 1872; received Dannebrog for professional services to the Princess Thyra, Duchess of Cumberland, 1872; Physician University Coll. Hospital, 1876; Secretary-General of Sanitary Congress, 1891, etc.; author of 'Essays on Rural Hygiene,' 'A Treatise on Medical Jurisprudence.' (G. V. P.)

PORTER, W. Haldane, B.A.; Barrister, Middle Temple; Chancellor's English Essay, Oxford, 1893. (W. H. Po.)

POST, George B.; Architect; Member of the Am. Society of Civil Engineers. (G. B. P.)

POTTER, Rt. Rev. Henry Codman, D.D., LL.D.; Bishop of the Diocese of New York; author of 'The Church and Her Children,' 'The Scholar and the State,' etc. (H. C. P.)

POULTON, Edward Bagnall, M.A., D.Sc.; Hon. LL.D. Princeton, F.R.S.; Hope Professor of Zoology, Oxford; Fellow of Jesus Coll., Oxford; Member of Council of Royal Society, 1897-99; Member of Hebdomadal Council of Oxford; Demonstrator in Anatomical Department of University Museum, 1877-79; Lecturer in Natural Science, and tutor of Keble College, Oxford, 1880-89: Lecturer in Natural Science, Jesus College, Oxford, 1880-88; author of 'The Colours of Animals,' 'Charles Darwin and the Theory of Natural Selection,' many memoirs on Zoological Subjects in the Proceedings and Transactions of the Royal, Linnæan, Zoological, Entomological, and other learned Societies. (E. B. P.)

POWELL, F. York, M.A.; Regius Professor of Modern History, Oxford; Student of Ch. Ch., Oxford; author of 'Icelandic Language,' etc., in Ninth Edition of 'Ency. Brit.,' 'Alfred the Great and William the Conqueror,' 'History of England to 1509.' (F. Y. P.)

POYNTING, John Henry, D.Sc., F.R.S.; late Fellow of Trin. Coll., Camb.; Professor of Physics and Dean of the Faculty of Science, Birmingham University; author of the Adams Prize Essay (1891) on the 'Mean Density of the Earth,' 'A Text-Book of Physics' (with Professor J. J. Thomson), and various physical papers. (J. H. P*.)

PRINCE, Hon. L. Bradford, LL.D.; President of the Bureau of Immigration of the territory of New Mexico, Santa Fé, New Mexico; ex-Governor of the State of New Mexico; President of the New Mex. Hist. Soc.; author of 'New Mexico' in Ninth Edition of 'Ency. Brit.' (L. B. Pr.)

PROCTER, Hon. John Robert, President U.S. Civil Service Commission, Washington, D.C.; Geologist State of Kentucky, 1880-1893; author of 'Kentucky' in Ninth Edition of 'Ency. Brit.' (J. R. P.)

PROUT, Major Henry Gosler, editor of 'The Railroad Gazette,' New York; sometime Governor of the Provinces of the Equator, Africa, and Colonel of Engineers, Army of the Khedive. (H. G. P.)

PROWSE, Daniel Wodley, K.C., LL.D., D.C.L.; retired Judge Central District Court of Newfoundland; appointed Judge Central District Court, 1869; Commissioner for the Consolidation of Colonial laws; Chairman Board of Health, 1893-96; author of 'History of Newfoundland,' 'Manual for Magistrates in Newfoundland,' numerous pamphlets and newspaper articles. (D. W. P.)

PULLAN, Rev. Leighton, Fellow of St John's Coll., Oxford; author of 'History of

Early Christianity,' 'Lectures on Religion,' etc. (L. P.)

PURSER, F., M.A., M.R.I.A.; Fellow of Trinity Coll., Dublin, and Professor of Natural Philosophy, University of Dublin. (F. Pu.)

PURSER, J., M.A., D.Sc., LL.D., M.R.I.A.; emeritus Professor of Mathematics, Queen's Coll., Belfast. (J. Pu.)

PUTNAM, George Haven, A.M., Litt.D.; Head of the publishing House of G. P. Putnam's Sons, N.Y.; led in reorganizing, 1887, the American Copyright League, and was its secretary during the movement for International Copyright which resulted in the Copyright Bill of 1891; Received Cross of the Legion of Honour from France, 1891; author of 'Question of Copyright,' 'Books and their Makers in the Middle Ages,' etc. (G. H. P*.)

PUTNAM, Hon. Herbert, Librarian of Congress, Washington, D.C. (H. P.)

PYLE, Joseph Gilpin; editor of the 'Post-Intelligencer,' Seattle, Washington; author of 'Minnesota' in Ninth Edition of 'Ency. Brit.' (J. G. P.)

Q

QUILLER-COUCH, Arthur Thomas, B.A.; Lecturer Classics Trin. Coll., Oxford, 1886-87; author of 'Dead Man's Rock,' 'Troy Town,' 'The Splendid Spur,' 'Noughts and Crosses,' 'The Delectable Duchy,' 'Adventures in Criticism,' 'The Oxford Book of English Verse,' 'The Laird's Luck,' finished R. L. Stevenson's uncompleted novel 'St Ives,' etc. (A. T. Q.-C.)

R

RADAU, R.; Membre de l'Académie des Sciences et du Bureau des Longitudes, Paris; writer on Astronomy, etc., part author of 'Géologic d'Ethiopie,' etc. (R. Ra.)

RAIKES, His Honour Judge Francis William, LL.D., K.C.; Judge of County Court (Hull); three years in Merchant Service, then passed into Royal Navy first; called to the Bar, 1873; author of 'The New Practice' (with Mr Justice Kennedy); 'Jurisdiction and Practice of County Courts in Admiralty' (with Mr Kilburn), 'Both to Blame,' paper read at Brussels International Law Conference, 1895; and various papers on 'Maritime Law,' translations and editions of the 'Maritime Codes of Europe,' etc. (F. W. Ra.)

RAMBAUT, Arthur Alcock, M.A. (Dub. and Oxon.); D.Sc., F.R.S., F.R.A.S.; Radcliffe Observer, Oxford; Assistant Astronomer Trinity College, Dublin, at Dunsink, 1882-92; Andrews Professor of Astronomy in the University of Dublin and Royal Astronomer of Ireland, 1892-97; author of various memoirs and papers on Astronomical subjects. (A. A. R*.)

RASHDALL, Rev. Hastings, M.A., D.C.L.; Fellow and Tutor of New College, Oxford; Lecturer in St David's College, Lampeter, 1883; Tutor in the Univ. of Durham, 1884-88; Fellow and Lecturer of Hertford Coll., Oxford, 1888-95; Chaplain and Theological Tutor of Balliol Coll., 1894-95; author of 'The Universities of Europe in the Middle Ages,' 'Doctrine and Development' (with R. S. Rait), 'New College.' (H. Rl.)

RÁTH, Dr Zoltán; Professor at the Royal Academy of Law, Kassa, Hungary; late of the Royal Hungarian Statistical Bureau; author of 'Evitzedünk egyenesadó-reform-jairól.' (Z. R.)

RAVENSTEIN, Ernest George; War Office, Topographical (now Intelligence) Department, 1855-75; Council Royal Statistical Society, 1877-92; President, Section E, Brit. Assoc., 1891; Professor of Geography, Bedford Coll., 1882-83; author of 'The Russians on the Amur,' 'Geographie und Statistik des Britischen Reiches,' 'Vasco da Gama's First Voyage,' 'Map, Equatorial Africa,' 'Systematic Atlas.' (E. G. R.)

RAYLEIGH, Lord, 3rd Baron, D.C.L. (Hon. Oxon.), LL.D., D.Sc. (Camb. and Dublin), F.R.S.; Professor of Natural Philosophy, Royal Institution; Scientific Adviser to Trinity House; Cavendish Professor of Experimental Physics, Cambridge, 1879-84; Secretary of Royal Society, 1887-96; author of 'Optics,' 'Wave Theory,' in Ninth Edition of 'Ency. Brit.,' 'Theory of Sound,' numerous scientific papers. (R.)

REDWOOD, Boverton, F.R.S.Ed., A.M.I.C.E., M.I.M.E.; Fellow of Inst. of Chem.; V.P. and Mem. of Council and Publication Com., Soc. Chem. Ind.; Fellow of Chem. Geol. and R. Geog. Soc.; D.Sc. Ohio Normal University; Mem. of Am. Chem. Soc., and Am. Philosophical Soc. (honorary); Hon. Corres. Mem. Imperial Russian Technical Soc.; Chevalier of the Order of Leopold; Consulting Chemist, with special experience in the technology of petroleum; Adviser on Petroleum to the Home Office; Consulting Adviser to the Corporation of London under the Petroleum Acts; Chemical Adviser to the Oil Trade Section of the London Chamber of Commerce; member of several juries at International Inventions and Health Exhibitions, president of International Jury for lighting appliances and materials at Brussels Exhibition, 1897, and member of Jury, Paris Exhibition, 1900; author of 'Cantor Lectures on Petroleum and its Products,' 'Petroleum: its Production and Use,' 'Report (with Sir Frederick Abel) on Accidents with Mineral Oil Lamps,' 'Report (with Sir Frederick Abel) on the Transport of Petroleum through the Suez Canal,' 'The Transport of Petroleum in Bulk,' articles on the Petroleum Industry, and Lamps in Chemical Technology, 'A Treatise on Petroleum,' 'The Detection and Estimation of Inflammable Gases and Vapours in the Air' (with Professor Clowes), 'Handbook on Petroleum' (with Capt. J. H. Thomson). (B. R.)

REEVES, Hon. William Pember, Agent-General for New Zealand; Member of Senate of University of London; edited the 'Canterbury Times,' and the 'Lyttelton Times'; Member of N.Z. Parliament, 1887-96; Minister of Education, Labour, and Justice, 1891-96; resigned position to become Agent-General for colony; author of 'The Long White Cloud, a History of New Zealand,' 'An Introduction to the History of Communism and Socialism,' also volume of New Zealand verse. (W. P. R.)

REICH, Emil, Dr. Juris, F.R.Hist.S.; author of 'History of Hungarian Literature,' 'History of Civilization,' 'Græco-Roman Institutions,' 'Historical Atlas of English History,' 'Historical Atlas of Modern History,' etc. (E. Re*.)

REID, Clement, F.R.S., F.L.S., F.G.S.; geologist on survey of England and Wales; formerly secretary and recorder to the Geological Section of British Association; author of 'Pliocene Deposits of Britain,' 'Origin of the British Flora,' many contributions to geological journals. (C. R.)

REID, Sir George, LL.D.,; President Royal Scottish Academy; author of 'Lithography,' 'Painting,' 'Turner,' in Ninth Edition of 'Ency. Brit.' (G. Re.)

REID, Hon. Whitelaw, A.M., LL.D.; editor of the New York Tribune; Ex-U.S. Minister to France; author of 'Greeley,' 'Newspapers,' in Ninth Edition of 'Ency. Brit.' (W. R.)

RENTON, A. Wood, LL.B.; Puisne Judge, Mauritius; author of 'Thurlow' in Ninth Edition of 'Ency. Brit.' (A. W. R.)

RENWICK, I. P. A., M.A., LL.B.; assistant editor of the 'Statesman's Year Book.' (I. P. A. R.)

REYNOLDS, Osborne, M.A., LL.D. Glasgow, F.R.S., M.I.C.E., Hon. Fellow Queens' Coll., Cambridge; Professor of Engineering, Owens College, Victoria University, Manchester; Fellow of Queens' College, Cambridge, 1877; President, Section G, British Association, 1887; author of upwards of sixty papers on original researches in 'Mechanics and Physics,' in the Philosophical Transactions and Proceedings of the Royal Society, etc. (O. R.)

RHODES, Hon. Bradford; editor of 'The Banker's Magazine,' New York. (B. R*.)

RHODES, James Ford, LL.D.; author of 'History of the United States from the Compromise to 1850.' (J. F. R.)

RICHARDS, Robert Hallowell, Sc.B.; Professor of Mining, Engineering, and Metallurgy, Massachusetts Institute of Technology. (R. H. R.)

RICHARDSON, Charles Francis, A.M., Ph.D.; Professor of English, Dartmouth College, N.H.; author of 'History of American Literature,' 'The Choice of Books,' etc., etc. (C. F. R.)

RICHARDSON, Professor Rufus B.; director of American School of Classical Studies, Athens. (R. B. R.)

RICHMOND, Sir William Blake, R.A., M.A., K.C.B.; Slade Professor at Oxford, 1878-83; President of Society of Miniature Painters, 1899. (W. B. Ri.)

RICKETTS, Charles, English printer, artist, and wood-engraver; one of the founders of the Vale Press; decorated 'Early Poems of John Milton,' 'The Poems of Keats,' etc. (C. Ri.)

RILEY, John Athelstan Laurie, M.A.; travelled in Persia, 1881; Turkey in Europe, 1883; Persia and Kurdistan, 1884, 1886, 1888; member of the House of Laymen of the Province of Canterbury; member London School Board, 1891-97; author of 'Athos, or the Mountain of the Monks,' various pamphlets and articles, subjects connected with education, Eastern Christians, and foreign travel. (J. A. L. R.)

RIPON, Bishop of, Rt. Rev. William Boyd Carpenter, Hon. D.D. Glasgow, Hon. D.C.L. Oxon.; Knight of the Order of the Royal Crown, Prussia; Hulsean Lecturer, Cambridge, 1878; Bampton Lecturer, Oxford, 1887; Pastoral Lecturer on Theology, Cambridge, 1895; Canon of Windsor, 1882-1884; Hon. Chaplain to the Queen, 1879-83; Chaplain-in-Ordinary, 1883-84; author of 'Commentary on Revelation,' 'Witness of Heart to Christ' (Hulsean Lectures), 'Permanent Elements of Religion' (Bampton Lectures), 'Lectures on Preaching,' 'Christian Reunion,' 'The Great Charter of Christ,' 'A Popular History of the Church of England.' (W. B. R.)

RISTORI, E. J., Assoc.M.Inst.C.E. (E. J. R.)

ROBERTS, W.; author of 'Christies',' 'The Book-hunter in London,' etc. (W. R*.)

ROBERTS-AUSTEN, Sir William Chandler, K.C.B., D.C.L. (Durham), F.R.S.; Chevalier de la Légion d'Honneur; chemist and assayer to Royal Mint since 1870; Professor of Metallurgy, Royal School of Mines since 1880; President of Iron and Steel Institute; author of 'Gold,' etc., in Ninth Edition of 'Ency. Brit.,' 'An Introduction to the Study of Metallurgy.' (W. C. R.-A.)

ROBERTSON, Sir George Scott, K.C.S.I., D.C.L.; entered Indian Medical Service, 1878; British Agent in Gilgit; conducted a political mission to Chitral, 1893; besieged in Chitral, during March and April 1895; installed the present ruler of Chitral, September 1895; author of 'The Kafirs of the Hindu Kush,' 'Chitral: The Story of a Minor Siege.' (G. S. R.)

ROBERTSON, James W.; Commissioner of Agriculture and Dairying, Ottawa, Canada. (J. W. R.)

ROBERTSON, John G.; Lecturer on the English Language, University of Strasburg. (J. G. R.)

ROBINSON, A. Mary F. (Mme. Duclaux; formerly Mme. Darmesteter), author of 'Emily Brontë,' 'The End of the Middle Ages,' 'Margaret of Angoulême, Queen of Navarre,' 'Retrospect, and other Poems,' 'Life of Renan,' 'Collected Poems,' 'Marguerites du Temps Passé,' 'Froissart,' 'Grands Ecrivains d'outre Manche,' etc. (A. M. F. D.)

ROBINSON, Rev. Charles Henry, M.A.; Hon. Canon of Ripon; Lecturer in Hausa in the University of Cambridge, 1896; travelled in Armenia in order to report to Archbishop of Canterbury on the condition of Armenian Church, 1892; conducted pioneer expedition to Kano, 1893-95; author of 'Hausaland, or Fifteen Hundred Miles through the Central Soudan,' 'Specimens of Hausa Literature,' 'Grammar of the Hausa Language,' 'Dictionary of the Hausa Language,' 'Studies in the Character of Christ,' 'Nigeria, Our Latest Protectorate,' 'Human Nature a Revelation of the Divine.' (C. H. R.)

ROBINSON, Gerald Philip; President of the Society of Mezzotint Engravers; late Mezzotint Engraver to Queen Victoria, and appointed same to the King, 1901. (G. P. R.)

ROBINSON, Rev. Joseph Armitage, D.D., Ph.D.; Canon of Westminster; Norrisian Professor of Divinity, Cambridge University, 1893-99; author of 'A Collation of the Athos Codex of the Shepherd of Hermas,' 'Appendix to The Apology of Aristides,' 'The Passion of St Perpetua,' 'The Philocalia of Origen,' 'Euthaliana,' 'Unity in Christ.' (J. A. R.)

ROCKHILL, Hon. William Woodville; Head of the Bureau of American Republics; sometime First Assistant Secretary of State;

U.S Commissioner to China, etc.; author of 'Land of the Llamas.' (W. W. R.)

ROCKWELL, General Alfred P., author of 'Fire,' 'Fire Extinction,' in Ninth Edition of 'Ency. Brit.' (A. P. R.)

ROGERS, Henry Wade, LL.D.; Lecturer at Yale University; sometime President of North Western University, Evanston, Ills.; Chairman of the World's Congress on Jurisprudence and Law Reform, World's Columbian Exposition; author of 'Expert Testimony, etc. (H. W. R.)

ROLLS, Hon. C. S.; pioneer in motor-car travelling. (C. S. R.)

ROSCOE, Sir Henry Enfield, Ph.D., LL.D., D.C.L., M.D., F.R.S.; Vice-Chancellor, University of London; Emeritus Professor, Owens College, Victoria University; Member of Royal Commissions on Noxious Vapours, Technical Instruction, Scottish Universities, Secondary Education, and Exhibition of 1851; President of the British Association (Manchester, 1887); President Society of Chemical Industry, 1881; President Chemical Society, 1882; author of 'Lessons in Elementary Chemistry,' 'Treatise on Chemistry,' 'Primer of Chemistry,' 'John Dalton,' 'New View of the Genesis of the Atomic Theory of Chemistry' (with Dr Harden). (H. E. R.)

ROSEWATER, Victor, A.M., Ph.D.; managing editor of the Omaha Bee, Omaha, Nebraska; Member Omaha Public Library Bd., Am. Economic Assn., Am. Library Assn., Neb. Historical Society; author of 'Special Assessments: a Study in Municipal Finance.' (V. R.)

ROSS, H. M., B.A.; formerly exhibitioner of Lincoln Coll., Oxford; writer on engineering and scientific subjects; associate editor of the new volumes of the 'Encyclopædia Britannica.' (H. M. R.)

ROSSETTI, William Michael; Professional Assistant to Board of Inland Rev. for Estate duty on Pictures and Drawings; author of 'Canova,' 'Correggio,' 'Fiesole,' 'Ghirlandajo,' 'Lippi,' 'Murillo,' 'Perugino,' 'Reni,' 'Rosa,' 'Shelley,' 'Titian,' 'Veronese,' etc., in Ninth Edition of 'Ency. Brit.'; 'Fine Art, chiefly contemporary,' 'Lives of Famous Poets,' 'Life of Keats,' 'Dante G. Rossetti as Designer and Writer,' 'Memoir of Dante G. Rossetti'; editor of 'The Germ,' 1850, of 'Shelley's Poems,' of 'Wm. Blake's Poems,' of 'Poems by Dante and Christina Rossetti,' of 'Ruskin,' 'Rossetti,' 'Præraphaelitism,' of 'Præraphaelite Diaries and Letters,' etc. (W. M. R.)

ROWLAND, Henry Augustus, Ph.D., LL.D., F.R.S., the late; Professor of Physics, Johns Hopkins University; recipient of Rumford, Draper, and Matteucci medals for scientific discoveries; Hon. Member Inst. of France, etc.; author of 'Screw' in Ninth Edition of 'Ency. Brit.' (H. A. R.)

RUFFINI, Arthur; Royal Naval Academy, Leghorn. (A. R*.)

RUGE, Dr Sophus; Professor of Geography, University of Dresden; author of 'Map' in Ninth Edition of 'Ency. Brit.,' 'Geschichte des Zeitalters der Entdeckungen,' 'Abhandlungen und Vorträge zur Geschichte der Erdkunde,' 'Christopher Columbus,' etc. (S. R.)

RUSSELL, Hon. Bertrand Arthur William, M.A.; Fellow of Trinity College, Cambridge; author of 'German Social Democracy,' 'Essay on the Foundations of Geometry,' 'Philosophy of Leibnitz.' (B. A. W. R.)

RUSSELL, George William Erskine, LL.D.; Parliamentary Secretary to the Local Government Board, 1883-85; Under-Secretary of State for India, 1892-94; for the Home Department, 1894-95; author of 'A Monograph on the Rt. Hon. W. E. Gladstone,' 'Letters of Matthew Arnold,' 'Collections and Recollections, 1898.' (G. W. E. R.)

S

SACHS, Edwin O., A.M.I.C.E.; Chairman of British Fire Prevention Committee; Fellow of the Royal Statistical Society; Associate of the Institution of Naval Architects, etc.; in 1898 he applied electrical power to the working of the stage at Drury Lane; in 1899 he was appointed technical adviser to the Royal Opera, Covent Garden; founded in 1897 the British Fire Prevention Committee, and in 1899 the first independent fire-testing station established in Europe; author of 'Modern Opera Houses and Theatres,' 'Stage Construction,' 'Fires and Public Entertainments.' (E. O. S.)

ST. JOHN, Molyneux; Ottawa, Canada. (M. St. J.)

SAMPSON, Rear-Admiral William Thomas, LL.D.; in command of U.S. North Atlantic Squadron, battle of Santiago; late Commandant U.S. Navy Yard, Boston, Mass.; Member of International Prime Meridian and Time Conference; U.S. Delegate to International Maritime Conference; Chief of U.S. Bureau of Ordnance, 1893-97. (W. T. S.)

SAUNDERS, George, B.A.; Berlin Correspondent of 'The Times'; late Berlin Correspondent of the 'Morning Post,' etc. (G. Su.)

SAYCE, Rev. Archibald Henry, M.A., LL.D., D.D.; Fellow of Queen's College, Oxford; Professor of Assyriology, Oxford; Member of O.T. Revision Company, 1874-84; Deputy Professor of Comparative Philology, Oxford, 1876-90; Hibbert Lect., 1887; Gifford Lect., 1900-1; author of 'Babylonia,' 'Cyrus,' 'Darius,' 'Grammar,' 'Humboldt,' 'Inscriptions' (Cuneiform and Semitic), 'Lydia,' in Ninth Edition of 'Ency. Brit.,' 'Assyrian Grammar for Comparative Purposes,' 'Translations in Records of the Past,' 1st series; 'Lectures on the Assyrian Language and Syllabary,' 'Babylonian Literature,' 'Introduction to the Science of Language,' 'The Monuments of the Hittites,' 'Fresh Light from the Monuments,' 'The Ancient Empires of the East,' 'Hibbert Lectures on Babylonian Religion,' 'The Hittites,' 'The Races of the Old Testament,' 'The Higher Criticism and the Verdict of the Monuments,' 'The Egypt of the Hebrews and Herodotus,' 'Early History of the Hebrews.' (A. H. S.)

SCHIDROWITZ, Philip, Ph.D. Berne; F.C.S. (Great Britain and Germany); Member of Societies of Chemical Industry and of Public Analysts; author (joint) of various papers on Acids, Wine, Analyses, etc. (P. S.)

SCHILLER, F. C. S., M.A.; Fellow and Tutor of C.C.C. Oxford. (F. C. S. S.)

SCHLICH, William, Ph.D., C.I.E., F.R.S.; Professor of Forestry, Cooper's Hill Coll.; appointed to the Indian Forest Department, 1866; Conservator of Forests, 1871; Inspector-General of Forests to the Government of India, 1881; organized the first School of Forestry in England at Cooper's Hill, 1885; author of 'A Manual of Forestry.' (W. Sch.)

SCHLOSS, David, M.A.; author of works on labour questions. (D. Sch.)

SCHOULER, James, LL.D.; Professor School of Law, Boston University, and Lecturer at Johns Hopkins University, Baltimore; author of 'History of the United States under the Constitution' and numerous works on Jurisprudence. (J. Sch.)

SCHRADER, Franz; Prix Gay de l'Académie des Sciences; editor of 'L'Année Cartographique,' 'Le Tour du Monde'; author of 'Aperçu de la Structure Géologique des Pyrénées,' etc. (F. Sch.)

SCHURMAN, Jacob Gould, D.Sc., LL.D.; President and sometime Professor of Philosophy, Cornell University; Chairman of the U.S. Philippine Commission, 1899; author of 'Kantian Ethics,' 'Ethics of Evolution,' 'Agnosticism and Religion,' etc. (J. G. S*.)

SCHURZ, Hon. Carl, LL.D.; Secretary of the Interior under President Hayes; author of 'Life of Henry Clay,' 'Abraham Lincoln,' 'Speeches.' (C. S.)

SCOTT, Austin, Ph.D., LL.D.; President Rutgers College and Rutgers Scientific School, New Jersey. (A. Sc.)

SCOTT, Dukinfield Henry, M.A., Ph.D., F.R.S.; Honorary Keeper Jodrell Laboratory, Royal Gardens, Kew; Assistant Professor of Botany, Univ. Coll., London, 1882-85; Royal Coll. of Science, London, 1885-92; a General Secretary of the British Association; co-operated with the late Professor W. C. Williamson in his 'Researches on Fossil Plants'; one of the editors of the 'Annals of Botany'; author of 'An Introduction to Structural Botany,' 'Studies in Fossil Botany'; author and joint-author of many botanical papers. (D. H. S.)

SCOTT, Harold Spencer; Barrister-at-Law, Lincoln's Inn. (H. S. S.)

SCOTT, Sir James George, G.C.I.E.; War Correspondent in Perak, 1875-76; Burma, 1879; Hong Kong, 1883-85; joined Burma Commission in 1886; member of Anglo-Siamese Boundary Commission, 1889-90; Superintendent Northern Shan States, 1891; Chargé d'Affaires in Bangkok, 1893-94; British Commissioner, Mekong Commission, 1894-96; British Commissioner Burma-China Boundary Commission, 1898-1900; author of 'The Burman, His Life and Notions,' 'France and Tongking,' 'Burma,' 'The Upper Burma Gazetteer.' (J. G. Sc.)

SCOTT, Hon. Sir John, M.A., D.C.L., K.C.M.G.; Deputy Judge-Advocate-General to His Majesty's Forces; Judge, afterwards Vice-President, International Court of Appeal in Egypt, 1874-82; Judge of High Court, Bombay, 1882-90; Judicial Adviser to the Khedive of Egypt, 1890-98; Vice-President International Law Association; Grand Cordon of the Medjidieh; Grand Cordon of the Osmanieh. (Jno. S.)

SCOTT, Leslie Frederic; Barrister-at-Law, Inner Temple. (L. F. S.)

SCOTT, Walter S.; foreign sub-editor of 'The Times.' (W. S. S*.)

SCRUTTON, T. E., M.A., K.C.; Barrister, Inner Temple; author of 'Law of Copyright,' etc. (T. E. S.)

SCUDDER, Horace Elisha, Litt.D., the late; editor of 'The Atlantic Monthly,' 1890-98; author of 'History of the United States,' 'Book of Fables,' 'The Life of James Russell Lowell,' etc. (H. E. S*.)

SECCOMBE, Thomas, M.A.; assistant editor, 'Dictionary of National Biography'; author of 'The Age of Johnson,' etc. etc. (T. Se.)

SEDGWICK, Adam, M.A., F.R.S.; Fellow and Tutor of Trin. Coll. Cambridge; Reader of Animal Morphology in the University. (A. Se*.)

SETON-KARR, Henry, M.A., M.P.; travelled and shot big game in Western America, British Columbia, and Norway; writer on sport and allied subjects. (H. S.-K.)

SEWARD, Albert Charles, M.A., F.R.S., F.L.S., F.R.G.S.; University Lecturer in Botany, Cambridge; Late Fellow of St John's College; Fellow and Tutor in Natural Science at Emmanuel College, Cambridge; author of 'Fossil Plants as Tests of Climate,' 'The Wealden Flora,' 'Fossil Plants for Students of Botany and Geology,' 'The Jurassic Flora,' also various Botanical papers contributed to scientific journals. (A. C. Se.)

SHADWELL, A., M.D.; Member of Council of Epidemiological Society; author of 'The London Water Supply,' 'Plague at Oporto,' 'Diphtheria at Darenth Asylum,' etc. (A. Sl.)

SHADWELL, L. L., M.A.; Barrister-at-Law, Lincoln's Inn; revising barrister, Middlesex, 1885-1902. (L. L. S.)

SHARP, David, M.A., M.B., C.M., F.R.S.; Past President of Entomological Society of London; author of 'Aquatic Carnivorous Coleoptera,' 'Insects.' (D. S*.)

SHARP, Robert Farquharson, B.A.; Assistant Librarian, British Museum; edited 'Lytton's Plays,' author of 'Dictionary of English Authors,' Wagner's drama, 'Der Ring des Nibelungen,' 'Translation of Victor Hugo's "Hernani,"' 'Makers of Music,' 'Architects of English Literature.' (R. F. S.)

SHAW, Albert, Ph.D.; editor of the American 'Monthly Review of Reviews'; author of 'Local Government in Illinois,' 'Municipal Government in Great Britain,' 'Municipal Government in Continental Europe,' etc. (A. Sw.)

SHAW, Flora L. (Lady Lugard); special correspondent for 'The Times' to South Africa and Australia, Canada and Klondike; author of articles on British colonial questions. (F. L. S.)

SHAW, Herbert, B.A.; Secretary of the Tyneside Geographical Society. (H. Sh.)

SHAW, Hon. Leslie Mortier, LL.D.; Secretary of the U.S. Treasury; formerly Governor of the State of Iowa. (L. M. S.)

SHAYLOR, J.; manager to Simpkin, Marshall, and Co. (J. Sh*.)

SHEARMAN, Montague; past President O.U.A.C.; joint-author of 'Football: Its History for Five Centuries,' author of 'Athletics and Football.' (M. S.)

SHEARMAN, Thomas Gaskell, the late; joint-author of 'Shearman and Redfield on Negligence'; author of 'Natural Taxation,' 'Crooked Taxation,' 'Distribution of Wealth,' 'The Single Tax,' etc. (T. G. S.)

SHERRINGTON, Charles S., M.A., M.D., F.R.S.; Professor of Physiology, Univ. Coll. Liverpool; Member of Council of Royal Society; Late Brown Professor of Pathology, University of London; Lecturer on Physiology, St Thomas's Hospital, London; Croonian Lecturer, Royal Society; Member of the Commission on Asiatic Cholera, 1886; Anglo-American Secretary, International Congresses of Physiology, Liége 1892, Berne 1895, Cambridge 1898, Turin 1901; author of numerous scientific papers to the Royal and other scientific societies, especially on the brain and nervous system. (C. S. S.)

SHERWELL, Arthur; author of works on Temperance questions. (A. Sh.)

SHIPLEY, Arthur Everett, M.A., F.Z.S.; Fellow, Tutor, and Lecturer at Christ's College, Cambridge; Lecturer on Advanced Morphology of the Invertebrata in the University; Demonstrator of Comparative Anatomy in the University, 1885-94; Fellow of Christ's College, 1887; Member of the Council of the Senate, 1896; author of 'Zoology of the Invertebrata'; author of 'Vine Disease,' 'Wasps,' 'Wheat Pests,' in Ninth Edition of 'Ency. Brit.'; joint-editor and part-author of the 'Cambridge Natural History'; editor of the 'Pitt Press Natural Science Manuals,' Biological Series; part-author of 'A Text-Book on Zoology,' etc. (A. E. S.)

SHORTER, Clement King; editor of 'The Sphere'; late editor of the 'Illustrated London News,' the 'Sketch,' and the 'English Illustrated Magazine'; author of 'Charlotte Brontë and Her Circle,' 'Sixty Years of Victorian Literature,' etc. etc. (C. K. S.)

SIBREE, Rev. James; for over twenty years a missionary in Madagascar; author of 'Madagascar' in the Ninth Edition of the 'Ency. Brit.,' 'Madagascar and its People,' 'The Great African Island,' 'Madagascar before the Conquest,' etc. (J. Si*.)

SIMPSON, Alexander Russell, M.D.; Professor of Midwifery and the Diseases of Women and Children, University of Edinburgh; editor of Sir James Y. Simpson's 'Lectures on Diseases of Women'; author of 'Contributions to Obstetrics and Gynæcology,' and of an 'Atlas of the Frozen Section of a Cadaver in the Genu-pectoral Position' (along with Dr Berry Hart), and many Memoirs. (A. R. S.)

SIMPSON, Rev. James Gilliland, M.A.; Principal of Leeds Clergy School; lately Rector of St Paul's, Dundee. (J. G. Si.)

SIMPSON, Lieut.-Col. W. A.; Assistant Adjutant-General U.S. War Department; Instructor U.S. Military Academy, West Point, 1883-87. (W. A. S.)

SINCLAIR, F. G., M.A., F.L.S.; author of many biological papers in scientific journals, etc. (F. G. S*.)

SKINNER, Frank C.; Principal Examiner and Chief of Classification Division, U.S. Patent Office. (F. C. S.)

SLOANE, Thomas O'Conor, Ph.D., A.M.; late Professor Nat. Sc., Seton Hall Coll., South Orange, N.J. (T. O'C. S.)

SLOANE, William Milligan, Ph.D., L.H.D., LL.D.; Professor of History, Columbia University, New York; sometime Professor of History in Princeton University, and editor of the 'Princeton Review'; Secretary to George Bancroft in Berlin, 1873-75; author of 'The French War and the Revolution,' 'Napoleon Bonaparte,' etc. (W. M. S.)

SLOCUM, William F., LL.D.; President Colorado College. (W. F. S.)

SMITH, Benjamin Eli, A.M.; assistant editor of the 'Century Dictionary'; editor of the 'Century Cyclopædia of Names,' and of the 'Century Atlas.' (B. E. S.)

SMITH, Hon. Charles Emory; Postmaster-General, Washington, D.C.; formerly United States Minister to Russia; editor of the 'Philadelphia Press' since 1880. (C. E. S.)

SMITH, George Barnett, F.R.G.S.; author of 'Mrs Browning,' in Ninth Edition of 'Ency. Brit.,' 'Shelley,' 'Life of Mr Gladstone,' 'Victor Hugo,' 'The Life of Mr Bright,' 'The Prime Ministers of Queen Victoria,' 'Life and Enterprises of Ferdinand de Lesseps,' 'The Life of Queen Victoria,' etc. (G. B. S.)

SMITH, Hubert Llewellyn, M.A.; Deputy Controller-General and Labour Commissioner, Labour Department, Board of Trade; Cobden Prize, Oxford, 1890. (H. L. S.)

SMITH, Dr Hugh M.; in charge of Division of Inquiry respecting Food Fishes, U.S. Commission of Fish and Fisheries. (H. M. S*.)

SMITH, John, C.B.; Inspector-General in Bankruptcy. (J. Sm*.)

SMYTH, Herbert Warrington, M.A., LL.M., F.G.S., F.R.G.S.; Sec. Mining Dept., Transvaal; Order of the White Elephant, Siam; Sec. Siamese Legation, 1898-1901; author of 'Journey on the Upper Mekong,' 'Five Years in Siam,' etc. (H. W. Sm.)

SNOW, Francis Huntingdon, LL.D.; Chancellor of the University of Kansas. (F. H. S.)

SNOW, Marshall Solomon, A.M.; Professor of History and Dean of the College, Washington University, St Louis, Missouri; author of 'Missouri' in Ninth Edition of 'Ency. Brit.,' 'The City Government of St Louis.' (M. S. S.)

SÖDERBERG, Dr E.; of the Central Statistical Bureau, Sweden; author of 'Samuel Johan Hedborn,' etc. (E. So.)

SOULE, R. H., B.A., M.E.; sometime General Manager of the Erie R. R. (R. H. So.)

SPIELMANN, Marion H.; editor of the 'Magazine of Art' since 1887; art critic to 'Daily Graphic' until, in 1891, art editor and part-founder of 'Black and White'; author of 'Works of G. F. Watts, R.A.,' 'Henriette Ronner,' 'History of "Punch,"' 'Millais and his Works,' 'The Unidentified Contributions of Thackeray to "Punch,"' 'John Ruskin,' 'Notes on the Wallace Collection in Hertford House,' 'The Portraits of Geoffrey Chaucer,' 'British Sculpture and Sculptors of To-day.' (M. H. S.)

SPIERS, R. Phené, F.S.A., F.R.I.B.A.; Master of the Architectural School and Surveyor of Royal Academy; Associate and Hon. Fellow of King's Coll. London; Past President of Architectural Association; Member of Council Royal Institute of British Architects; Hon. and Corres. Member of the Société Centrale des Architectes, Paris; Sociedad de los Arquitectos, Madrid; edited 'Pugin's Normandy,' 'Fergusson's History of Architecture'; author of 'Architectural Drawing,' 'Architectural Essays on Pierrefonds,' 'Domed Churches in Perigord,' 'Mosqueat Damascus,' etc. (R. P. S.)

SPRING-RICE, Stephen Edward, C.B.; Principal Clerk H.M. Treasury; Auditor of the Civil List; private secretary to successive Financial Secretaries to the Treasury, 1881-1888, and to Chancellor of the Exchequer, 1886. (S. E. S.-R.)

SQUIRE, William Barclay, M.A., F.S.A., F.R.G.S.; Assist. Brit. Museum; Hon. Sec. Purcell Soc.; Joint Hon. Sec. Eng. Com. International Music Society; late musical critic of 'Westminster Gazette,' 'Saturday Review,' and 'Globe' (London); author of various articles on music; and editor of 'Byrd's Masses,' 'The Fitzwilliam Virginal Book,' etc. (W. B. S*.)

STANTON, Rev. Vincent Henry, D.D., M.A.; Ely Professor of Divinity, Cambridge, and Canon of Ely; Hulsean Lecturer, 1879; author of 'The Jewish and the Christian Messiah,' 'The Place of Authority in Matters of Religious Belief.' (V. H. S.)

STATHAM, H. H.; editor of 'The Builder'; author of 'Architecture for General Readers,' 'Architecture among the Poets.' (H. H. S.)

STEBBING, Rev. Thomas Roscoe Rede, M.A., F.R.S., F.L.S., F.Z.S.; Fellow of King's College, London; Fellow of Worcester Coll. Oxford; prepared Report on the Amphipoda of the 'Challenger' Expedition; Chairman of Conference of Delegates, corresponding societies of British Association, 1899; author of 'Translation of Longinus On the Sublime,' 'Essays on Darwinism,' '"Challenger" Reports,' 'Zoology,' 'A History of Crustacea,' etc. (T. R. R. S.)

STEDMAN, Edmund Clarence, L.H.D., LL.D.; poet and critic; author of 'Poems,' 'Victorian Poets,' 'Poets of America,' 'The Nature and Elements of Poetry'; editor of 'Library of American Literature,' 'Victorian Anthology,' etc. (E. C. S.)

STEED, H. WICKHAM; Correspondent of 'The Times' at Rome. (H. W. S.)

STEPHEN, Sir Herbert, Bart., LL.M.; Clerk of Assize for the Northern Circuit; author of 'The Law Relating to Malicious Prosecutions,' 'Prisoners on Oath,' etc. (H. S*.)

STEPHEN, Leslie, Litt.D., M.A.; Hon. Fellow of Trin. Hall, Camb.; President of Ethical Society; formerly Fellow and Assistant Tutor, Trin. Hall Coll., and Clark Lecturer in English Literature; editor of Cornhill Magazine, 1871-82; Dictionary of National Biography, 1882-91; author of 'Hours in a Library,' 'History of English Thought in the Eighteenth Century,' 'Essays on Freethinking and Plain Speaking,' 'The Science of Ethics,' 'Life of Henry Fawcett,' 'An Agnostic's Apology,' 'Life of Sir James Fitz-James Stephen,' 'Studies of a Biographer,' 'The English Utilitarians'; edited 'Letters of John Richard Green.' (L. S.)

STEPHENS, F. G. one of the Pre-Raphaelite Brotherhood; late art critic of the 'Athenæum'; author of 'Landseer' in Ninth Edition of 'Ency. Brit.,' 'Catalogue of Satires' (Brit. Mus.), 'Artists at Home,' 'George Cruikshank,' 'Memorials of W. Mulready,' 'French and Flemish Pictures,' 'Sir E. Landseer,' 'T. C. Hook, R.A.,' etc. (F. G. S.)

STERLAND, Miss M. B.; writer on Ecclesiastical History. (M. B. S.)

STERLING, Maj.-Gen. John B.; Egypt, 1882; Sudan and Cyprus, 1885. (J. B. S.)

STEWART, John Alexander, M.A., LL.D.; Tutor of Christ Church; White's Professor of Moral Philosophy, Oxford; author of 'The English MSS. of the Nicomachean Ethics,' 'Notes on the Nicomachean Ethics.' (J. A. St.)

STOCK, Eugene; Editorial Secretary of the Church Missionary Society. (E. St.)

STOCKMAN, Ralph, M.D., F.R.C.P.Ed., F.R.S.Ed.; Professor of Materia Medica and Therapeutics, University of Glasgow; assistant in the University of Edinburgh for six years, and afterwards Lecturer on Materia Medica in the School of Medicine. (R. S*.)

STRANGE, Edward Fairbrother; Assistant Keeper, National Art Library; Assistant, South Kensington Museum, 1889; National Art Library, 1891; author of 'Alphabets: a Handbook of Lettering,' 'Japanese Illustration,' 'Worcester, the Cathedral and City,' and numerous essays on art subjects. (E. F. S.)

STREATFIELD, R. A., B.A.; author of 'Masters of Italian Music,' 'The Opera,' etc. (R. A. S.)

STURT, H.; Queen's College, Oxford. (H. St.)

SUPLEE, Henry Harrison, B.Sc.; Member of the American Society of Mechanical Engineers; Member of the Franklin Institute; Membre du Société des Ingénieurs Civils de France; Mitglied des Vereines Deutscher Ingenieure; associate-editor of 'Engineering Magazine,' New York and London; author of the English translation of Reuleaux's 'Konstrukteur,' and other works. (H. H. S*.)

SWINBURNE, Algernon Charles; author of 'Beaumont and Fletcher,' 'Congreve,' 'Keats,' 'Landor,' 'Marlowe,' 'Mary' (of Scotland), 'Tourneur,' 'John Webster,' in Ninth Edition of 'Ency. Brit., 'The Queen-Mother, and Rosamond,' 'Atalanta in Calydon,' 'Chastelard,' 'Poems and Ballads,' 'William Blake,' 'Songs before Sunrise,' 'Bothwell,' 'Songs of Two Nations,' 'George Chapman,' 'Poems and Ballads' (2nd series), 'A Study of Shakespeare,' 'Mary Stuart,' 'Tristram of Lyonesse, and other Poems,' 'Miscellanies,' 'A Study of Victor Hugo,' 'Locrine,' 'Poems and Ballads' (3rd series), 'Study of Ben Jonson,' 'Studies in Prose and Poetry,' 'Rosamund, Queen of the Lombards,' etc. (A. C. S.)

SYMONS, Arthur; author of 'An Introduction to the Study of Browning,' 'Days and Nights,' 'Silhouettes,' 'London Nights,' 'Studies in Two Literatures,' 'The Symbolist Movement in Literature,' 'Images of Good and Evil,' 'Collected Poems.' (A. Sy.)

SYMONS, H.; British Museum. (H. Sy.)

T

TAIT, Peter Guthrie, M.A., D.Sc., the late; Professor of Natural Philosophy, Edin.; Sec. Royal Soc., Edin.; Hon. Fellow St Peter's Coll., Cambridge; Professor of Mathematics, Queen's Coll., Belfast, 1854; author of 'Light,' 'Sir W. Rowan Hamilton,' etc., in Ninth Edition of 'Ency. Brit.,' 'Dynamics of a Particle,' 'Quaternions,' 'Thermo-Dynamics,' 'Heat,' 'Light,' etc. (P. G. T.)

TANSLEY, A. G., M.A., F.L.S.; Asst. Professor of Botany, University Coll., London; author of 'Memoirs on the Anatomy of Plants'; editor of 'The New Phytologist,' etc. (A. G. T.)

TAUSSIG, Frank William, Ph.D., LL.D.; Professor of Political Economy, Harvard University, and editor of the 'Quarterly Journal of Economics'; author of 'Tariff History of the United States,' 'Wages and Labour,' etc. (F. W. T.)

TAYLOR, Charles, M.A., D.D., Hon. LL.D. (Harvard); Master of St John's Coll., Cambridge; author of 'Geometrical Conics,' 'The Gospel in the Law,' 'The Teaching of the Twelve Apostles,' etc. (C. T*.)

TAYLOR, Hon. Hannis, LL.D.; U.S. Minister to Spain, 1893-97; author of 'The Origin and Growth of the English Constitution.' (H. T*.)

TCHERTKOFF, V.; author of 'Christian Martyrdom in Russia'; agent for Count Tolstoy in England. (V. T.)

TEDDER, Henry Richard, F.S.A.; Secretary and Librarian of the Athenæum Club; librarian to Lord Acton, 1873-74; one of the organisers and joint-sec. of 1st International Conference of Librarians, 1877; joint hon. sec. of Library Association, 1878-80; hon. treas. of the same, 1889-97, and 1898-1901; President, 1897-98; treas. and sec. Metropolitan Free Libraries' Committee, 1878-80; hon. treas. second International Conference of Librarians, 1897; joint-editor of first three volumes of Transactions of

Library Association, and of Reports of 1st and 2nd International Library Conference; author of 'Libraries,' etc., in Ninth Edition of 'Ency. Brit.,' and of many papers in publications of Library Association, some printed separately, articles in reviews, etc. (H. R. T.)

TELBIN, William; English scenic artist; author of 'Scenery,' 'Act Drops,' etc., in 'Magazine of Art,' etc. (W. Te.)

TEMPLE, Lieut.-Col. Sir Richard Carnac, Bt., C.I.E.; Knight of Grace; Chief Commissioner, Andaman and Nicobar Islands, and Superintendent, Penal Settlement at Port Blair; served Afghan Campaign, 1878-79; Burmah War, 1887-89; Cantonment Magistrate, Panjab; Assistant Commissioner, Burmah, and Cantonment Magistrate, Mandalay, 1887; Deputy-Commissioner, 1888; to special duty with Government of India, 1890; Official President, Rangoon Municipality, and Port-Commissioner, Rangoon, 1891; has been member of the Council R. Asiatic Soc.; Asiatic Soc., Beng.; Cor. Member American Philosophical Socy.; Smithsonian Institute; Numismatic Socy. of Philadelphia; edited 'Fallon's Dict. of Hindustani Proverbs,' 'Burnell's Devil-Worship of the Tuluvas'; has been editor and proprietor of the 'Indian Antiquary,' since 1884; founded and edited the 'Panjab (Indian) Notes and Queries,' 1883-87. (R. C. T.)

THAYER, William Roscoe, A.M.; editor of 'The Harvard Graduates' Magazine'; author of 'The Dawn of Italian Independence,' 'Poems New and Old,' 'Throne Makers,' etc. (W. R. T.)

THEOBALD, F. V., M.A.; Foreign Member of Association of Economic Entomologists, U.S.; Zoologist to the South-Eastern Agricultural College; Lecturer in Economic Entomology to the Horticultural College, Swanley; author of 'A Text-book of Agricultural Zoology,' 'The Parasitic Diseases of Poultry,' 'British Flies,' 'Insect Life,' etc. (F. V. T.)

THOMPSON, Sir Edward Maunde, K.C.B., D.C.L., LL.D., V.P.S.A.; corresponding member of the Institute of France and of the Royal Prussian Academy of Sciences; Director and Principal Librarian, Brit. Museum; Assis. Brit. Mus., 1861; Keeper of the MSS. and Egerton Librarian, 1878; Sandars Reader in Bibliography, Cambridge, 1895-96; editor of 'Chronicon Angliae'; author of 'Miniature,' 'Paleography,' etc., in Ninth Edition of 'Ency. Brit.,' 'Letters of Humphrey Prideaux,' 'Correspondence of the Family of Hatton,' 'Chronicon Adae de Usk, 1377-1404,' 'Diary of Richard Cocks in Japan, 1615-22,' 'Chronicon Galfridi le Baker de Swynebroke, 1303-1356,' 'Adae Murimuth Continuatio Chronicorum, 1303-1347,' 'Robertus de Avesbury de gestis mirabilibus Regis Edwardi Tertii': joint-editor of publications of the Palæographical Society, and of the Facsimile of the Laurentian Sophocles, 'Handbook of Greek and Latin Palæography.' (E. M. T.)

THOMPSON, Sir Henry, Bt., F.R.C.S., M.B., London; Surgeon Extraordinary to King of the Belgians; Com. Order of Leopold; Consulting Surgeon to University Coll. Hospital, London, and emeritus Professor of Clinical Surgery; surgeon to University Coll. Hospital, 1863; Professor of Pathology and Surgery, Royal College of Surgeons, 1884; President of the Cremation Society of England; author of 'Practical Lithotrity and Lithotomy,' 'Cremation, or Treatment of the Body after Death,' 'Modern Cremation,' 'Charley Kingston's Aunt,' 'All But,' 'On Food and Feeding,' 'Diet in Relation to Age and Activity,' etc. etc. (H. Th.)

THOMSON, Basil H.; Governor of Dartmouth Convict Prison; late of the Colonial Service; acted as Prime Minister of Tonga, etc.; author of 'Diversions of a Prime Minister,' 'South Sea Yarns,' etc. (B. H. T.)

THOMSON, David Croal; editor of 'The Art Journal'; author of 'The Life and Work of Thomas Bewick,' 'The Life and Work of H. K. Browne ("Phiz"),' 'The Barbizon School of Painters,' 'Corot,' 'Luke Fildes, R.A.,' 'The Tate Gallery,' 'Fifty Years of Art,' 'The Paris Exhibition, 1900.' (D. C. T.)

THOMSON, Prof. Elihu; Electrician for the General Electric Company; inventor of electric welding and other important electrical appliances. (E. T.)

THOMSON, John Arthur, M.A.; formerly Lecturer on Zoology and Biology, School of Medicine, Edinburgh; Regius Professor of Natural History, Aberdeen University; part-author of 'Evolution of Sex'; author of 'The Study of Animal Life,' 'Outlines of Zoology,' 'The Natural History of the Year,' 'The Science of Life,' etc. (J. A. T.)

THOMSON, Joseph John, D.Sc., LL.D. Glasgow and Princeton, Ph.D. Cracow, F.R.S.; Cavendish Professor of Experimental Physics, Cambridge; Fellow of Trinity College; Lecturer Trinity College; Roy. Socs. Upsala and Turin; President of Cambridge Philosophical Society, 1894; President of Section A, British Association, 1896; author of 'A Treatise on the Motion of Vortex Rings,' 'Application of Dynamics to Physics and Chemistry,' 'Recent Researches in Electricity and Magnetism,' 'Elements of the Mathematical Theory of Electricity and Magnetism,' etc. (J. J. T.)

THORODDSEN, Dr Theodor H.; Icelandic expert and explorer; author of 'History of Icelandic Geography,' etc. (Th. T.)

THURSFIELD, James Richard, M.A.; formerly Fellow of Jesus Coll., Oxford; author of 'Peel,' 'The Navy and the Nation,' conjointly with Sir George S. Clarke. (J. R. T.)

THURSTON, Prof. Robert Henry, A.M., C.E., LL.D.; Director of Sibley College, and Professor of Mechanical Engineering, Cornell University; sometime President Am. Society Mechanical Engineers; inventor of Testing Machines, etc.; author of 'Manual of the Steam Boiler,' 'History of the Steam Engine,' 'Materials of Engineering,' etc. (R. H. T.)

THWING, Charles Franklin, D.D., LL.D.; President Western Reserve University and Adelbert College; author of 'American Colleges,' 'The Reading of Books,' 'Within College Walls,' 'American College in American Life,' etc. (C. F. T.)

TIEDEMANN, H.; Anglo-Dutch journalist; ex-President of the Foreign Press Association. (H. Ti.)

TODD (J.), Spencer Brydges, C.M.G.; Secretary Dept. of Agent-General for Cape of Good Hope in London; Executive Commissioner, Paris, for Universal Exhibition, 1878; appointed by H.R.H. Prince of Wales a member of the International Jury; author of 'The Resident Magistrate at the Cape of Good Hope,' 'Handy Guide to Laws and Regulations at the Cape of Good Hope.' (S. B. T.)

TREBLE, Rev. Edmund John, A.K.C.L.; Eng. Chap., Wiesbaden; author of 'Plain Teaching about the Church of England,' etc. (E. J. T.)

TRENT, William Peterfield, A.M., LL.D.; Prof. of English, Columbia University, New York; formerly editor of the 'Sewanee Review'; author of 'English Culture in Virginia,' 'Southern Statesmen of the Old Régime,' 'Life of William Gilmore Simms,' 'Robert E. Lee,' etc. (W. P. T.)

TRIPP, Hon. Bartlett; late U.S. Minister to Austria; Chief-Justice of the Supreme Court of Dakota Territory, 1885-89. (B. T.)

TROTTER, Lieut.-Colonel Henry, C.B.; British Delegate on the European Commission of the Danube, and H.B.M. Consul-General for Roumania; served 1863-75 on great Trigonometrical Survey of India; accompanied mission to Yarkand and Kashgar, 1873-74; special service in China, 1876; additional military attaché at Constantinople during Turko-Russian War, 1877-78; Consul for Kurdistan, 1878-82; military attaché, Constantinople, 1882-89; Consul-General in Syria, 1890-94; has acted as H.M. Chargé d'Affaires at Bucharest; author of various papers contributed to the Royal Geog. Soc. (H. Tr.)

TROUP, Charles Edward, M.A., C.B.; Principal Clerk in the Home Office since 1896; chairman of Committee on Identification of Habitual Criminals; editor of 'Judicial Statistics of England and Wales'; author of 'The Future of Free Trade.' (C. E. T.)

TUKE, Sir John Batty, M.D., D.Sc., F.R.C.P.Ed., F.R.S.Ed., M.P.; Medical Superintendent, Saughton Hall Asylum, Edinburgh; Member of General Medical Council of Registration and Education; Medical Superintendent of Fife and Kinross Asylum, 1865-73; author of 'Aphasia,' 'Hippocrates,' 'Hysteria,' 'Insanity,' in Ninth Edition of 'Ency. Brit.,' 'Morrison Lectures,' 'Insanity of Over-exertion of the Brain.' (J. B. T.)

TURNER, Cuthbert Hamilton, M.A.; Fellow of Magdalen College, Oxford; co-editor of the 'Journal of Theological Studies.' (C. H. T.)

TURNER, Frederick J., Ph.D.; Professor of American History, University of Wisconsin; author of 'Wisconsin,' in Ninth Edition of 'Ency. Brit.' (F. J. T.)

TURNER, Herbert Hall, D.Sc., F.R.S.; Savilian Professor of Astronomy, Oxford; Fellow of New College, Oxford; member of Senate of Cambridge University; formerly Fellow of Trin. Coll. Camb., and chief assistant Royal Observatory, Greenwich; author of 'Modern Astronomy.' (H. H. T.)

TYLOR, Edward Burnett, LL.D., D.C.L., F.R.S.; Professor of Anthropology, Oxford; Keeper of the University Museum since 1883; author of 'Anthropology,' 'Cannibalism,' 'Demonology,' 'Giant,' 'Magic,' etc., in Ninth Edition of 'Ency. Brit.'; 'Anahuac, Mexico and the Mexicans,' 'Researches into the Early History of Mankind,' 'Primitive Culture,' 'Anthropology,' 'The Natural History of Religion.' (E. B. T.)

U

UKITA, Goji; Chancellor of the Japanese Legation, London. (G. U.)

UNWIN, William Cawthorne, F.R.S., M.I.C.E.; Hon. Life M.I.M.E.; Hon. Mem. Am. Soc. M.E.; Hon. Assoc. R. I. Brit. Architects; Professor of Civil and Mechanical Engineering, Central Technical College, City and Guilds of London Institute; instructor at Royal School of Naval Architecture and Marine Engineering, Kensington, 1868-72; Professor of Hydraulic Engineering, Royal Indian Engineering College, Cooper's Hill, 1872-85; Professor of Engineering, Central Technical College of the Guilds of London, Kensington, since 1885; President, Section G, British Association, 1892; on the Council of Royal Society, 1894; on the Council Inst. Civil Engineers, 1900; on the Senate London University, 1900; author of 'Hydraulics,' etc., in Ninth Edition of 'Ency. Brit.,' 'Wrought Iron Bridges and Roofs,' 'Machine Design,' 'The Testing of Materials of Construction,' 'The Development and Transmission of Power from Central Stations,' etc. (W. C. U.)

V

VAN DER WAALS, J. D.; Doctor of Math. and Physics, Leyden; Professor of Physics, Amsterdam; Gen. Sec. Royal Academy of Sciences, Amsterdam; Cor. Member de l'Académie des Sciences de Paris, etc.; author of 'The Continuity of the Gaseous and Liquid States of Matter,' etc. (J. D. v. d. W.)

VAN DYKE, Prof. Henry, D.D., LL.D.; Professor of English Literature, Princeton University; author of 'The Poetry of Tennyson,' 'Little Rivers,' 'The Gospel for an Age of Doubt,' 'The Toiling of Felix, and other Poems,' etc. (H. van D.)

VAN DYKE, John Charles, L.H.D.; author of 'History of Painting,' 'Old Dutch and Flemish Masters,' etc. (J. C. Van D.)

VASCONCELLOS, Captain Ernesto de; Secretary of the Committee of Colonial Cartography, Department of Marine and Fisheries, Portugal; Secretary of the Lisbon Geographical Society; author of 'As Colonias Portuguesas,' etc. (E. de V.)

VAUGHAN, H.E. Herbert, Cardinal, D.D., Priest of the Title of SS. Andrew and Gregory on the Coelian Hill; Archbishop of Westminster; Bishop of Salford, 1872-92; author of a large number of pamphlets and letters concerning educational, social, and religious questions, etc. (✠ H. E. V.)

VERDINOIS, Frederigo; Italian man of letters; translated 'Cantico di Natale' and 'La Piccola Dorrit' from Dickens, Shakespeare's 'Midsummer Night's Dream,' etc. (F. V.)

VERNON-HARCOURT, Leveson Francis, M.A., M.I.C.E.; Professor of Civil Engineering at Univ. Coll. London; proceeded to India, 1896, to inspect the river Húgli, reporting to Calcutta Port Commissioners; British Member of Jury for Civil Engineering, Paris Exhibition, 1900; author of 'River Engineering,' 'Water Supply,' in Ninth Edition 'Ency. Brit.,' 'Rivers and Canals,' 'Harbours and Docks,' 'Achievements in Engineering,' 'Civil Engineering as applied in Construction,' etc. (L. F. V.-H.)

VERWORN, Max, M.D., Ph.D.; Professor of Physiology, Jena, author of 'Allgemeine Physiologie,' 'Psycho-physiologische Protisten-Studien,' etc. (M. V.)

VETCH, Col. Robert Hamilton, R.E., C.B.; employed on defences of Bermuda, Bristol Channel, Plymouth Harbour, and Malta, 1861-1876; Secretary of R.E. Institute, Chatham, 1877-1883; commanded R.E. Submarine Mining Batt., 1884; Assistant Inspector-General of Fortifications at War Office, 1884-89; Deputy Inspector-General of Fortifications and Secretary of the Defence Committee, and of the Joint Naval and Military Committee on Defence, War Office, 1889-94; Chief Engineer in Ireland and Colonel on Staff, 1894-98; author of 'Gordon's Campaign in China,' 'Life of Lieut.-Gen. Sir Gerald Graham'; edited 'The Professional Papers of the Corps of R.E.'; also the 'R.E. Journal,' 1877-84. (R. H. V.)

VILLARS, Paul; Knight of the Legion of Honour; and London Correspondent of 'Le

Journal des Débats,' 'Le Figaro,' etc.; author of 'Sketches of England,' 'Scotland and Ireland,' etc. (P. V*.)

VINELLI, Dr Marcello; editor of 'La Unione Sarda,' Cagliari, Sardinia. (M. Vi.)

VINES, Sydney Howard, D.Sc. London, M.A., D.Sc. Camb., F.R.S.; President of the Linnean Society of London; Sherardian Professor of Botany, Oxford; Fellow of Magdalen College; Fellow and Lecturer of Christ's Coll. Cambridge, 1876; Reader in Botany, Cambridge, 1883; Hon. Fellow of Christ's Coll. Cambridge, 1897; author of 'Reproduction,' etc., in Ninth Edition of 'Ency. Brit.,' 'Lectures on the Physiology of Plants,' 'A Student's Text-Book of Botany,' papers in various scientific journals, etc. (S. H. V*.)

W

WADSWORTH, S., M.A.; Barrister-at-Law, of the Inner Temple and of Lincoln's Inn; joint-editor of the 17th edition of Davidson's 'Concise Precedents in Conveyancing.' (S. Wa.)

WAGER, Harold W. T., F.L.S.; formerly Lecturer in Biology, Yorkshire Coll. Leeds; H.M. Inspector of Science Schools; author of 'Memoirs on Cytology and Reproduction of the Lower Organisms,' etc. (H. W*.)

WAGLE, N. B. (N. B. W.)

WAGNER, Dr Hermann; Professor of Geography in Göttingen University; author of 'Germany (Geography)' in Ninth Edition of 'Ency. Brit.,' 'Lehrbuch der Geographie,' editor 'Geographisches Jahrbuch,' etc. (H. Wa.)

WALDSTEIN, Charles, Litt.D., Ph.D., L.H.D.; Knight Commander of the Order of the Redeemer; and Ernestine Saxon Order; Fellow of King's College, Cambridge, 1894; member of Council of British Archæological School, Athens, etc.; Lecturer in Classical Archæology in Univ. of Camb., 1880; Director of Fitzwilliam Museum, Camb., 1883-89; Director of American Archæological School, Athens (retaining Readership at Camb.), 1889-1893, retaining Professorship there till 1896; Slade Professor of Fine Art, 1895-1901; author of 'Balance of Emotion and Intellect,' 1878, 'Essays on the Art of Phidias,' 1885, 'The Work of John Ruskin,' 1894, 'The Study of Art in Universities,' 1895, 'The Expansion of Western Ideals' and the 'World's Peace,' 1899, 'The Jewish Question' and the 'Mission of the Jews,' 1899, and numerous reports of excavations and archæological memoirs. (C. W*.)

WALKER, James, D.Sc., F.R.S.; Professor of Chemistry, University College, Dundee. (J. Wal.)

WALKER, Norman, M.B., F.R.C.P.; Assistant Physician of Edinburgh Infirmary; part author of 'An Introduction to Dermatology.' (N. W.)

WALLACE, Sir Donald Mackenzie, K.C.I.E., K.C.V.O.; Private Secretary to Marquesses of Dufferin and of Lansdowne as Viceroys of India, 1884-89; attached to the Czarewitch as political officer during his tour in India and Ceylon, 1890-91; Director of the Foreign Department of 'The Times,' 1891-99; Assist. Private Secy. to H.R.H. the Duke of Cornwall and York during his colonial tour, 1901; member of Institut de Droit International and Officier de l'Instruction Publique of France; joint-editor of New Volumes of 'Encyclopædia Britannica"; author of 'Russia,' 'Egypt and the Egyptian Question,' etc. (D. M. W.)

WALLACE, William, M.A., LL.D.; assistant editor of the 'Glasgow Herald'; author of 'Burns and Mrs Dunlop,' 'Scotland Yesterday'; edited 'Chambers's Life and Works of Burns,' etc. (W. Wa.)

WALLIS, John Edward Power, M.A.; Advocate-General of Madras; Inns of Court Reader in Constitutional Law, 1892-97; author of 'State Trials' for the State Trials Committee, and numerous articles on constitutional law and history. (J. E. P. W.)

WALPOLE, Sir Spencer, K.C.B., Hon. LL.D. Edin.; Inspector of Fisheries, 1867; Lieut.-Governor of the Isle of Man, 1882; Secretary to the Post Office, 1893-99; author of 'History of England from 1815,' 'Life of Rt. Hon. Spencer Perceval,' 'Life of Lord John Russell,' 'The Electorate and the Legislature,' 'Foreign Relations,' 'The Land of Home Rule. (S. W.)

WALTON, Hon. Sir Joseph, K.C.; Judge of the King's Bench Div.; chairman of the General Council of the Bar, 1899; Recorder of Wigan, 1895-1901; author of 'Practice and Procedure of Court of Common Pleas at Lancaster.' (W.)

WARD, H. Marshall, D.Sc., F.R.S., F.L.S., F.R.Hort.S.; Professor of Botany, Cambridge; Fellow of Sidney Sussex College, Cambridge; Hon. Fellow of Christ's College, Cambridge; President of the British Mycological Society; corresponding Member Cryptogamic Society of Scotland; Cryptogamic Botanist to Ceylon Government, 1880-82; Berkeley Fellow, Owens Coll., 1882; Fellow of Christ's Coll., 1883; Professor of Botany in Forest School, Cooper's Hill, 1885-95; author of 'Schizomycetes' in Ninth Edition of 'Ency. Brit.,' 'Timber and some of its Diseases,' 'The Oak,' 'Sachs' Lectures on the Physiology of Plants,' 'Laslett's Timber and Timber Trees,' 'Diseases of Plants,' 'Grasses,' 'Disease in Plants.' (H. M. W.)

WARD, James, M.A., LL.D., D.Sc.; Fellow of Trin. Coll. Camb. and Professor of Mental Philosophy, Cambridge; Gifford Lecturer, University of Aberdeen, 1895-97; author of 'Herbart,' 'Psychology,' in Ninth Edition of 'Ency. Brit.,' 'Naturalism and Agnosticism.' (J. W*.)

WARD, Robert de C., A.M.; Instructor in Climatology Harvard University. (R. de C. W.)

WATERHOUSE, Major-Gen. James; Unemployed Supernumerary List, Indian Staff Corps; Vice-President Roy. Phot. Soc.; Hon. Mem. Vienna Phot. Soc. 1901; Indian Ordnance Dept. 1866; Assist. Surveyor-Gen. in charge of photographic operations in the Surveyor-General's Office, Calcutta, 1866-97; took part in the observation of total eclipses, 1871 and 1875, and of transit of Venus, 1874; President of the Asiatic Society of Bengal, 1888-90; awarded Roy. Phot. Soc. Progress Medal, 1890, also Vienna Phot. Soc. Voigtlander Medal, 1895; author of 'The Preparation of Drawings for Photographic Reproduction,' and numerous papers in the 'Bengal Asiatic Society's Journal' and various photographic journals and publications. (J. Wa*.)

WATSON, Alfred Edward Thomas ('Rapier'); editor of the 'Badminton Library' and 'Badminton Magazine'; musical and dramatic critic of the 'Standard'; edited the 'Illustrated Sporting and Dramatic News,' writing under the signature 'Rapier,' 1880-95; author of 'Sketches in the Hunting Field,' 'Race Course and Covert Side,' 'Types of the Turf,' 'Steeplechasing,' chapters in the Badminton volumes on Hunting, Riding and Driving, Racing and Chasing, 'The Turf,' etc. (A. E. T. W.)

WATSON, Colonel Charles Moore, C.M.G., M.A.; Deputy Inspector-General of Fortifications, War Office; served in Sudan under the late Gen. C. G. Gordon, C.B., 1874-1875; A.D.C. to Field-Marshal Sir Lintorn Simmons, G.C.B., 1878-80; employed in Indian Office, 1880-82; special service, Egyptian War, 1882; employed in Egyptian Army, 1882-86, with rank of Pasha (3rd class Osmanieh); Assistant Inspector-General of Fortifications, 1891-96; Deputy Inspector-General 1896. (C. M. W.)

WATTS, Philip, F.R.S.; Director of Naval Construction; formerly Naval Architect and Director of War Shipbuilding Department of Sir W. G. Armstrong, Whitworth and Co. (P. Wa.)

WATTS-DUNTON, Theodore; poet, novelist, and critic; author of 'Poetry,' 'Rossetti,' 'Sonnet,' 'Vanbrugh,' 'Wycherley,' etc., in Ninth Edition of 'Ency. Brit.,' 'The Coming of Love,' 'Aylwin'; edited 'Lavengro,' etc. (T. W. D.)

WAUGH, Arthur; London Correspondent to the 'New York Critic,' 1893-97; literary adviser to Kegan Paul and Co. Ltd.; author of 'Gordon in Africa,' 'Alfred, Lord Tennyson'; edited 'Johnson's Lives of the Poets'; edited the 'Pamphlet Library,' 'Legends of the Wheel,' 'Robert Browning.' (A. Wa.)

WEBB, Gen. Alexander Stewart; President of the College of the City of New York; Brig.-Gen. of Volunteers in the Civil War; author of 'The Peninsula,' 'M'Clellan's Campaign of 1862,' etc. (A. S. W*.)

WEBBER, Maj.-Gen. C. E., C.B., M.I.C.E., M.I.E.E.; Indian Mutiny, 1857-60; instructor in topography, R.M.A.; with Prussian Army in 1866; Paris Exhibition, 1867; Egyptian expedition, 1882; Nile expeditions, 1884-85; founder (with late Sir Francis Bolton) and past President of the Institution of Electrical Engineers; author of various articles on military subjects, Telegraphy, Telephony, and Electrical Engineering. (C. E. W.)

WEBER, Gustavus A.; U.S. Dept. of Labour, Washington, D.C. (G. A. W.)

WEDMORE, Frederick; art critic of the 'Standard,' London; author of 'Pastorals of France,' 'Renunciations,' 'English Episodes,' and 'Orgeas and Miradou,' with other short stories and imaginative pieces; 'The Life of Balzac,' 'Studies in English Art,' 'Méryon,' 'Etching in England,' 'Fine Prints: On Books and Arts,' 'The Collapse of the Penitent.' (F. We.)

WELCH, Lewis S., A.B.; editor of the 'Yale Alumni Weekly.' (L. S. W.)

WELDON, Walter F. R., M.A., D.Sc., F.R.S.; Linacre Professor of Comparative Anatomy, Oxford; late Fellow of St John's Coll. Cambridge; late Jodrell Professor of Comparative Anatomy and Zoology, University Coll. London. (W. F. R. W.)

WELLS, Joseph, M.A.; Fellow and Tutor, Wadham College, Oxford; Delegate of Local Examinations, for Extension of University Teaching and for Training of Teachers; on Oxford and Cambridge Schools Examining Board; author of 'A Short History of Rome,' 'Oxford and its Colleges,' 'Wadham College.' (J. We*.)

WELLS, Captain Lionel de Lautour, R.N.; Chief Officer, Metropolitan Fire Brigade; author of 'Jack Afloat,' 'M.F.B. Drill-book.' (L. de L. W.)

WESTLAKE, John, K.C., LL.D.; Professor of International Law, Cambridge; author of 'A Treatise on Private International Law, or the Conflict of Laws,' 'Chapters on the Principles of International Law.' (Jno. We.)

WETHERELL, W.; assistant editor, 'Liverpool Daily Post.' (W. We.)

WHATES, H.; assistant editor of the 'Standard'; editor of the 'Politician's Handbook.' (H. Wh.)

WHEATLEY, Henry Benjamin; Asst. Secretary, Society of Arts, Assistant Sec. Brit. Royal Commission, Section of Chicago Exhibition, 1893; Hon. Sec. Early English Text Society, 1864-72; Treasurer, 1872-1901; author of 'Index,' etc., in Ninth Edition of 'Ency. Brit.,' 'Anagrams,' 'Round about Piccadilly and Pall Mall,' 'What is an Index?' 'Samuel Pepys and the World he lived in,' 'How to form a Library,' 'How to Catalogue a Library,' 'London Past and Present,' 'New Edit. Pepys' Diary,' 'Historical Portraits,' 'Prices of Books,' 'Pepysiana,' etc. (H. B. W*.)

WHEELER, Maj.-Gen. Joseph; Member of U.S. Congress, 1881-99; Lieut.-Gen. and Senior Cavalry General of the Confederate Armies in the Civil War; in charge of the cavalry under Gen. Joseph E. Johnston; Maj.-Gen. of Volunteers, U.S.A., Span.-American War. (J. Wh.)

WHETHAM, William Cecil Dampier, M.A., F.R.S.; Fellow of Trinity Coll. Cambridge; Lecturer on Physics, Cambridge; author of various papers on scientific subjects, and of text-book on 'Solution and Electrolysis,' etc. (W. C. D. W.)

WHITAKER, Edgar; editor of the 'Constantinople Messenger'; author of 'The Outlook in Asiatic Turkey'; translated Giacometti's 'Russia's Work in Turkey,' etc. (E. W*.)

WHITE, Horace; editor of the N.Y. 'Evening Post'; sometime editor of the 'Chicago Tribune'; author of 'The Silver Question,' 'The Tariff Question,' 'Money and Banking,' 'The Gold Standard,' etc. (H. Wh*.)

WHITE, James; Department of the Interior, Ottawa. (J. Wh*.)

WHITE, James Forbes, M.A., LL.D.; art critic; author of 'Rembrandt,' 'Velasquez,' in the Ninth Edition of the 'Ency. Brit.' (J. F. W.)

WHITFELD, W. H.; successor to 'Cavendish' on the 'Field.' (W. H. W*.)

WHYTE, Frederic W.; author and dramatic critic; author of 'Actors of the Century'; trans. of A. Filon's 'English Stage,' etc. (F. W. W.)

WILHELM, C.; designer of theatrical spectacle; author of 'Essays on Ballet and Spectacle,' etc. (C. Wi.)

WILKINSON, Henry Spenser, M.A., on staff of the 'Morning Post'; author of 'Citizen Soldiers,' 'Essays on the War Game,' 'Exercises in Strategy and Tactics' (from the German), 'The Command of Artillery in the Army Corps and the Infantry Division' (from the German), 'The Brain of an Army,' 'The Volunteers and the National Defence,' 'Imperial Defence' (in collaboration with Sir Charles Dilke), 'The Great Alternative, a Plea for a National Policy,' 'The Command of the Sea,' 'The Brain of the Navy,' 'British Policy in South Africa,' 'Lessons of the War,' 'War and Policy.' (H. S. W.)

WILLCOX, Walter F., LL.B., Ph.D.; Chief Statistician, U.S. Census Bureau; Professor of Social Science and Statistics, Cornell University; Member of the American Social Science Association, and Secretary of the American Economical Association; author of 'The Divorce

Problem: A Study in Statistics,' 'Social Statistics of the United States,' etc. (W. F. W.)

WILLEY, A., D.Sc. (A. W*.)

WILLIAMS, Aneurin; author of 'Relation of Co-operative Movements to National and International Commerce,' etc. (A. Wɪ*.)

WILLIAMS, E. H., M.D.; formerly Associate Professor of Pathology, State University of Iowa; and Assistant Physician at the Hospital for the Insane, Matteawan, N.Y., and at the Manhattan State Hospital, N.Y. (E. H. W.)

WILLIAMS, Sir E. Leader; consulting engineer Manchester Ship Canal; engaged as engineer since 1846 on the works of the Great Northern Railway, Shoreham and Dover Harbours, River Weaver and Bridgwater Canal Navigations; chief engineer of the Manchester Ship Canal during its construction; Member of Council of Institution of Civil Engineers; author of papers printed in 'Proceedings of Institution of Civil Engineers.' (E. L. W.)

WILLIAMS, Henry Smith, M.D., B.Sc.; former lecturer in the Hartford School of Sociology, U.S.A.; editor of forthcoming 'History of the World' in 25 volumes; author of 'The Story of Nineteenth Century Science,' 'The History of the Art of Writing,' 'The Lesson of Heredity,' etc. (H. S. W*.)

WILLIAMS, R. Vaughan, B.A.; Mus. Doc., Trinity College, Cambridge. (R. V. W.)

WILLIAMS, Talcott; editor of the 'Philadelphia Press.' (T. W*.)

WILLSON, Beckles; staff of 'Boston Globe,' U.S.A., 1887; correspondent in Cuba, 1888; editor, 'Press of Atlanta,' Georgia, 1889; staff of 'New York Herald,' 1890; staff of 'London Daily Mail,' 1896-98; author of 'Harold: an Experiment,' 1891, 'Drift,' 1893, 'The Tenth Island,' 1897, 'The Great Company,' 1899. (B. W*.)

WILSON, Maj.-Gen. Sir Charles William, R.E., K.C.B., K.C.M.G., D.C.L., LL.D., F.R.S.; secretary to North American Boundary Commission, 1858-62; surveys of Jerusalem and Palestine, 1864-66; Ordnance Survey of Scotland, 1866-68; survey of Sinai, 1868-69; director Topographical Department W.O., and A.Q.M.G. Intelligence Department, 1869-76; Ordnance Survey of Ireland, 1876-78; Royal Commission on Registration of Deeds and Insurances in Ireland, 1878; British Commissioner Servian Boundary Commission, 1878-79; Consul-Gen. Anatolia, 1879-82; special mission to Eastern Rumelia, 1880; and to Consulates in Asiatic Turkey, 1881; special service in Egypt and attached to Lord Dufferin's mission, 1882-1883; D.A.G. (Intelligence Department) Nile Expedition, 1884-85; Ordnance Survey of Ireland, 1885-86; Director-Gen. Ordnance Survey, 1886-94; Director-Gen. of Military Education, 1895-98; president Geographical Section British Association, Belfast, 1874; Bath, 1888; Vice-President Royal Geographical Society, 1897-1901; author of 'Notes to Ordnance Survey of Jerusalem,' 'Notes to Ordnance Survey of Sinai' (part), 'Picturesque Palestine' (Jerusalem vol.), 'From Korti to Khartûm,' 'Life of Lord Clive,' Murray's Handbooks to 'Constantinople' and 'Asia Minor.' (C. W. W.)

WILSON, W. J.; of the Canadian Geological Survey. (W. J. W.)

WINTER, Miss E. G.; contributor to 'The Times' Gazetteer. (E. G. W.)

WOLCOTT, Hon. Roger, the late; Governor of Massachusetts, 1897-99. (R. Wo.)

WOLF, Lucien; sub-editor and leader-writer, 'Jewish World,' 1874-93; staff of 'Daily Graphic'; London correspondent, 'Le Journal,' Paris; Fellow of Inst. of Journalists; first President and now Vice-President of Jewish Historical Society of England; author of 'Sir Moses Montefiore'; joint-editor with Joseph Jacobs of 'Bibliotheca Anglo-Judaica'; 'Menasseh B. Israel's Mission to Oliver Cromwell'; many essays on foreign and colonial politics in 'Fortnightly Review,' 'Nineteenth Century,' and other magazines. (L. W.)

WOLFF, Rt. Hon. Sir Henry Drummond, G.C.B., G.C.M.G.; Ambassador-Extraordinary and Plenipotentiary at Madrid, 1892-1900; author of a 'Life of Napoleon at Elba'; 'Memnon Letters on the Suez Canal,' 'Some Notes of the Past.' (H. D. W.)

WOOD, General Sir Evelyn, G.C.B., G.C.M.G., V.C.; commanding 2nd Army Corps; entered Navy, 1852; served in Crimea with Naval Brigade, 1 Oct. 1854 to 18 June 1855; Knight of Legion of Honour, Medjidieh, Turkish medal; Ashantee, Kaffir, Zulu, and Transvaal Wars, 1879-81; commanded Chatham District, 1882-83; 2nd Brigade (2nd Division) Expedition to Egypt, 1882; raised the Egyptian Army, 1883; served in Nile Expedition, 1894-95; commanded Eastern District, 1886-88; Aldershot Division, 1889-93; Quartermaster-Gen. to the Forces, 1893-97; Adjutant-General to Forces, 1897-1901; author of 'The Crimea in 1854-94,' 'Cavalry at Waterloo,' 'Achievements of Cavalry.' (E. Wo.)

WOODBERRY, George Edward, A.B.; Professor of English Literature, Columbia University, New York; author of 'The North Shore Watch,' 'Life of E. A. Poe,' 'Heart of Man,' 'Studies in Letters and Life,' 'Makers of Literature,' etc. (G. E. W.)

WOODHEAD, German Sims, M.A. M.D. Edin., F.R.C.P.Ed., F.R.S.Ed.; Fellow of Trinity Hall, Cambridge; Prof. of Pathology, Cambridge Univ., since 1899; formerly Director of the Laboratories of the Conjoint Board of the Royal Colleges of Physicians (London) and Surgeons (England); President Royal Medical Society; acted as Assistant Commissioner to the Royal Commission on Tuberculosis, 1892-95; Surgeon-Capt. Volunteer Medical Staff Corps; author of 'Practical Pathology,' 'Pathological Mycology' (with Arthur W. Hare, M.B.), 'Bacteria and their Products,' 'Report to the Royal Commission on Tuberculosis,' 'Report on Diphtheria' to the Metropolitan Asylums Board; editor of the 'Journal of Pathology and Bacteriology.' (G. S. W.)

WOODWARD, Arthur Smith, F.R.S., Hon. LL.D. (Glasgow); Asst. Keeper of Geology, British Museum; author of 'Cat. of Fossil Fishes in the British Museum,' 'Outlines of Vertebrate Palæontology,' etc. (A. S. Wo.)

WOOLSEY, Theo. S., LL.D.; Professor of International Law, Yale University; editor of 'Woolsey's International Law' (6th ed.), and of 'Pomeroy's International Law'; author of 'America's Foreign Policy.' (T. S. W.)

WORCESTER, Dean Conant; Assistant Professor of Zoology, University of Michigan; Member of the First and Second U.S. Philippines Commission; author of 'The Philippine Islands and their People.' (D. C. W.)

WRIGHT, Hon. Carroll Davidson; U.S. Commissioner of Labour; author of 'Factory System of the United States,' 'Strikes and Lockouts,' 'Cost of Production of Iron, Steel, etc.,' 'Industrial Evolution of the United States,' 'Outline of Practical Sociology,' etc. (C. D. W.)

WRIGHT, Charles Theodore Hagberg, B.A., LL.D.; Secretary and Librarian, London Library; Assistant Librarian, National Library of Ireland, 1890-93. (C. T. H. W.)

WRIGHT, Lewis; author of 'The Book of Poultry,' 'The Practical Poultry Keeper,' 'The Poultry Club Standards'; editor of 'Fulton's Book of Pigeons,' etc. (L. Wʀ.)

WYATT, J. W., A.M.I.C.E.; Fellow Roy. Indian Engineering Coll., Cooper's Hill; author of 'The Art of Making Paper,' etc. (J. W. W.)

Y

YOUNG, Alexander Bell Filson; assistant editor of the 'Pilot' since 1901; special war correspondent of the 'Manchester Guardian,' S.A.; author of various songs and instrumental works 'The Relief of Mafeking,' 'Five Lyrics,' 'A Volunteer Brigade,' 'Mastersingers,' etc. (A. B. F. Y.)

YOUNG, Rev. William; for many years Minister at the English Presbyterian Church, Kersal, Manchester; Joint Secretary of the Religious Tract Society. (W. Y.)

Z

ZIMMERN, Miss Alice; author of 'The Renaissance of Girls,' 'Education in England' 'Methods of Education,' etc. (A. Z.)

Vol. 28

ELE-GLA.