UNIV. OF
TORONTO
LIBRARY

THE SCIENTIFIC MONTHLY

P
Sci
S

THE SCIENTIFIC MONTHLY

VOLUME VII

JULY TO DECEMBER, 1918

468188
18.11.47

NEW YORK
THE SCIENCE PRESS
1918

Q
1
S817
v.7

Copyright, 1918
THE SCIENCE PRESS

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

THE SCIENTIFIC MONTHLY

JULY, 1918

THE ENGINEERING PROFESSION FIFTY YEARS HENCE II

By Dr. J. A. L. WADDELL, D.Sc., D.E., LL.D.

NEW YORK CITY

IT takes a bold man to endeavor to foretell what changes will occur in engineering during the next fifty years; nevertheless the speaker will make the attempt for the purpose of pointing out a few of the salient possibilities, some of which are easily within reach and should be attained as quickly as possible, while others may, by some engineers, be deemed chimerical. It must be remembered, though, that that highly imaginative French author, Jules Verne, in some of his wildest flights of fancy, was merely foretelling actual occurrences which are to-day so common as to cause no comment.

The speaker has concluded that the most effective way for him to make these various prognostications is by means of an imaginary annual address of the retiring president of the American Academy of Engineers in the year 1968; and he hopes that he will be pardoned for having, when so doing, assumed that the said retiring president is his own grandson and namesake. Such an assumption can certainly do the youngster no harm; but, on the contrary, it may serve him as an incentive to endeavor, should he choose some line of engineering as his life's work.

RETROSPECT

ANNUAL ADDRESS OF

J. A. L. WADDELL, 2d,

Retiring President of the American Academy of Engineers,

Washington, D. C., March 10, 1968

Gentlemen: As retiring president of the American Academy of Engineers in this sixty-eighth year of the twentieth century, at a meeting held specially to celebrate the fiftieth anniversary of the incorporation of the Academy, I have deemed it to be eminently appropriate and fitting to choose as the subject of my address

THE PROGRESS OF THE ENGINEERING PROFESSION DURING THE PAST HALF-CENTURY

In dealing with this subject it has been my aim not only to record the advancement of the engineering profession as a whole, and in detail that of its numerous divisions and subdivisions, but also to indicate the influence which our Academy has had on that development.

As one looks back upon the history of this and other countries since the close of the Great War some forty-eight years ago, he can not help being struck by the immense influence which at every turn engineering has had upon the world's reconstruction and its subsequent development. Almost every step of importance that has been taken was initiated and carried out by engineers; and American technicists in every line have been the ruling spirits in all matters bearing upon the welfare of the nations, taking the lead over the engineers of all the other nationalities, in so far as progress is concerned. The reason for this is that the Great War not only killed off the flower of the European engineers, but also caused most of the European technical schools practically to close their doors, while the United States took the wise precaution of keeping the attendance at such institutions as nearly as possible up to the normal. Of course, the said attendance, immediately after the entrance of our country into the titanic struggle in 1917, was materially decreased by the volunteering into the service of a large proportion of the upper classmen and a smaller proportion of the lower classmen from all of our institutions of learning and especially from the engineering departments of the universities and from the technical and the trade schools; but by the earnest effort of the members of our closely affiliated organization, The Society for the Promotion of Engineering Education, backed by strong pressure from the Administration at Washington, the attendance in the freshman classes of these institutions was at once actually increased a little above normal, and the next year was materially augmented. The result of this wise movement was that as soon as peace was declared and the necessity for world-reconstruction became evident, American engineers were able to secure not only far more than their *pro rata* share of the work involved, but practically all the important jobs for several years. The hold that they then secured on the engineering work of the world has never since been broken; although, as the European countries commenced to recuperate, their engineers began to get their organizations into better shape, thus reducing somewhat the preponderating influence of the American technicists.

Another reason for that preponderance is that after stupidly doing practically nothing to secure the trade of Latin-America for several years after the war started in Europe, the American bankers, manufacturers and business men finally awoke to the fact that their golden opportunity had arrived, consequently they bestirred themselves and became firmly established in Central and South America, and to a lesser degree in China, before the European manufacturers could get fairly well started again. The smaller success in China was due to the foresight and energy of the Japanese, who established themselves securely in that country while the fighting was still going on. The systematic and combined efforts of American bankers, manufacturers, business men and engineers, applied at the psychological time when nearly all the other peoples of the world were exhausted physically, mentally and financially, resulted ultimately in making the United States the great creditor nation, the American dollar the universal unit of value, and New York City the world's money-center.

In making this retrospect I have been forcibly struck by the greatly increased personal effectiveness of the individual engineer of to-day as compared with that of the individual engineer of the previous half-century. By effectiveness I refer to the extent of the valuable work that a man accomplishes in his entire lifetime. To-day the effectiveness of a high-grade engineer is fully three times as large as it was fifty years ago. For this there have been several causes, among which may be mentioned longevity, education, economics, research, development of a spirit of loyalty, governmental restriction of wasted effort, cessation of war, systematization of technical literature, and increase in number and sizes of technical libraries. I shall take up in the above order and discuss each of these causes.

Longevity

Thanks to the efforts and hard study of biologists, surgeons and physicians, the ordinary limiting life of man has increased from the biblical three score years and ten to a full century.

The studies of the biologists, combined with the coercive work of the Bureau of Sanitation at Washington, have resulted in cutting down nearly to zero the death-roll from all insect-borne diseases, such as typhus fever, malaria, yellow fever, bubonic plague, hookworm, meningitis and mountain fever, as well as other scourges such as smallpox, pellagra, typhoid fever, cholera and leprosy.

The iron hand of the law, combined with a forced enlightenment of the public of all ages and both sexes through the newspapers and the schools, has succeeded in reducing the evil effects of venereal or vice diseases to a very small fraction of their former virulence.

The investigations of the dietetists have taught humanity how best to eat, drink and exercise, not only so as to prolong life but also so as to enjoy it by the possession of good health; and the schools of all grades have taught these doctrines so thoroughly that the unscientific eating and drinking of three or four decades ago is now exceedingly rare. The almost universal adoption of the practise by physicians of giving preventive medicine, instead of trying to overcome disease after it has secured a hold on the patient, has resulted in materially increasing longevity and improving the status of the general health of the community.

The total prohibition of liquor by the federal government in the third decade of the century added, on the average, six years to the life of those men who, otherwise, would have been steady drinkers, besides cutting down crime, profligacy and insanity.

The neutralization of both sexes for crime, insanity, feeble-mindedness and bad cases of venereal disease not only has reduced by seventy-five per cent., in a single generation, the number of criminals, lunatics and idiots, but also has had a noticeable effect on the increase in longevity.

While the efforts of certain scientists to prohibit the use of tobacco have proved to be a failure, as far as the populace is concerned, they have succeeded in convincing thinking men that the effect of nicotine on the system is to reduce materially one's mental acumen; consequently a very large percentage of the scientists and engineers of to-day do not use the weed. As a direct result of this there is a small but quite appreciable augmenting of their individual output.

The stamping out of diseases and the increase in longevity have had a double effect upon the improvement of the engineering profession; for not only has each engineer now a greater number of years than formerly to devote to his work; but also his general health is so much better that he can accomplish much more per hour and can work more hours per day than he did in previous years. It has been noticed, too, that there is a more widespread love for work and mental effort among engineers of all lines and classes than there used to be; and this is very properly attributable to their better general condition of health. Again, if one were to plot the annual effective accomplishment of the average engineer of the present period, it would be seen that the amount continues to increase almost to the time of death, instead of reaching a maximum long before then, as used to be the case half a century ago. By the term "annual effective accomplishment" I do not mean either the number of hours per year that an individual can work or the yearly amount of useful labor that one man can do, but the results that are attained annually through his direction and advice based upon his accumulated experience, and, especially, upon his knowledge of engineering economics.

Education

During the last fifty years there have been many fundamental improvements in both general and technical education, and these have had much to do with the increased effectiveness of engineers. In the common schools it has been found practicable, without overworking the children, to improve their mentality and increase their knowledge many fold, simply by adopting scientific methods of imparting instruction and by employing a much higher grade of teachers than was customary forty or fifty years ago. In the old days there seemed to be a notion prevalent that if a man or woman were a failure at most things, he or she would do well enough for a teacher, and that there was no need for paying high salaries to instructors. To-day an entirely different view is held, for now teachers as a class are about the best paid people in the community; and their standing therein is second to none.

The most important and fundamental accomplishment in education has been teaching pupils how to think and how, when studying, to concentrate their minds, rather than cramming their memories with a mass of facts, many of which are of doubtful value on account of being subject to change.

The study of vocational fitness of both children and adults which was inaugurated in the early twenties, and which required a full decade to establish as an economic necessity, has done much to improve engineering by preventing the unfit from entering its ranks.

In respect to technical education, thanks to the Society for the Promotion of Engineering Education, it may be stated that the methods governing it have been fundamentally changed. In the old days many insufficiently trained young men, and many who were intellectually and temperamentally unfit, were allowed to enter the technical schools, where during a period of four years they were stuffed with facts *ad nauseam*, with the result that the graduates were not deep thinkers; besides which, they were sadly deficient in those lines of education which were not purely technical. They were, in short, highly trained human machines, capable of earning a living in the employ of some large manufacturing or contracting company, but incompetent either to take their places as worthy citizens, or to originate things of real value by concentrated mental effort.

After many experiments and failures, it was learned that engineering cannot be taught in a four-year course, and that an engineer's education should cover many studies besides those of pure technics. Again, it was learned that it is bad policy to try to train all engineering students for the same ultimate object, because some men will do well as subordinates and others as leaders and originators. The ultimate solution of the problem of technical education was the establishment of three kinds of technical schools, viz., trade-schools for the rank and file, or for those who by their individual limitations are doomed to mediocrity; broad engineering courses for good students, teaching them thoroughly mathematics, the humanities, economics, elementary technics and general culture; and postgraduate schools for the best of the technical graduates, giving elaborate instruction in both the theory and the practise of the various special lines of work. The result is that the profession is now well supplied with capable "hewers of wood and drawers of water"; that there is turned out annually a large number of highly cultured and broad-gauge young men who are drilled in the elements of technics, who are well fitted to begin service in almost any line of activity, and who will be able to advance rapidly therein; and that there is an adequate number of specially trained technicists who can at once successfully fill important positions.

Economics

Up to the beginning of the third decade of the century, but little attention had been paid by engineers in general or by instructors in engineering to the important subject of "Economics." It is true that the leading American engineers had individually studied deeply into the matter when making their designs, and that a few of the technical writers (especially in bridge subjects) had touched upon the question; but it was not until 1915, when the Society for the Promotion of Engineering Education appointed a special committee on "The Study of Economics in Technical Schools," that a systematic effort was made to devote due attention in such schools to that fundamentally important feature of engineering. The result of the committee's report, which was presented in 1917, was ultimately the publication under the auspices of that Society of an elaborate treatise on "The Economics of Engineering," written by a large number of specialists in all lines of technical activity. This book served as a basis for the preparation of other works more suited to students' use; and the study of economics in all the technical schools of the country was soon thereafter undertaken in earnest, with the result that to-day all engineering projects are much more economically handled in respect to both design and construction than they used to be. I might mention that in the accomplishment of this great desideratum our Academy cooperated most effectively with the Society for the Promotion of Engineering Education.

Incidentally, it might be stated that the economics of engineers' time and effort have been made the subject of much deep thought, and that important results have been accomplished thereby through time-and-labor-saving devices such as the slide-rule, the pantagraph, the integrating machine and numerous other mechanical computers, through systematization of the individual's work and the avoidance of duplication in investigations, and through the thorough checking of all calculations and plans before work thereunder proceeds.

The compulsory introduction of the metric system of weights and measures about the end of the third decade of the century, while at first proving to be a hardship and an expense to most people, and especially to engineers, eventually became a great time-saver for all computers.

As a side-issue in the matter of economics, I might mention that, over forty years ago, the federal government, as a matter of political economy, undertook the storage of grain and other food products so as to carry over the surplus from the years of plenty to the years of scarcity, and thus to equalize both the earnings of the producer and the general cost of living. Large grain bins and cold-storage plants were built and operated by the government in all parts of the country; and the result of the movement has been eminently satisfactory. Parenthetically, I might state that this step inaugurated a campaign of extermination against rats and mice, which was later extended to include all useless cats and dogs. The economy effected by this campaign amounted to some hundreds of millions of dollars annually; consequently it has been made a permanent institution under federal-government control.

Research

Up to the third decade of the century the work of engineering research was handled mainly in the universities and technical schools, although the Bureau of Standards at Washington had been making many important investigations; but since then the greater part of such research has been done by the federal government through that bureau, and on a much larger scale than formerly. The beneficial effect on the profession of the results of the many researches in all lines of technics is simply incalculable. By its recommendations to the federal government concerning proposed investigations and by suggestions of its own thereto, our academy has rendered most effective service in this line of activity.

Development of a Spirit of Loyalty

Regarding loyalty to the profession, Sir Francis Bacon said:

> I hold every man a debtor to his profession, from which as men of course do seek to receive countenance and profit, so ought they of duty to endeavor themselves, by way of amends, to be a help and ornament thereto.

The development of a spirit of loyalty to our profession has been a slow process, spread over a long period of years; but I am happy to say that to-day it pervades all ranks of engineering and is the mainspring of both individual and concerted action in all matters professional. The instruction of engineers in respect to the necessity for professional loyalty was the work of the various technical societies of the country, which were systematically instigated thereto by the American Academy of Engineers. The members of our organization take great satisfaction in this accomplishment.

Governmental Restriction of Wasted Effort

While it is true that, in the early days of modern engineering, the factor of competition in design and the stimulation to mental effort which it produced had much to do with the advancement of American engineers ahead of their European brethren, it was gradually carried to greater and greater excess until it resulted in being a heavy burden upon the profession. It became customary among municipalities and the promoters of enterprises to advertise for competitive studies and plans. Sometimes, but by no means always, they would offer a small prize, hardly large enough to cover the cost of a single set of papers, the real bait being the promise of the engineering to the successful competitor. In many cases the project failed to materialize, in others even the payment of the prize was dodged, and it was not an uncommon occurrence to have the total expenditure on studies by the numerous competitors far exceed the net amount of the total fee earned by the successful competitor.

Some forty years ago, the academy took hold of the matter, pointing out the injustice done to the profession, and succeeded in having Congress pass a law making all such competitions illegal, and providing that any person, company, or community desiring competition on engineering or architectural projects or plans must limit the number of competitors, must pay each unsuccessful competitor a fee large enough amply to cover his entire expense in the competition, and that the prize for the successful competitor must be either retention on the work at the standard rate of compensation, or a sum of money at least five times the amount of the expense to which he is put in preparing his competitive papers, the actual amounts of the payments being settled in advance by agreement between the promoter and the various competitors. This law, while cutting out all illegitimate and unnecessary competitions, has not militated materially against the public's receiving, whenever necessary or advisable, the benefit of competitive effort; but it has proved a great boon to the consulting and independent engineers of America. The Canadian Academy of Engineers, which was established in 1923, soon followed our lead in this movement, and succeeded in having similar legislation passed by the Dominion Parliament.

Cessation of War

The sudden cessation of war throughout the world, after the conquering of the Central Powers by the Allies nearly a half-century ago, with the establishment of permanent peace by means of an armed alliance, and with the subsequent gradual reduction of the policing armament which ensued as the nations became accustomed to arbitration and alive to its wonderful advantages, permitted some of the best brains of the world to turn from thoughts of destruction to those of construction; and thus the engineering profession received the benefit of an increased amount of highly skilled labor and inventive genius.

To-day any invention of an instrument of destruction is frowned upon by all thoughtful people; and any one who advocates war in any shape is treated as a public enemy and punished accordingly. As a result of the successful establishment of world peace, Congress in 1937 changed the name of the War Department to that of "Peace Department," and the name of the Navy Department to that of "Navigation Department."

Systematization of Technical Literature

By the suggestion of our academy, the federal government in 1923 undertook to issue annually (and later semi-annually) a pamphlet giving for each engineering specialty a list of the best and most useful technical books published in the English language, and indicating in condensed form their contents. This is kept up to date by the direction of a committee of the academy, all books being dropped from the list as soon as their practical usefulness ceases. The result of this innovation has been to enable both individual engineers and the libraries of schools and municipalities to purchase the treatises they need without squandering their money on works that will be of no practical assistance.

Increase in Size and Number of Technical Libraries

The mass of technical literature has gradually become so large that it is impracticable for most engineers to purchase all the books they need; consequently, at the request of our academy, the federal government has initiated the custom of making allowances to public libraries for the purchase of technical works. It is, therefore, practicable for an engineer located in a city of any size to find all the references he needs in his work without having a large library of his own. This arrangement has been of great service to the profession, especially to its younger members.

Some of the other important items of influence in the general improvement of the status of engineering during the last fifty years are the following: The establishment of the American Institute, the inauguration of the Department of Public Works, the Federal licensing of engineers, the permanent alliance of labor and capital, the formation of the Industrial Army, the reform of the Patent Office, the universal distribution of power by the government, the enforced conservation of materials, the utilization of by-products, the proper restriction of the employment of the term "Engineer," the avoidance of disasters to great engineering constructions through extra checking of plans, the establishment of a code of engineering ethics, the inauguration of legalized distinctions, the determination of minimum charges for services, the improvement of technical literature, the systematic promotion of projects, the working of American engineers abroad, the installation of concerted publicity movements, and, finally, the due recognition of the profession by the nation. As before, I shall discuss each of these items in the order in which they are mentioned.

American Institute

When the founders of our academy first proposed its formation, they had a still greater step in mind, as was indicated in public on several occasions, viz., the establishment of an American Institute on the lines of *L'Institut de France,* to include besides our own organization the then-existing National Academy of Sciences and all future duly-organized American academies, such as those of Architecture, Medicine, Literature, Law, Journalism, Art, Political Economy and Universal Peace.

During the third decade there were established only three of these academies, making five all told. Then the dream of the founders of our academy came true, for the American Institute was formed in 1927; and within the next five or six years the other academies just mentioned were organized, each one, as soon as established, becoming a member of the institute. This organization holds regular meetings only twice a year; but occasionally it has called a special meeting to discuss and take action upon some burning question of the hour. The fine building for the institute, in which are located the headquarters or offices of all the component academies, was presented by the federal government in 1929 at a cost of about twenty million dollars. The bringing together of engineers and other learned men from the various walks of life to discuss matters of great moment in which their lines cross has done much for humanity; and especially has it benefited the engineers by forcing them out of the narrow ruts into which they constantly tended to fall, and broadening them by contact with many of the most brilliant minds of their compatriots.

A number of special meetings in the Institute House of two and sometimes three academies have been held for the purpose of taking action on questions in which they were jointly interested; and these meetings also have been found eminently productive of good for the commonwealth. Among other benefits obtained in this manner might be mentioned the partial purification of politics (it would prove an impossible task to cleanse it thoroughly!), the remodeling of the American diplomatic service so as to make it superior to that of any other nation, and the reform of the Patent Office.

Department of Public Works

The first great task undertaken by our academy was the establishment of a Department of Public Works to take over all the engineering work which had hitherto been distributed rather illogically among several of the departments of the government. It required a hard fight to accomplish this; but the results have proved, beyond the peradventure of a doubt, the importance of the measure. This department is practically removed from politics, because its secretary (always a civil engineer of high standing, undoubted attainments and special fitness) continues to hold his position in spite of changes of administration, retaining it as long as he is mentally and physically fit to attend properly to the work of his high office.

Licensing of Engineers

During the second decade of the century there had been much controversy among engineers concerning the advisability of not permitting technical men to practise without first securing a license. Many were the arguments advanced by both sides, and most of them were sound. Those favoring the movement declared that engineering could never attain to its full measure of public respect without the license system, while those opposed stated that the control of their professional activities by the numerous states would be intolerable. A compromise was finally effected by a general agreement to accept a federal license, based upon broad lines, and to repeal the few state technical-license-laws that had already been put into operation. As you all know, the result was eminently satisfactory. Not one of us would be willing to revert to the non-license days.

I do not believe that any one would dare to contradict me when I claim that the credit for the satisfactory settlement of this long-mooted point belongs to the American Academy of Engineers.

Alliance of Labor and Capital

Up to the year 1929, from time to time there had been struggles of a bitter nature between organized labor and capital, to the great detriment of progress in all lines of business. These disagreements seriously interfered with the work of engineers by paralyzing the progress of their constructions and by discouraging the investment of money in sound enterprises involving engineering. The conditions finally became so bad that nobody could safely undertake to materialize any large project. It was then that our academy stepped into the breach, and, after several years of continuous effort, succeeded in forming an amalgamation of working men, contractors, manufacturers and bankers which has been the means of absolutely preventing strikes, every incipient dispute now being settled by arbitration. Organized strikes of any kind are to-day treated as "conspiracy" by the laws of the land.

Industrial Army

Some forty years ago when our standing army was finally reduced to a mere police force, the government recognized that some similar body was necessary in order to provide labor for the unemployed; hence it inaugurated the "Industrial Army," composed mainly of volunteers, but also having some regiments recruited solely from the hobo and the minor-criminal classes. These men are drilled and trained in the lines of peace as formerly were soldiers in the lines of war, so as to make them effective. They are sent out on public works, and their services are occasionally loaned to the large contractors. They are paid monthly and are fed and clothed at government expense. Their services have proved of great value in agriculture; for, owing to their mobility, they are sent from south to north in the harvest season, then shipped south again and gradually moved northward so as to care for the plowing of the land and the cultivating of the crops.

There are separate regiments for the different kinds of work; but in case of necessity, the character of the men's occupation is changed. The enlistment period is four years; and deserters are punished just as drastically as were formerly those from the military army and the navy.

The establishment of this industrial army has proved to be a great boon to the engineering profession, in that there is at all times a certain amount of dependable labor which can be utilized on important constructions. Moreover, it tends to stabilize the price of labor, and thus encourages promoters and contractors to undertake great enterprises.

Patent Office Reform

The reform of the Patent Office was a hard nut to crack, but by working jointly with the American Academy of Law we managed to accomplish it. In former times that office was a standing joke. Anybody could patent almost anything; and conflicting patents were quite common. The government evidently was of the opinion that any one who was not satisfied with the way his patent was recognized by his competitors could secure satisfaction by an appeal to the law; but that process usually proved to be interminable and exceedingly expensive. Engineers considered that a patent was simply a club with which to frighten off intruders—and as such it often proved a failure. Again, it was customary to grant patents for the most minor details of design and for the smallest kinds of improvements, notwithstanding the fact that some eminent jurists declared such patents to be invalid.

To-day all such conditions are changed. Patents are being granted only for those things which are truly innovations; and it is almost unheard of to find one patent conflicting with another. To accomplish this is what the Patent Office officials are paid to do; and no shirking of the responsibility is any longer permitted.

Power Distribution

One of the most fundamental and drastic actions ever instituted by the federal government was the permanent taking over by it of the entire power supply of the United States and making the unit prices thereof the same in all localities, the exact schedule rate to the consumer being dependent to a certain extent on the amount he uses regularly. The results of this innovation were a marvellous economy of energy for the nation, a universal satisfaction on the part of all power users, and an almost automatic adjustment of fairly uniform production throughout the entire year.

All kinds of power are included. All large waterfalls are utilized, even to the total drying up of Niagara Falls, except for two hours on each Sunday afternoon during the months of May to October, inclusive, at which times, as you know, only enough water is allowed to pass over the falls to produce the desired scenic effect.

Coal is now burned mainly at the mouth of the mine instead of being transported long distances at great expense by rail—in fact for a while the experiment was tried of burning it *in* the mine; but this was soon abandoned after several costly conflagrations had occurred.

Natural gas is employed somewhat for power purposes; but generally it is found more satisfactory to pipe it to the cities for domestic use.

Following the lead of an eminent Italian engineer, we have been endeavoring with more or less success to utilize the internal heat of the earth; but there are only a few places in our country which are suitable for this process of power production.

For a long time it was thought that the utilization of tidal energy could not be made a paying enterprise, but in the early thirties a successful plant was built in New Brunswick to harness some of the power of the noted tidal bore. Both ebb and flow were utilized, although not to the same extent. Of course, only a small portion of the energy of the flowing water could be impounded, but there is enough and to spare at that locality. Afterwards, the employment of tidal energy was done on a commercial scale and upon a paying basis at a number of places in the United States; but it is not a very economic way of obtaining power.

The extraction of energy from wave motion, as suggested by Joseph Tomlinson, a noted Canadian engineer, as long ago as 1876, has never proved to be a commercial success, because the cost of the apparatus is too great in comparison with the value of the energy collected. It does pay, however, in the case of small, isolated lighthouses where to convey the required energy from the mainland would be either impracticable or very expensive.

The great improvement that has lately been effected in the efficiency of sun-power motors has enabled us to utilize direct solar energy upon a commercial basis in the states of California, Arizona, New Mexico and Western Texas, also in the Territory of Lower California. The last was purchased from Mexico in 1920 after the cessation of that country's series of continuous revolutions, in order to give it money to pay all legitimate claims for damages to the Mexican properties of American citizens and British subjects, and to enable it to carry on its government during the period of reconstruction.

The products of all the power-producing plants are combined and distributed in the most economic manner practicable, the method varying with the time of year and with the hygrometric conditions of the various districts. The ability of the government to distribute the power throughout the country, economically and as desired, is due mainly to a most important discovery by an American metallurgist of the alloy "electroconite," which, in the form of wire, combines a satisfactory strength with a resistance of only about one tenth of that of the best previously known conductor.

The credit for establishing the government control of the manufacture and distribution of power is due essentially to the constant and systematic efforts of the American Academy of Engineers.

At one time the wireless transmission of power was seriously considered, and, in truth, it was shown to be a possibility; but when trying it on a commercial basis there developed so many unanticipated obstacles that it was abandoned. Similarly, it was shown to be feasible to produce electric energy directly from coal, but practically it was found more economical to burn it. Greatly improved methods of doing so were discovered, so that to-day there is utilized a far higher percentage of the energy of the coal than was even dreamed of formerly.

Conservation

The conservation of the country's resources for a long time occupied the attention of many prominent, far-sighted and patriotic Americans, who pointed out that eventually the nation would assuredly come to grief, unless it ceased wasting its resources. While their preaching was not altogether without effect, it was not until 1938 (when the joint efforts of the American Academy of Economics and our own organization induced the government to establish a Department of Conservation) that effective measures to curtail waste were established and enforced. The result has been a decided benefit to our profession, in that now we all know what materials can and what can not be used for our constructions, and that the public will not be allowed to bring the commonwealth to poverty and disaster by needless waste.

Utilization of By-products

In the beginning of the twentieth century, the study in America of how best to utilize by-products was begun; and it was carried on in a rather desultory manner in the universities and some of the technical schools. The University of Kansas made a rather spectacular start in this line of research, the work being carried out upon a strictly business basis, and achieved quite a success; but soon thereafter, owing to a change in the personnel of the faculty, the endeavor was dropped.

It required the advent of the Great War in Europe to teach Americans that they must make themselves independent of the rest of the world by manufacturing at home all the necessaries of life for both peace and war. This condition aroused to action our chemists and chemical engineers, and incidentally caused them to study the utilization of by-products, thus materially increasing the wealth of the nation.

Restriction of the Term "Engineer"

It seems almost ridiculous or impossible of belief that the long-continued misuse of a name should seriously militate against the proper appreciation by the public of a great profession; but such certainly was the case. The term "engineer" formerly was applied indiscriminately to locomotive drivers, electric motor men, stationary-engine men, and even to the operators of insignificant gasoline engines, as well as to the members of the engineering profession; and the public was unable to distinguish clearly between the highly trained professional man and the roustabout engine-manipulator. For long years our profession failed to receive due public recognition; and this absurd misconception of terms was one of the principal reasons therefor. The trouble was finally overcome by the concerted action of the leading technical societies, both national and local, the members of which pledged themselves on every occasion to correct, either orally or in writing, every misuse of the term, irrespective of the standing or character of the delinquent. It did not take more than a twelvemonth to establish the change upon a permanent basis.

Avoidance of Disasters by the Extra Checking of Plans

About the end of 1917, after having had the idea in mind for several years, a well-known engineer-author suggested in the technical press that, in order to avoid disasters to great public or private engineering constructions, such as the two which occurred to the famous Quebec Bridge, all the plans for such structures should be thoroughly checked by an engineer or engineers of the highest standing who had not been in any way concerned in the making of the design, the compensation for such checking being paid by the client and not by the designing engineers. Although the scheme met with some opposition at first, it was eventually adopted. The non-occurrence of any great disaster of the kind during the last four or five decades affords ample proof of the wisdom of the precautionary expedient.

Code of Engineering Ethics

For many years our profession struggled along without having an established code of ethics—much to its detriment. Various technical societies made half-hearted attempts to establish codes, but most of them were "to laugh." A code suitable to one society did not prove acceptable to some of the others, and the large societies could not agree on the matter; but soon after the organization of our academy, we took hold of the subject methodically and energetically, and by means of a small committee, representing the principal lines of engineering activity, succeeded in evolving a code, which, after some slight modifications that were made to suit the desires of certain of the larger organizations, was accepted universally as standard. With the exception of a few minor changes made of late years, it is the code under which we all are now operating, and by which we are strictly governed in our dealings with each other, with our clients, and with the public.

Distinctions

Up to the time that the United States entered the Great War, there was a popular prejudice in our country against decorations and titles, on the plea that they were undemocratic; the government itself going so far as to prohibit its paid employees from accepting any foreign order of knighthood or any similar distinction, except through a special act of Congress. No matter, though, how much quiet sneering was done by Americans about the acceptance of foreign decorations by private citizens, it was to be noticed that none of them were ever rejected when offered.

Owing to the fact that in 1917 some of the governments of the Allies offered distinguished-service decorations for gallant conduct to several American soldiers, and that permanently to refuse them permission to accept the honor would have been discourteous to our friends, Congress early in 1918 repealed the law which prohibited the paid employees of the government from accepting orders, medals and other decorations from foreign governments. The result was that by the end of the war the "decoration habit" had taken such a hold on the American people that ere long several orders of knighthood and merit were formally established by Congress. Fortunately, the distribution of these honors has been kept absolutely free from political control; and to-day American men of learning prize these decorations far more highly than they do any pecuniary rewards that they receive in compensation for their professional services.

Minimum Charges for Professional Work

After years of effort on the part of the American Institute of Consulting Engineers, that society finally succeeded in having Congress pass a bill placing an inferior limit on the compensation for engineering services; and the profession ever since has been trying, with more or less success, to force its members to live up to the requirements. Our academy, while not actively engaged in this endeavor, gave the institute its moral support. The observance of this law has not only directly increased the compensation of the independent engineers but also indirectly has been the means of augmenting that of their salaried brethren; besides, it has raised the profession greatly in the estimation of the public.

Improvement of Technical Literature

Although the technical literature in America during the first two decades of this century was far superior to that of the preceding century, there was still considerable room for improvement. There were too many books on the market which either were merely compilations or were without *raison d'être.* Most of these were written by either professors of engineering who did not possess the necessary practical knowledge or by young practitioners, ambitious to make a name for themselves before they had earned their spurs.

By the appointment of a standing joint-committee of the Society for the Promotion of Engineering Education and our academy, and through an unrecorded understanding with the leading publishers of scientific books, no technical treatise will be published by these companies unless it receives the written approval of that committee. Moreover, in order to save authors' time, the committee stands ready to advise with would-be authors concerning any proposed treatise before actual work is begun on the preparation of the manuscript, or at any time subsequent thereto. The influence of this committee on the character of American technical literature has been marked. The quality has been improved, while the quantity has been lessened.

(*To be Concluded*)

WEATHER CONTROLS OVER THE FIGHTING DURING THE SPRING OF 1918

By Professor ROBERT DeC. WARD

HARVARD UNIVERSITY

THE military operations of the present spring (1918) have been of such critical importance in relation to the probable outcome of the whole war that all factors which have played any part in the fighting deserve careful attention. In the following article, the part played by meteorological controls is set forth as fully as is possible at this time. The facts here included have been collected from the regular official despatches, and from the reports of reliable war correspondents and military experts. It is obviously not possible, as yet, to do full justice to the subject, and some of the facts here included may need revision when fuller information becomes available.

Throughout the late winter and the first three weeks of spring, the probable date of the expected German offensive was a matter of momentous interest. No really active winter campaigns have been carried on in the western war zone. As a whole, the season of aggressive military operations has been April to November. In 1915, the spring campaign may be said to have begun on April 22. In 1916, the German Verdun drive was begun in late February (21st), at a season meteorologically unfavorable, in order, probably, to forestall the expected British and Russian spring drives. In 1917, the British inaugurated their offensive about Arras on April 9. Spells of warm, thawing weather characteristically come with increasing frequency in March and April, but unless the season is "early," major operations are more than likely to be held up by storms and bad roads until spring is well established. During last February (1918) there were, as usual, fogs, heavy rains and bad roads, but the increasing number of fine, warm days, accompanied by drying ground, caused the Allied commanders to expect an early German offensive. March "came in like a lion," with gales and snowstorms; heavy rains and cold, and then followed alternating spells of fine and warm, and of cold and stormy weather.

The great German offensive began on the early morning of March 21. From all the evidence that has so far come to hand it is clear that the time must have been carefully chosen after consultation with the meteorological experts. It was a spell of fine, dry weather ("exceptional weather favored his [the enemy's] designs"), and dry weather is one great essential, especially in the low country on the Western front, for the rapid movement of troops, of ammunition and of supplies. With heavy rains, deep mud and impassable roads, no quick, effective advance can be made. A dry spell in western Europe usually means that there is a well-developed area of high pressure to the eastward. This type of weather, when well established, is not unlikely to last for several days, longer, as a rule, than dry spells usually last in the early spring in the eastern United States. In western Europe, such spells bring easterly winds, which are often chilly, and also night fogs. Easterly winds are, furthermore, obviously favorable for the use of gas by the enemy, and also carry the smoke of artillery firing to the west, thus helping to screen the attacking troops.

Such conditions, easily inferred by any meteorologist who has a knowledge of European weather types, prevailed during the first ten days of the German offensive. All the meteorological factors were in favor of the enemy. The attack began in a thick fog along much of the front. The enemy advanced in many places unseen by the Allied troops, the smoke cloud also helping to serve as a screen. Gas was successfully used in various localities. The Allied gunners could hardly see their own horses; the firing had to be more or less haphazard; the infantry was obliged to advance without adequate artillery preparation. The surprise of the British 5th Army was largely attributed to the fog. Airplane observation was difficult along much of the front. In some places the fog evidently threw the assaulting German troops into confusion, the different units being temporarily unable to join forces as had been planned. As was to be expected, the easterly winds soon became colder, and the troops were reported as needing heavy overcoats, especially at night.

This spell of fine dry weather lasted, with but a few local and temporary interruptions in the way of showers or snow flurries, for a little over a week, but it was a week during which the enemy was able to make very considerable progress. Then heavy rains set in, continuing off and on, in spells, as is usual in the spring in Flanders. The Germans were at once greatly handicapped because of the difficulties of moving their troops, artillery and supplies through the deep and sticky mud. The weather conditions were then in favor of the Allies. The Germans had simply outrun their guns. There was some respite from the incessant German attacks, and there was time to perfect plans and to strengthen defenses. The mud did not hamper the Allies as much as the Germans, because the roads back of the Allied lines had not been so badly broken up by the gun-fire. The German papers mentioned the handicaps resulting from the rains, and explained the slackening of their offensive as being due to the weather. There is no reason to doubt that this was at least in part the case. It is clear that the condition of the roads, especially when the distance from their starting point was taken into account, made it unwise, if not impossible, for the Germans to continue their attempt at that time to break through between the British and French armies. The heavy rains may have played a more important part than many people imagine.

During the renewed German offensive, early in the second week of April, the enemy again took advantage of a thick early morning fog, during a dry spell, when the ground was hard. It was quite impossible for the Allied troops to see the enemy until the latter was very close to the front lines.

The April despatches make frequent mention of alternating spells of rainy and of fine, sunny weather; and of many German surprise attacks made in fogs (as, *e. g.*, at Mt. Kemmel on April 26), which are very frequent at all seasons on the western front. During the first week of April several days of rain brought a general suspension of major operations. Mr. F. H. Simonds, in his weekly account of the war, wrote:

> Perhaps if it had not rained he (the enemy) might have gotten through, just as Victor Hugo and other French writers insist that Napoleon would have won at Waterloo if it had not rained the night before, and delayed the French attack the next morning.

The dry spells were at once taken advantage of by the aviators for reconnaissance work and for bombing, and by the Germans, for renewed attacks. On April 20 there were reports of belated snow-squalls, and of inclement weather, accompanied by a temporary lull in the fighting. An interesting illustration of the marked attention paid by the Germans to meteorological conditions is found in the arrangements for moving troops in different weather conditions. According to press despatches,

> Orders are issued under which in the first zone, on clear days, foot troops may not move in any greater number than four men together, mounted men not more than two together, and vehicles not more than one at a time, with a minimum distance of 300 yards between groups. The

restrictions are relaxed when the weather is not clear, so as to permit the movement of groups of forty infantrymen, twenty cavalrymen, and ten vehicles. In the second zone it is permissible to form groups of the size allowed in the first zone on hazy days, but there must be intervals of 500 yards. In this manner movements generally escape attention.

Heavy rains fell on several days early in May; the roads were in very bad condition; shell-holes and all depressions were filled with water. That the expected renewal of the German drive was thereby delayed is undoubted. It is to be expected that, when so much depends upon the most favorable combination of all possible elements which may make for success, the enemy will wait for favorable weather conditions before attempting a general attack. To advance when the quick movement of reserves, of guns, of ammunition and of supplies is impossible, owing to the condition of the roads, is to run a very unnecessary risk. Several days of very fine weather, reported after the middle of May, were not accompanied by a renewal of the German offensive. One correspondent suggested that what the enemy wanted was misty, foggy conditions, such as he chose at the beginning of the first great advance on March 21. A Paris despatch, May 18, also intimated that "the beginning of the offensive by which the Germans expect to achieve final success now depends solely on weather conditions."

There is no doubt that the enemy took advantage of every spell of fine weather to improve his roads, and to bring up supplies and ammunition. One of the best-informed of the war correspondents, Mr. Philip Gibbs, wrote under date of May 24:

> Heavy rainstorms have broken up the fine spell of sunshine which made this May so splendid. This change does not fill us with regret, because dirty weather now may be in our favor, and hinder the enemy in his offensive schemes. . . . Bad weather, however, acts against both sides, and though they (the Germans) should be held fast in the mud, the British do not want to lose visibility for their flying men or machine gunners. . . . The enemy is very cunning in making use of climatic conditions, and adapts his methods to them.[1]

Berlin despatches, dated May 25, stated that the bad weather was preventing active operations.

The German offensive was renewed on May 27. At the time of sending the present article to the press, very few details regarding the meteorological conditions are available. So far as information has come to hand, it appears that the weather was fine, with bright moonlight at night. One Berlin despatch, of May 29, notes changeable weather. The delay in opening this new offensive has been ascribed, by one correspondent, to the

[1] New York *Times*, May 25, 1918.

desire of the Germans to postpone their attack until better weather conditions in the Trentino sector should make it possible for the Austrians to begin their offensive in that area.

There have been several interesting occurrences in connection with the use of gas. On April 10, four regiments of Prussian Guards were reported as having suffered severely during an attack on Armentières, when the wind shifted suddenly, and blew their gas back in their own faces. On May 12, another similar case was reported, the enemy becoming disorganized in consequence. A Swiss report dated Geneva, May 7, noted that the municipal authorities at Mülhausen, in Alsace, had ordered all inhabitants to obtain gas masks as a protection "against aerial gas attacks." The statement added that, owing to the prevalence of westerly winds, great quantities of the poisonous gases used by the Germans on the western front had drifted east, toward the Rhine. This story is hardly credible, for the gases are rapidly diffused and diluted when carried far by wind. It is worth noting that the Germans are now using gases in four ways. First, gas clouds, which depend on a favorable wind; second, projectors, which also depend on the wind; third, long-range artillery gas shells; and fourth, hand grenades. The direction and velocity of the wind enters as a critical factor in the first two cases. In connection with gas attacks of the first sort a good deal of information is now available. We know that the German "gas regiments" contain a considerable number of trained meteorological observers, who watch the current weather conditions. While the gas goes with the wind, it is clear that topography plays a part in its diffusion, which is best in a flat country, and poorest in a broken country. A recent writer, Major S. J. M. Auld, has told us that the outline of the trench system and the angle at which the wind is blowing are carefully correlated, in order that the gas shall not be driven back into any part of the German trenches. A "factor of safety" is determined for the angle between the wind direction and the line of the trenches. Ordinary gas attacks are not made when the wind direction is within about 45° of any trench within gassing distance. Further, details as to the most favorable wind velocity have been forthcoming. If the wind is too strong, the gas is dispersed, or moves too fast. If the wind is too light, it takes the gas too long to cross "No Man's Land." Very light winds are also more likely to change their direction than stronger winds, and may blow the gas back into the German lines. The best winds blow between 4 and 12 miles an hour. A wind of 8 miles carries the gas cloud about twice as fast as a man moves away who retreats rapidly. It is perfectly clear that the German meteorologists have made very careful study of wind and weather before launching such gas attacks, and their success, in a large majority of cases, shows how well their weather forecasts were made.

From the eastern front there is naturally very little to report. Here it was the ice—the result of the cold winter of the Baltic and its adjacent gulfs—that played a part. A Petrograd despatch, dated March 15, noted the movement of 3,000 German troops from the Aland Islands to the coast of Finland in transports, preceded by an ice-breaker. A later despatch (April 7) reported that the Germans were marching from the Aland Islands across the ice at the mouth of the Gulf of Bothnia towards Abo, on the coast of southern Finland, and that the arrival of the German fleet off the Finnish coast threatened the safety of the Russian ships at Helsingfors, which were unable to escape owing to the lack of an ice breaker. A British Admiralty statement, issued May 16, noted that several British submarines were frozen solidly in the ice in the harbor of Helsingfors at the time when the German naval forces were approaching. It was suggested that the ice be broken up around the submarines, and that they should then attempt to dive under the ice and reach open water outside the harbor. After careful consideration of this plan, the British commanders decided that it was impracticable. The submarines were therefore blown up.

There has been a good deal of discussion, since the war began, regarding the most favorable season for submarine activity. Opinions have differed on this question. At present, naval opinion in Washington seems to be that the season makes little difference. The smoother water and the longer daylight of summer are an advantage during that season, but these may be offset by the better opportunity which the submarines have, during the long winter nights, to come to the surface to recharge their batteries, to rest their crews, and to make long trips unsubmerged, thereby increasing their effective area.

It was not to be expected that there would be any considerable activity in the Trentino sector of the Italian front until well along into the spring. The deep winter snows of that rugged mountainous region are unlikely, under ordinary conditions, to melt sufficiently to make active campaigning possible until May, or perhaps even early June. Heavy snowfalls were reported early in March. On March 18 an Associated Press despatch noted that "the snow along the mountain fronts has been reduced considerably by mild weather recently, but the amount remaining is still sufficient to retard extensive operations." On the Piave front spring freshets made the stream "too wide and deep for crossing by considerable bodies of troops." Late in April (28th and 30th) severe winter weather prevailed along the Italian front, heavy snowfalls (6 feet deep in places) and "blizzards" being reported in the Alpine sector, and intense cold on the Venetian plain. Several days of torrential rain had swollen the Piave and Adige Rivers. Such conditions made an Austrian offensive impossible, the snow having obstructed the roads, and rendering the movement of the enemy troops very slow and difficult.

> The delay caused by the snow and the general atmospheric conditions permits the Italians to complete their defensive works, and add to their reserves of guns and ammunition.[2]

Shortly before the middle of May (10th) the Italians began the spring campaign, after a long period of winter inactivity, by capturing the dominating position of Monte Corno, a summit reported as 6,000 feet high, and still snow-covered. The topography and the snow presented great difficulties to the Italian troops, but the enemy was taken by surprise and a considerable number of Austrians were made prisoners. The advance of spring, accompanied by the melting of the snows and more favorable weather, led to the expectation, on the part of the Italians, of a speedy inauguration of the expected Austrian offensive. A Rome despatch, dated May 20, was as follows:

> The only obstacle which prevents an enemy attack immediately is the weather, which this year continues to be rainy, foggy, and even cold in some of the higher regions, with continual hailstorms. But the weather is becoming undeniably milder. The snow is beginning to melt, while avalanches often bury the emplacements and the huts which have been excavated.

During the last days of May, the Italians won a brilliant victory in the Tonale region, some 12,000 feet above sea level, northwest of Trent. The ground was still covered with snow, and the fighting was among glaciers.

In Palestine the British continued their advance. The weather was still on the whole favorable for military operations, the heat and drought of the summer not yet having really set in. An interesting illustration of the part played by local meteorological phenomena occurred on March 16, 78 miles northwest of Medina, when, under cover of a sandstorm, a company of the Turkish Camel Corps was surprised and destroyed.

[2] Rome despatch to Italian Embassy in Washington, May 4.

Both duststorm and Camel Corps bear witness to the climate of the region in which this incident took place.

In Mesopotamia there has been considerable activity. After months of preparation, the British have lately been advancing northward along both the Tigris and the Euphrates Rivers, the objective being Mosul, an important Turkish base. The hottest and driest season of the year is rapidly approaching, both in Palestine and in Mesopotamia, and major operations are not likely to be carried on in either country unless there is absolute necessity for the continuance of an active campaign. A report dated May 7 mentioned a heavy rain near Kerkuk (Mesopotamia). Such rainfalls are improbable again until the next winter rainy season sets in, after the almost intolerable heat of the summer and autumn is over. Major-Gen. Sir Frederick Maurice, in his war summary of May 24, said that

> Not the least of the advantages we have gained by our recent efforts is that we occupied a portion of the Persian foothills, which give a healthier country for the summering of our troops than the plains of Bagdad afford.

At sea, the weather factor has played a considerable part. In the daring raid on the German naval bases at Zeebrugge and Ostend (April 22), Admiral Keyes, according to the reports, waited for "certain conditions of wind and weather" before he gave orders for his fleet to cross the Channel. What the British wanted was a weather type which should combine an ordinary ocean fog with winds favorable for the use of a smoke curtain for purposes of concealment. The British vessels advanced under a dense smoke screen, aided later by a fog. Aerial work was necessarily interfered with. A clear and concise press report of the operations is as follows:

> The losses of the Zeebrugge raiders were due almost entirely to a shift of the wind, which prevented the complete success of the smoke screen. Fortunately, the wind held in the right direction long enough to enable the *Vindictive* and her consorts to approach the mole, but changed and dissipated the screen as the men landed. This enabled the Germans to find targets.
>
> At Ostend the shift of the wind came a little earlier and upset the plans of attack. Small craft with smoke apparatus ran in according to program and set up a screen. Then they lit two large flares to mark the entrance of the harbor for the concrete cruisers. Unfortunately, before these could get up, the screen was blown away and the German gunfire quickly destroyed the flares. This left our cruisers with nothing to guide them, and though they tried to proceed by guesswork under heavy fire, these gallant efforts were in vain.

According to Sir Eric Geddes, the difficulties at Ostend were "considerably increased by mist, rain and low visibility, and the consequent absence of aerial cooperation." The Italian naval exploit at Pola, which resulted in the destruction of an Austrian dreadnaught, was favored by a very dark night, and an offshore wind, which prevented the sounds of preparation from being carried landward.

The war in the air is being carried on with steadily increasing intensity. Aviators are flying in weather conditions—rain and snow storms; gales and mists—which were only very lately regarded as prohibitive. As aerial warfare continues on the western front, the disadvantage under which the Allied flyers labor because of the prevailing westerly winds are receiving more and more emphasis. As a well-known aviator has recently expressed it, "if an airman ever wishes for a favorable wind it is when he is breaking for home. . . . These westerly gales were one of the worst things we had to contend with at the Front. They made it very easy for us to dash into enemy territory, but it was a very different story when we started for home and had to combat the tempest." In connection with general air raids, several points are worth noting. On March 11 nine squadrons of German airplanes attacked Paris during a fog, which "was thick enough to cause the general belief that there was little chance that the Germans would attempt an air raid." It may very likely have been for this reason that these weather conditions were selected. A German raid on Hull and its vicinity on March 13 was also "completely unexpected. The night was dark, and a slight drizzle was falling." This raid, and others, have shown that the German aviators no longer depend on moonlight. Early in March, the Germans made their first night air-raid on London when there was no moon. The stars were out, however, and there was little wind. On May 19 another raid was made on a very clear night, when the moon was shining. On April 12 a German air raid on Paris was made on a "still, dark night, of the sort most favorable for an aerial attack, and a raid was generally expected." And on May 21, during another raid, the night was clear and calm, with a brilliant moon, "ideal for an aerial attack."

In connection with the work of the German army meteorological service, it has, since the beginning of the war, been a matter of some interest to know how the enemy obtains the observations, especially from the western coast of Ireland, which are very necessary in constructing weather maps and in making forecasts. Captured documents show that their meteorological reports are fairly complete, despite the fact that no publication of weather data or forecasts is permitted in English newspapers. An English meteorological expert declares that the answer to the question is not through any system of spies and land wireless, but that the data are obtained from observations taken by submarines. He thinks that a submarine working off the western Irish coast is detailed to send weather reports to Germany by relays through the wireless apparatus working around the British Isles.

In the African war zone, where so many political changes have taken place but from which so little direct information has come, the spring months have witnessed an advance of the allied troops on the remnants of the German forces which escaped from German East Africa to Portuguese East Africa. An official despatch dated London, April 11, says:

> In Portuguese Nyassaland, despite the difficulties caused by heavy rains and flooded rivers, our columns from the coast and from Lake Nyassa are approaching Medo and Msalu, respectively, and their advanced troops are in contact with those of the main enemy forces concentrated in these localities.

A later report (April 27) from the British War Office stated:

> Since April 17 the convergent advance of General Northey and General Edwards's troops has proceeded under better weather conditions. The main enemy force is in the vicinity of Namungo. British and Portuguese troops are moving in the direction of Msalu River, while further south other British and Portuguese columns have been disposed north and south of the River Lurio.

PLANT AND ANIMAL LIFE IN THE PURIFICATION OF A POLLUTED STREAM

By C. ELSMERE TURNER, M.A., C.P.H.

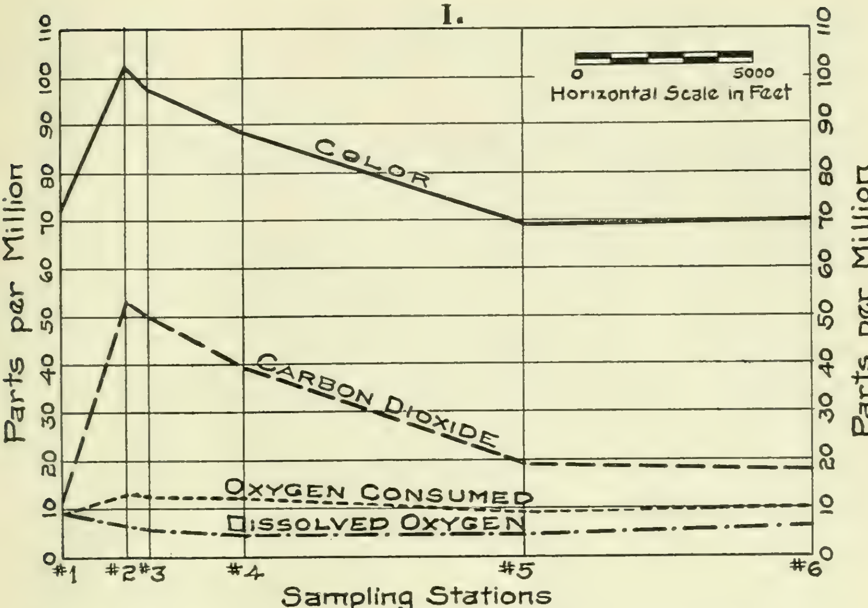
INSTRUCTOR IN THE DEPARTMENT OF BIOLOGY AND PUBLIC HEALTH, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

RIVERS and other streams have always been resorted to by man for the disposal of his wastes. And yet unless greatly overtaxed they remain fairly clean. The problem here raised reminds one of that wonder of the ancients that all the rivers run into the sea and yet the sea is not full. What becomes of all the dirt and the street-wash and the sewage that find their way into our streams?

The "self-purification" of streams is an old and captivating phrase graphically describing a process which is patent even to a superficial observer. On the Merrimac, for example, Concord, Manchester and Nashua, important cities of New Hampshire, poured all their sewage into the noble river flowing past their doors, while Lowell, Mass., only sixteen miles below Nashua, did not hesitate to drink the water now again clear and bright, which reached the intake pipe of its city water works. More wonderful still, Lawrence, only nine miles below Lowell, drank directly from the same stream after the sewage of the 80,000 inhabitants of that city had been added to it. Alternating pollution and purification is the common characteristic of streams. The mechanism of pollution is obvious, but how about the process of purification? It was to throw further light if possible upon the self-cleansing of polluted streams, that the Sanitary Research Laboratory of the Massachusetts Institute of Technology carried on for two years an investigation of a small stream polluted by a relatively large quantity of partially purified sewage effluent which reaches it from slow sand filters.

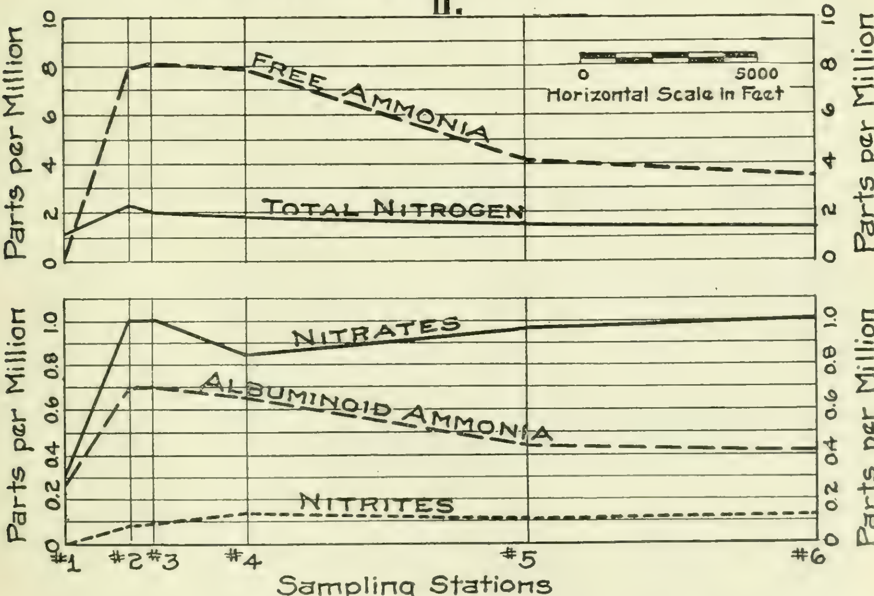
Whence comes the water of a normal brook or river? The answer is, partly from the atmosphere as rain or snow, partly from the earth's surface through tributary rills or brooklets, but largely from the ground upon which it has fallen, through which it is filtered, and from which it arrives comparatively pure from all but the smallest suspended matters. This ground water, however, does contain dissolved gases and salts together

I.



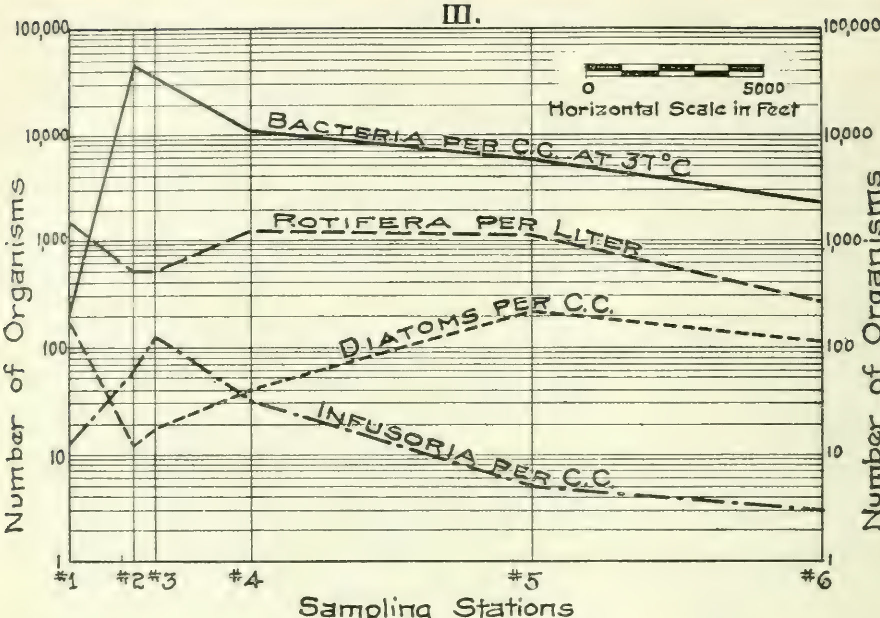
Yearly Averages of
COLOR, CO_2, O_2 CONSUMED AND DISSOLVED O_2
at Stations #1 to #6 Inclusive

II.



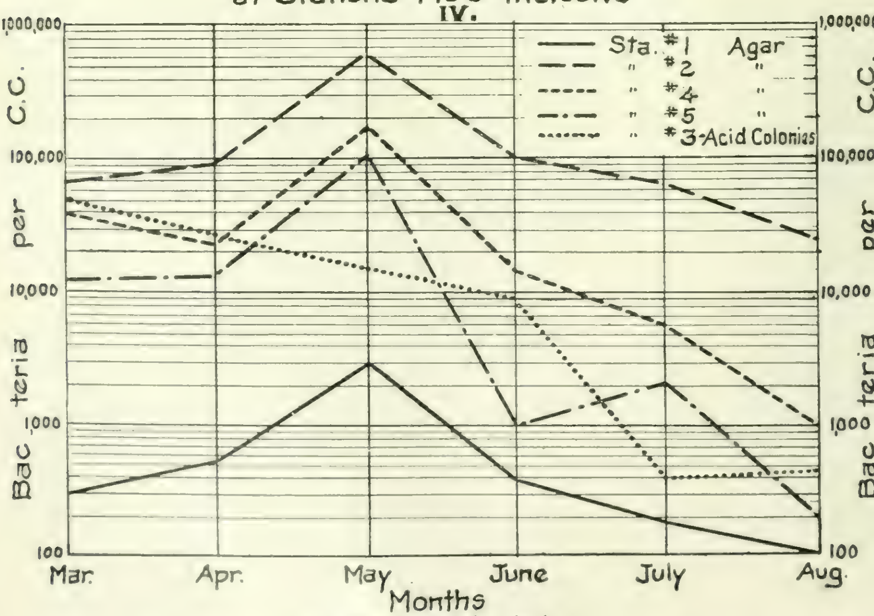
Yearly Averages of
NITROGEN AS FREE NH_3, ALBUMINOID NH_3, NITRITES,
NITRATES AND TOTAL N at Stations #1 to #6 Inclusive

III.



Yearly Averages of
ORGANISMS
at Stations #1 to #6 Inclusive

IV.

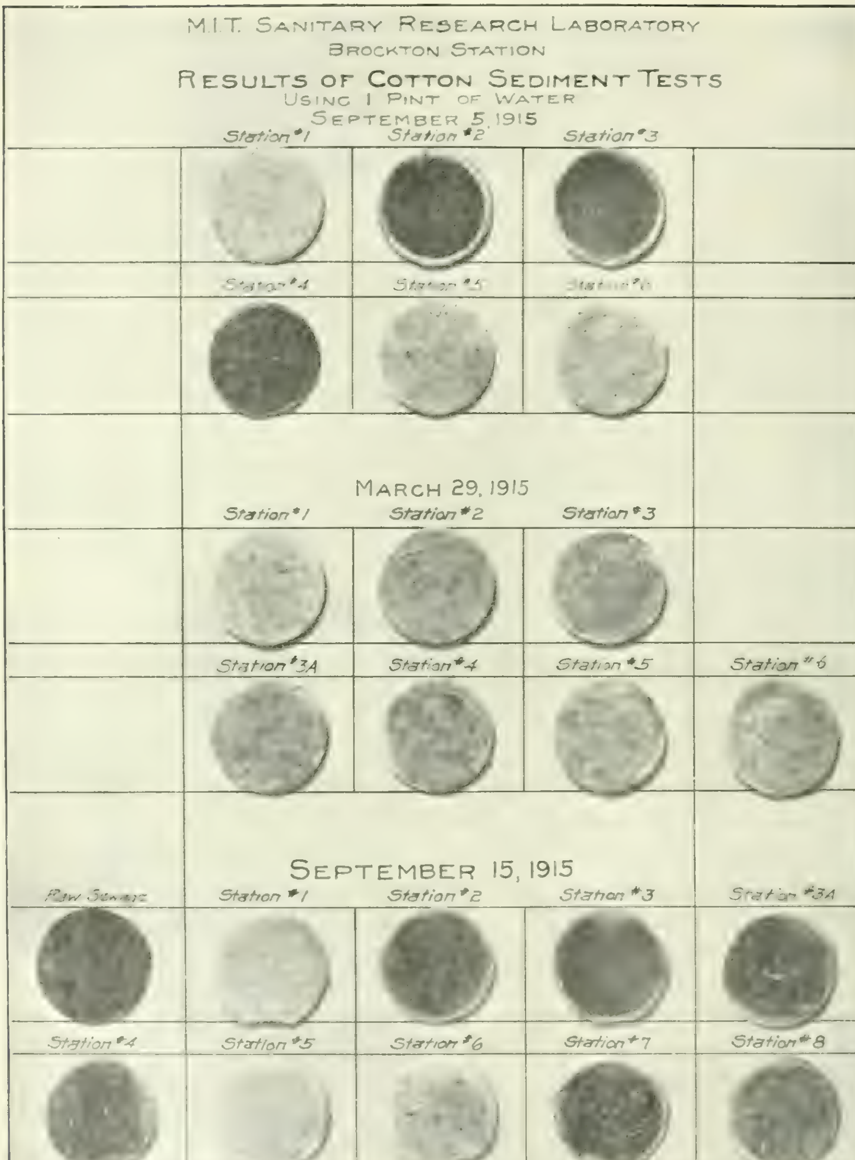


Average Monthly
TOTAL BACTERIA AND ACID COLONIES ON AGAR
for the 6 Months ending Sept. 1, 1915

with a small amount of organic matter. On the other hand, water which arrives after a journey overland generally brings with it more or less dirt and débris. In the stream under consideration, contributions of a large volume were received from the underdrains of artificial sand fields upon whose surface had been poured the Brockton city sewage. A strange and heavy burden was thus laid upon a quiet stream hitherto unpolluted. The first thing that happened was a mixture of two very unlike waters, that of the brook and that of the underdrains. This little creek of pure water with a summer flow of only one half million gallons per day, bright, clear, sweet smelling, containing little carbonic acid and few bacteria, poor in nitrates, poor in organic matter but rich in dissolved oxygen, becomes charged with a daily flow of two million gallons of water poor in oxygen, laden with carbon dioxide, burdened with bacteria, rich in plant foods, malodorous and full of broken-down organic compounds of uncertain composition and dubious ancestry. Forthwith various fermentations and other mysterious biological operations begin.

Above the Brockton sewage beds the brook has a clean, sandy or peaty bottom and the usual variety of plants and animals to be found in a clear New England brook. As the first effluent drains pour in their contribution, the bottom of the stream in summer becomes brown with a gelatinous growth of the iron bacterium, *Crenothrix*, which may occur to a depth of two or three inches over the whole bed of the stream. As the proportion of polluted water is greater, the bottom becomes black with organic material which has settled out from solution and suspension together with silica and other inorganic material forming a sort of "pollution carpet" or "false bottom" in which biological activity is very intense, and where chemical changes are rapidly taking place. There are many bacteria in the polluted water but the number in this bottom mud is much greater, while protozoa, rotifers, worms and insect larvæ also abound. The sides of the stream in many places are gray with furry growths of the colonial protozoa, *Carchesium*.

Throughout the regions where this false bottom is present —and it extends for three fourths of a mile below the filter beds —there may be seen large patches of the red worm, *Tubifex tubifex*. The countless individuals making up these colonies of bristle worms, so typical of pollution, remain with their heads in their burrows, the tails, like a red flag of pollution, waving in the water above them in search of oxygen. They quickly disappear into their holes at the slightest disturbance



in the water such as might be made by the approach of a fish, for it must be noted that higher animals are not driven away by the amount of pollution here present. Minnows are frequently seen in this part of the stream, often nibbling at the furry growths of *Carchesium* mentioned above. In the spring suckers are to be found here and occasionally brook trout or brook pickerel make their appearance. They are, however, more abundant in the stream below or above the area of greatest pollution. Snapping turtles, water snakes and the green frog, *Rana clamata*, are frequently seen and the valley of the brook contains an abundance of bird life including wild ducks, crows, robins, bobolinks, blackbirds, grackles and sparrows.

By far the most conspicuous of the insect larvæ in this region of abundant food material is the "blood worm" or larva of the midge, *Chironomus decorus*, which is one of the most efficient scavengers of this type of stream bottom. The mature insect is about the size of the mosquito and in appearance bears a close resemblance, although fortunately its habits are much less objectionable. In this species there is no irresistible impulse to gorge itself with blood and usually the mature form never feeds. The eggs are laid in rows in a gelatinous sack which is attached to some object at the surface of flowing water. Each sack contains 1,200 to 1,500 eggs and so numerous are they that a partly submerged railroad tie was found to furnish a hatching place for over 300,000 midges. The larva is hatched as a white wiggler nearly 1 mm. long which soon settles to the bottom and spends most of its time in eating, growing in three or four days to one fourth of an inch in length and taking on a pink color which soon develops into a brilliant red. At this time the larva begins to make a case for itself by gluing together the material about it with a gelatinous substance from its salivary glands. In many places on the muddy and soft stream bottom, these little mounds, each with an opening at the top, number four or five hundred per square foot. A 30 c.c. sample of bottom mud collected to a depth of 2″ in August, 1914, contained 130 of these larvæ. The larval period lasts from several days to several weeks depending upon the temperature, then follows a brief pupal stage in which the insect undergoes metamorphosis and at the end of which the pupa, which is also active, rises to the surface. The pupal case is split along the back, the imago emerges, rests for a minute on the floating pupal case and then flies away. If the good fortune by which it escaped fish and predatory insects continues and it is able to avoid the numerous dragon flies and other enemies for a day or two it reproduces and dies. From the omnivorous habits of the larvæ, their value as food for fish, and the number of mature insects which leave the water entirely, it is obvious that *Chironomus* is an important factor in the removal of organic matter.

Of the great variety of insect larvæ found in this region, mention may here be made of only one other, the larva of the

Midsummer view of the Stream from near Station 2. This shows the part of the stream which is receiving pollution from the sand sewage-filter beds. Note that the stream is somewhat swifter here and the vegetation on the banks is most luxuriant. From photo taken July 21, 1915.

club-footed gnat, *Ptychoptera clavipes.* These brown air-breathing larvæ have the same habitat as do the blood worms, although they are not as numerous or as important from the standpoint of stream purification. The first generation appears about the middle of March and from that time they are abundant until late fall. Both the larval and pupal stages are

A corresponding view on January 26, 1916, showing where some of the sewage effluent drains enter the stream, as well as the appearance of the banks in winter and the increased volume of water.

to be found in relatively shallow and quiet water with the elongated breathing tubes reaching to the surface.

It must not be concluded that plant life is absent from this region. To be sure the variety of higher plants disappears at the point of pollution, but one by one these plants reappear as the pollution is reduced, so that the region three quarters of a mile below the filter beds contains the rankest growth of water plants to be found in any part of the stream. Throughout the summer and until late fall they choke the stream in this region, reducing the velocity of the current, furnishing shelter to a wide variety of smaller animal and plant forms, supplying oxygen to the stream, and acting as a contact filter upon which may settle out suspended and colloidal substances. So efficient is this filter that attempts to measure the velocity of stream flow by adding a coal-tar dye to the water were completely frustrated.

In the masses of these plants as well as upon the stream bottom, there may be found innumerable snails and small crustacea. Upon one occasion fifty snails were gathered by one scoop with the two hands at a point one half a mile below the filter beds. The Isopod, *Asellus*, which is present in all parts of the stream, is so abundant here that as many as twenty may often be seen upon a square foot of the stream bottom, while a handful of water grass or pond weed may contain twice this number. Smaller crustacea, the water fleas, are also abundant, their presence being correlated with that of the simple green algæ. In a pool a short distance below the filter beds the water is green in summer with *Chlamydomonas* and *Euglena*. At such times the Daphnia-like form, *Simocephalus*, is so abundant that even the surface water contains more than one thousand per liter. In all these the digestive tract is filled with the green flagellates which appear to constitute the chief food. Special chemical tests show that there is a daily seesaw between the oxygen dissolved in the water and CO_2 under these conditions. The former goes up continually through the daytime under the stimulation of sunlight upon the chlorophyll-bearing flagellates, and the latter goes up continually through the night because of animal activity, the total volume of oxygen in the two gases remaining practically constant. In the fall when these water fleas are most abundant myriads of *Hydra* are found throughout the higher plants.

This in brief is the picture of the stream as we find it through the summer months, when it teems with an activity so

This view, looking north near Station 4, July 21, 1915, shows how completely the higher aquatic plants fill this part of the stream in summer. Station 4 is located at a point in the very center of the picture.

intense that the term "living earth" as applied to the bottom of a polluted stream takes on a new significance. We are better able to understand the intensity of this biological digestive process when we add to our picture of these larger forms a measure of the microscopic organisms to be found in the water and some measure of the chemical process which is here carried on. The accompanying diagrams show the quantity of chemical substances and microorganisms in the water

A corresponding view, January 26, 1916, shows how differently this same region appears under winter conditions and high stream flow.

at various points, Station 1 being on the unpolluted stream above the filter beds and Station 2 at the point of greatest pollution. The distance from Station 2 to Station 3 is 980 ft., to 3a it is 2,000 ft., to 4 it is 3,650 ft., to 5 it is 11,580 ft. and to 6 it is 19,700 ft. The discussion thus far has been confined to the area between Stations 2 and 4.

Chemical changes are also graphically shown. By careful measurements and computations from our chemical analyses, it was found that in summer the average reduction in total organic nitrogen, as measured by the Kjeldahl process, in the first three quarters of a mile below Station 2 was as great as 39 lbs. per day. If we were to consider this upon the basis of protein consumption, it would mean that the equivalent of more than 150 lbs. of beefsteak is digested daily by the small stream in traveling this distance.

Standard chemical and bacteriological methods were used in making the weekly analysis from which the averages here graphically represented were computed but the method of securing the biological data may require some explanation. It was soon learned that quantitative determinations of micro-organisms according to the Sedgwick-Rafter process were of little value if the samples were collected from the surface water. The forms thus found were the floating organisms which had been brought down from up the stream instead of the forms "working" at that point. Accordingly the bottom of the brook was disturbed across its entire breadth by means of a garden rake and a sample from the clouded water thus produced collected in a 500 c.c. wide-mouthed bottle at a depth of 6 inches below the surface. Naturally these samples were somewhat widely varying but since they were collected near the surface they can not overestimate the number of organisms and the graphs made from the yearly average really show the effect of pollution upon the smaller plant and animal life of the stream.

A word should be said about this region in winer. Early in December the higher plants disappear. The volume of the stream increases to ten or occasionally twenty million gallons per day, the nitrification of the sewage in passing through the sand filters is less complete and the whole stream presents a markedly different appearance, as may be seen from the accompanying photographs. At about this time, the water mould, *Leptomitus*, appears near the effluent drains and within a couple of weeks covers the bottom and sides of the stream throughout the first three quarters of a mile of its flow. There are literally tons of the mould present, which soon changes from its fleecy white appearance to a dirty gray color because of the accumulation of dirt and organic matter which has settled upon it from the polluted water. This is a new pollution carpet which nature has spread over the bottom of the swollen stream for the winter season. Among the threads of the mould intense biological activity takes place. As many as 400,000 bacteria per c.c. are present and the protozoa (*Colpidium, Chlamydomonas, Euglena viridis, Euplotes*) total 125 per c.c., while *Asellus*, midge larvæ and naid worms are abundant. The stream overflows the meadows, and over these acres of flooded marsh land, *Leptomitus* occurs in abundance. The water shows little or no improvement in this region in winter beyond that directly due to dilution, and because *Leptomitus* is continually breaking down and flowing along with the current, some samples in early spring show even more organic matter three quarters of a mile below the filter beds. At this season the meadows become covered with filamentous green algæ (*Conferva* and *Spirogyra*) which grow with *Leptomitus* and gradually supplant it. The fungus is figuratively driven up the stream and into the mouths of the effluent drains to emerge again the following winter. The algæ appear first at some distance down the stream and slowly work their way toward the point of pollution. As the water subsides, these growths are left as a black deposit on the soil resembling sewage scum in appearance. With the arrival of warm weather the filter beds become more efficient, the zone of greater pollution which is measured by the presence of *Leptomitus* is shortened, the biological activity of the stream increases and summer conditions return.

We have as yet considered only the first three quarters of a mile of the polluted stream. At this point a small effluent stream joins the one under observation and during the summer months the self-purification mentioned above is so important and complete that below this point, from a biological point of view, the stream is comparatively normal except perhaps that more plants are present because of the greater amount of plant food. The false bottom no longer persists and to the casual observer nothing unusual would be noted either in the water or plant and animal life.

Samples were taken regularly at points one mile and two miles below the juncture of the two streams with results which appear in part in the accompanying diagrams. The chemical studies reveal the presence of distinct pollution, but it is clear that biological activities are less intense and that, because of this, chemical changes are much slower. In the winter when the purification is much slower and depends largely upon the factor of dilution, these lower regions of the stream are in a worse condition. But *Leptomitus* is never found growing below the juncture of the two streams except for such small masses as may be carried down by the current and persist temporarily. The chief interest, therefore, attaches itself to the more intense digestive process above described, showing how nature lends her assistance to the sanitary engineer, enabling him to carry the sewage effluent of the shoe manufacturing city of 65,000 people into a tiny brook only six or eight feet wide.

The complete details and conclusions of a two years' study are contained in the original report, but some of the general facts, without special reference to quantitative results, may be briefly stated. It is obvious that the biological factors of stream purification are much more important than the strictly chemical and physical factors. The activities during the summer months were sufficiently intense to take care of the burden being placed upon the stream at that time and also to remove the load of pollution which the winter had left. Certain organisms are characteristic of an unpolluted stream. Others are characteristic of pollution and by their presence and numbers indicate the intensity of biological activity. Some forms like rotifers and certain green algæ may be present in either polluted or unpolluted water and their correlation with each other and various plants and animals must be understood to appreciate their significance.

The organic matter, introduced with a sewage effluent, results in the increase of organisms in a cycle beginning with bacteria and ending with the higher forms, each type of animal appearing with a definite food supply. A comparison of this investigation with studies made upon other streams and grosser types of pollution shows that the smaller, shallower and more nearly stagnant the body of water with which the pollution is mixed and the more nitrified and clarified the effluent, the more rapid is the succession of zones of higher animal life and the more complete the process of purification.

EVOLUTION BY MUTATION

By Professor T. H. MORGAN
COLUMBIA UNIVERSITY

STUDENTS of Mendelian heredity have shown during the last seventeen years great reluctance in bringing their results to the bar of the evolutionary theory. They have hesitated, I think, because they felt that they had in hand a body of well-established information in regard to heredity which they did not want to compromise by applying to it the kind of procedure that in other fields of evolution is, even to-day, taken seriously.

The pressure on the Mendelians has come, then, from without rather than from within. But the Mutationists and the Mendelians are twin brothers because they appeal to the same scientific procedure, viz., analytical experimentation, and because both study the process of discontinuous variation. It has been more than insinuated, more than once and from more than one quarter, that the kind of unit characters that the Mendelians are studying has nothing to do with the kind of characters that evolution has to deal with. On what kind of evidence is this assertion based? Evidently it has its roots in the notorious fact that the Mutationist pays very little attention to the kind of a character that he uses in his work; the more extreme, the better, because he can the more easily identify it. But *he* knows (although the systematist tries to make it appear that he does not know) that between such extreme and even bizarre characters, and those that systematists themselves use for diagnostic purposes there is every gradation conceivable.

Species as Groups of Genes

One of the most interesting ideas that De Vries brought forward in his mutation theory was that groups of "small species" or of varieties are made up of many common genes and differ in a relatively small number of genes. The genetic analysis of a group of smaller species would consist in finding out how the different genes were distributed amongst the members of this group. Phylogenetic relationship comes to have a different significance from the traditional relationship expressed in the descent theory; but this point of view is so novel that it has not yet received the recognition which we may expect that it will obtain in the future when relationship by common descent will be recognized as of minor importance as compared with relationship due to a community of genes while differences are due to different combinations of genes.

If related species have many genes in common they may be expected to produce at times the same mutants. In fact, it is not at all uncommon to find even in Mendelian literature such forms as albinos spoken of as though they represent the same mutation wherever it arises. Attractive as such a view appears, experience has shown that it is very unsafe to judge as to the nature of the mutation from the appearance of the character alone. Two different white-flowered races of sweet peas are known which give the wild purple-flowering pea when crossed, showing that they represent different mutations. Similarly, at least two recessive white races of fowls are known, as well as a third dominant white race. Three independent mutations have produced white birds. Whether albino mice, rats, rabbits, squirrels and guinea pigs have arisen through a mutation in the same common gene can not be determined because they can not be crossed to each other. When we consider that many factors may combine to produce a given pigmented animal and that a change in any one of them may affect the end result, it will be evident that the expectation would be against rather than for the conclusion that the same gene had changed in all cases. Only when it could be shown that a particular gene of the complex is more likely to change in a given direction than other genes of the complex would this interpretation become plausible.

There is some evidence in *Drosophila melanogaster* showing that the same mutation to white eyes has occurred several times, and the additional and all-important proof obtained that it is the same locus that has produced the white-eyed mutant. This may appear to give some slight support to the view that albino mutants appearing in other related species may be due to the same mutative changes but without additional evidence this conclusion is problematical.

In the mammals melanic individuals have been frequently described, but there is no direct evidence to show that they are due to the same change. In the roof rat there is a black type that is dominant to the gray of this race, while the black type of the Norway rat is recessive to the gray of that race. It seems probable that they are different mutations but not necessarily so.

Yellow in the mouse is dominant and lethal; two races of yellow rats are known, both recessive forms. The relation of yellow to black in mice is different from the relation of either of the yellows to black in the Norway rat. If the blacks are the same mutant the yellows are different, if either yellow of the rat is the same as the yellow of the mouse the blacks must be different, etc.

The uncertainty of reaching any conclusion in regard to the nature of the mutation from the appearance of the character of the mutant is excellently illustrated in such a group of mutants as that of the fruit fly, where a considerable number of cases are known in which mutants that are almost indistinguishable externally have been shown to be due to mutations in different parts of the germ plasm. There are five kinds of black mutants, three or more yellows and several eye colors that are practically indistinguishable. The evidence showing their difference is based on the results of crossing, where, as a rule (except, for example, for complete or incomplete dominants), reversion to the wild type occurs. In addition, the localization of the gene causing the modification shows them to be different.

The method of localizing genes opens up an opportunity for obtaining evidence in regard to like-mutants in related species that can not be crossed and a step forward in this direction has been taken by C. W. Metz for other species of the genus *Drosophila*. In a species, *D. virilis*, he has had 12 mutants appear and these fall into three groups of linked genes. Three of them, yellow, forked and confluent, resemble externally characters of *D. melanogaster*. Yellow and forked are sex-linked and look like the same characters in *melanogaster*. Confluent is like a second chromosome character of the same name in *melanogaster* in three respects: first, the structural similarity, second, that the character is dominant in both forms, and third, that it is, Metz thinks, lethal in homozygous state. The terminal position of yellow and the large amount of crossing over with forked are roughly speaking the same in both.

Even in this case further work is needed, first, because within the same species the occurrence of similar-looking characters due to different factors is known, *i. e.*, there are two genes for yellow color (yellow and lemon) in the first chromosome and in the same part of that chromosome, and second, because it is not to be expected that the number of crossovers would be identically the same between the same loci in different species, since marked variations are known within a single species.

Unless such species can be crossed the only convincing evidence that we can hope to get will be to establish the same *linear order* in the chromosome for several genes whose characters appear to be the same or similar.

Is the Direction of Mutation given in the Constitution of the Gene?

Whether we think of the gene as a complex molecule or as a quantity of material holding together through cell generations, it seems plausible that its mutations will be conditioned by its nature. If it is a molecule these changes may be strictly limited, numerous though the possible changes may be; but if it is only a definite "quantity" of something, the amount of its increase (plus) or decrease (minus) might *seem* less restricted, since any amount of increase or decrease might appear possible. We are left to pure speculation. Do the observed facts of mutation furnish any data on which to base even a guess? As has been said, we are scarcely warranted in drawing any conclusions from the nature of the character as to the nature of the gene, because, *a priori* at least, any change in the gene might cause an increased or decreased effect on the characters chiefly influenced by that gene. If, however, we boldly disregard this danger it may seem plausible that the building up of a complex molecule would be more likely to have a more limited range of possibilities than the rearrangement or degradation of that molecule. If this could be made probable, progress, in the sense of greater genic complications, would seem less likely to occur than degeneration. As hinted before, the recessive nature of the great majority of observed mutations might seem to harmonize better with this view. But we are too ignorant concerning these questions to make a discussion of them profitable.

Is the outlook any brighter if we take only quantitative changes in the gene as a basis for speculation? If the gene varies about a modal amount that accounts in part (for the environment also comes in here to complicate the effects on the character) for the degree of development of the character, it would seem to follow that the more the amount of the gene, the greater its effect on the character, and the less its amount, the smaller its effect. If we go further and suppose that nearly the maximum amount of a gene possible under the physiological conditions of the cell is more likely to be that maintained by selection in the wild species, it would follow that decreases in this amount are more likely to happen than increases, hence the more frequent occurrence of mutation by loss or recessive mutations. The facts concerning allelomorphic series indicate that the amounts "lost" (if the change is of this sort) are not progressive, but, so to speak, haphazard, and this, too, is consistent with the idea that such recessive changes may involve any amount of loss. Contrariwise, if the upper range in amount is near the maximum possible for the cell physiology, positive advance might take place more gradually and progressively, giving changes like those of orthogenesis claimed by paleontologists and some systematists to be the way in which species advance. This hypothetical situation is, however, uncertain in a high degree the moment one realizes that changes up and down of a character appear more often brought about now by one, now by another gene, rather than of the principal one, *i. e.*, the one on which, owing to a mutation, especial attention is focused. In fact, at present it is not even probable that progressive character changes are generally due to progress in the principal gene (except in multiple allelomorphs) and there is verifiable evidence in the only cases where really crucial evidence has been obtained that the changes are due to other genes.

It is true that when writers have brought forward evidence of continuous and progressive change in a character they have not concerned themselves with the analysis of the change in the germ plasm that has brought it about—in fact, in most of these cases the possibility of advance in a principal gene or of advance through modifying genes had not been appreciated or even understood. Paleontologists who have in the main been the strong advocates of orthogenesis have based their conclusions on the observed advances in a character in the same series and in "parallel" series. They overlook the fact that to-day there is experimental evidence demonstrating that variations as small even as those they record have been shown to rest on mutational stages. If the progress has been in the direction of adaptation, natural selection of small mutant differences will completely cover their findings. If it is claimed that in some of these cases the orthogenetic series is not in the line of adaptive advance, the burden of proof lies heavily on their shoulders. Moreover, the fact that recent work has made clear that genes generally have more than a single effect on the organization opens wide the door of suspicion, for the observed morphological progress might be a by-product of influences that have other and important, though unseen, effects. In a word, an orthogenetic series of changes does not in itself without a closer analysis than has as yet been furnished, establish that an *innate* *principle, urge, vis-a-tergo, or driving "force"* is causing the successive moves. The genetic evidence from multiple factors must create at least a strong suspicion against the "will to believe" in the mystic sentiments for which these terms always stand. That a progressive series of advances in a gene might take place with a consequent advance in the many characters involved is *thinkable,* especially if it could be shown that environmental changes cause parallel progress in the gene and this in turn in the character. How *probable* this is the reader must decide for himself in the light of the very clear evidence that each character is affected by changes in many genes differently located in the germ plasm and that it is not a progressive change in one gene that makes selection possible but changes in any one of many genes.

Chance Mutation and Natural Selection

The mutation process rests its argument for evolution on the view that among the possible changes in the genes, some combinations may happen to produce characters that are better suited to some place in the external world than were the original characters. Apparently this appeal to chance, like Darwin's appeal, has offended some sentimental adherents of the doctrine of organic evolution, because it has seemed to them inconceivable that chance could ever bring about the assembling of such an intricate piece of machinery as a highly complex organism. The attempt to mitigate the rude shock of the appeal to chance was made by Darwin by pointing out that evolution had been gradual and that the assemblage has not taken place out of chaos, but each stage has been built up on one a little less complex than the preceding one. Nevertheless, the fact remains that persistent efforts continue to be made from time to time to introduce into the theory of evolution some sort of directive agent. The Lamarckian theory has tried to bring about a more immediate relation between the organism and its environment of such a kind that the adaptive change that appears in the body as a result of a reaction between the environment and the animal or plant is reflected into the germ plasm. Bergson has cut the knot by postulating an innate adaptive responsiveness of the animal to every critical situation that calls out a response. The adherents of orthogenesis appeal, apparently—in so far as they commit themselves—to some sort of innate principle that causes advance in complexity along one line and they seem to hint at times even along directed lines of adaptation. Still more elusive are vague appeals made to some unknown principle—some sort of Mystical Element resident in living material and peculiar to it that is *Responsible* for evolution.

We are not concerned with any of these so-called "Laws" or Principles or Agents, but there is a relation between chance and evolution shown by living things that has been largely neglected, or at least vaguely referred to, even by natural selectionists, that is of fundamental importance when evolution is treated as a phenomenon of chance.

This relation may be stated in a general way as follows: Starting at any stage, the degree of development of any character increases the probability of further stages in the same direction. The relation can better be illustrated by specific cases. The familiar example of tossing pennies will serve. If I have thrown heads five times in succession, the chance that at the next toss of a penny I may make a run to six heads is greater than if I tossed six pennies at once. Not, of course, because five separate tosses of heads will increase the likelihood that at the next toss a head rather than a tail will turn up, but only that the chances are equal for a head or a tail, so that I have equal chances of increasing the run to six by that throw, while if I tossed six pennies at once the chances of getting six heads in one throw are only once in 64 times.

Similar illustrations in the case of animals and plants bring out the same point. If a race of men averages 5 feet 10 inches, and *on the average* mutations are not more than two inches above or below the racial average, the chance of a mutant individual appearing that is 6 feet tall is greater than in a race of 5-foot men. If increase in height is an advantage the taller race has a better chance than the smaller one. This statement does not exclude the possibility that a short race might *happen* to beat out in increment of growth a taller race, for it might more often mutate; but chance favors the tall. In this sense evolution is more likely to take place along the lines already followed, if further advantage is to be found in that direction.

A rolling snowball that already weighs 10 pounds is more likely to reach 15 pounds than is another that has just begun to roll. The chance that a monkey could change into a man is far greater than that ameba could make the transition. The monkey has accumulated, so to speak, so many of the things that go to make up a man that his chance of reaching that goal is vastly greater than ameba's.

There is also a peculiarity of animals and plants that assists greatly towards progress along lines already started. The individual multiplies itself, and a new mutant character that is advantageous becomes established in a large number of individuals, or even in all individuals of the race. The number of individuals increases the chance of a new random mutation along the path already taken. It is true that the number also increases the chance of a random variation in the opposite direction but as this, by hypothesis, is the less advantageous direction it will fail to establish itself in numbers.

Artificial Selection and Mutation

Darwin built up his evidence for natural selection, and even for evolution, on the *artificial* selection of *variations* of animals and plants under domestication. It is in this field that the student of Mendelism revels. Almost without exception he finds that the domestic races of animals and plants are built up by mutational differences. It is this evidence that to-day is a hundredfold stronger for the theory of evolution than it was in Darwin's time. Shall we turn our back on it now when the evidence is clearer than ever before that the variations shown by domesticated animals and plants are in no way distinct from variations in the wild type?

The slightest familiarity with wild species will suffice to convince any one that they differ from each other generally not by a single Mendelian difference, but by a number of small differences. The student of Mendelian heredity at least is not likely to fall into the error of identifying single Mendelian differences with the sum total of differences by which wild types and often even wild varieties differ from each other. And whenever he has had an opportunity to study these single differences in wild varieties he has found that they seem to originate and to be inherited in the same way as other Mendelian characters.

To-day it is possible, in several groups where many small differences are known, to reconstruct races of individuals containing several of these small differences that any trained systematist, ignorant of their artificial origin, would classify as good species. To deny this shows only unfamiliarity with the genetic field; to admit it is to concede all that is claimed in favor of the theory that mutants may furnish the materials for selection.

PLANNING A RESEARCH LABORATORY FOR AN INDUSTRY[1]

By Dr. C. E. K. MEES

ROCHESTER, N. Y.

DURING the last two years the importance and value of industrial research has become widely recognized; and there has been a general awakening on the part of those who control industries to the desirability of including in their organization a research laboratory to act as a nucleus of scientific knowledge for the industry, and to carry out specific investigations which are judged to be of value.

When the executive directing such an industry, however, looks for information as to how to proceed in order to establish a research laboratory, he is likely to find that the specific information which he requires is by no means easy to obtain. While there are many articles pointing out the value of a research laboratory, little has been written as to the steps which should be taken by an industry that has determined to establish one.

Let us take the hypothetical case of the vice-president of a company who, as a result of his reading, has become convinced of the desirability of establishing a research laboratory, but who, himself, has no experience in scientific work of any kind, knows only that the greater part of scientific research is done in university laboratories, and has no idea either of the cost of a laboratory, of how it should be established, or of what return he can expect from it. What is he to do in order to present a specific case to his fellow executives, or to proceed in the establishment of a laboratory, should he be empowered to do this?

The object of this paper is to suggest a specific answer to the problem of such an executive, putting the answer in such terms that it may be applicable to a large number of different industries.

In considering the organization of an industrial research laboratory we must deal first with the relation of the research laboratory to the rest of the organization of which it is a part, and secondly with the internal organization of the laboratory itself. The relation of the laboratory to the other departments of the company will be closely associated with the origin of the laboratory.

[1] Lecture delivered April 12, 1918, before the New York Section of the Society of Chemical Industry, The American Electrochemical Society, and the New York Section of the American Chemical Society.

If there is a technical scientific expert in the executive of the manufacturing company, he may have established the laboratory and become its director, and in this case the laboratory will necessarily be very closely associated with the work of the executive who initiated it.

A laboratory may also be established under a separate director, not himself associated with the executive officers of the company, but as a reference department for the executives. In this case also it will be very closely associated with the officers of the company and will tend to be more concerned with questions of policy and the introduction of new products than with any other of the problems of the company.

In a large company a research laboratory may be established as a separate department having its own organization, and be available as a reference department for all sections of the company, in which case its activities will cover a very wide field, but at the same time it will not have as direct an influence upon the policy of the company as will happen if it is closely associated with one or more of the executive officers.

Whatever the size of the industrial concern may be, the organization of the research laboratory should be responsible directly to the management.

The work of a research laboratory almost always involves questions of policy, and not merely manufacturing questions, and frequently close connection with the advertising and selling departments of the company is very necessary. In several cases where research work has been conspicuously successful, this has been the case.

Let us assume, therefore, that on the establishment of the research laboratory we are considering arrangements will be made in the organization of the company by which the laboratory will be brought into contact not only with the manufacturing sections of the company but with the financial and sales direction.

Turning next to the internal organization of an industrial research laboratory, there are two forms of organization possible. For brevity these may be spoken of as the "departmental" system and the "cell" system.

In the departmental system the organization is that familiar to most businesses. The work of the laboratory is classified into several departments: physics, chemistry, engineering, and so on, according to the number necessary to cover the field, and each of these departments has a man of suitable scientific attainments in charge of it. In a large department each of these men will in turn have assistants responsible for sections of the department, all the heads of departments finally being responsible to the director of the laboratory. Under the alternative or cell system the laboratory consists of a number of investigators of approximately equal standing in the laboratory, each of them responsible only to the director, and each of them engaged upon some specific research. Each such investigator, of course, may be provided with assistants as may be necessary.

Each of these systems has advantages and disadvantages. Under the departmental system the advantages are strict organization, good cooperation throughout the departments, a plentiful supply of assistants for the abler men who form the heads of departments or sections of the departments. The chief disadvantage is that the system tends to stifle initiative in the younger men. While it is true that research men require to serve a considerable apprenticeship to older investigators, there comes a time when every man wishes to try to develop his own line of research on his own initiative and to carry out work by himself, and while it is quite possible to provide for such men in a departmental organization, there is some danger that men who are really capable of original work may not get the opportunity to carry it out. The cell system, on the other hand, provides a good arrangement for men of original initiative and of the self-reliant type; it enables a man to continue a single line of work by himself for a long time and to bring to a conclusion work which in a departmental organization might have been abandoned because of its apparently unremunerative character. On the other hand, the cell system tends to exaggerate the vices of such men. They tend to become secretive, to refuse cooperation, to be even resentful if their work is inquired into, while if a man who has developed a line of work for himself in a cell leaves the laboratory, it may be difficult for anybody else to take up the work, in which case a great deal of time and money is lost, and work which should have been carried forward is left unfinished. Another objection to the cell system is that men who are good organizers and who are of the type of men that can carry on work requiring many assistants do not easily find a place in it.

In practice, some system between these two systems of organization is essential and will develop in any laboratory. It is not possible to work a rigid departmental system, and, on the other hand, no cell system in its most definite form could be effective. The form of organization which is the easiest in administration is undoubtedly some modification of the departmental system, since only by this means can young students, fresh from college, acquire adequate training and at the same time keep in touch with different branches of their subject and avoid the danger of overspecialization too early. A laboratory should therefore be organized in departments with an intra-departmental arrangement under which a young man who develops the ability to carry out his own work may be able take up work on his own initiative, still retaining his position in the department and carrying on his work under the general supervision of the chief of his department. There will always be a tendency in the departmental organization for men to desire to split away from the department to which they are attached and become semi-independent in the laboratory, and this tendency must be resisted in the organization and by the director of the laboratory. At the same time, it is important that too rigid a control should not be exercised so that men feel that they are prevented from exercising their own initiative.

A laboratory for a specific industry will generally tend to be of what has been called the "convergent" type, that is, one in which all the different sections of the laboratory representing different branches of scientific work have their energies directed towards the solution of problems relating to the same subject. The problems of such a laboratory will, therefore, all be inter-related and the work of the laboratory will be directed towards one common end.

The organization of such a convergent laboratory has been discussed in a former paper.[2] It is shown there that charts could be prepared illustrating the organization which would be available for almost any convergent laboratory, so that, if we have to work out the organization of a research laboratory which is to study any inter-related group of problems, we can do it by the construction of similar charts. Thus, we may arrange a chart showing the derivation of the branches of the subject considered from the sections of pure science involved. We can place on one side biological, physical and chemical problems, subdividing each section so that each one represents work capable of being handled by one man in the laboratory. It will now be possible to draw a new chart, showing on the circumference the different sections of the laboratory for which accommodation, apparatus and men must be provided, and showing the relation of these sections to the problem as a whole. Having worked this out, it is easy to find the amount of space and the number of men which will be required, or which the funds available will allow for each part of the work.

Now, before applying these charts for laboratory organization to a specific industry, let us look at the question of the

[2] "The Production of Scientific Knowledge," *Science*, 1917, p. 519.

physical organization of the laboratory itself: the building and scientific equipment, the cost of building, and the cost of the

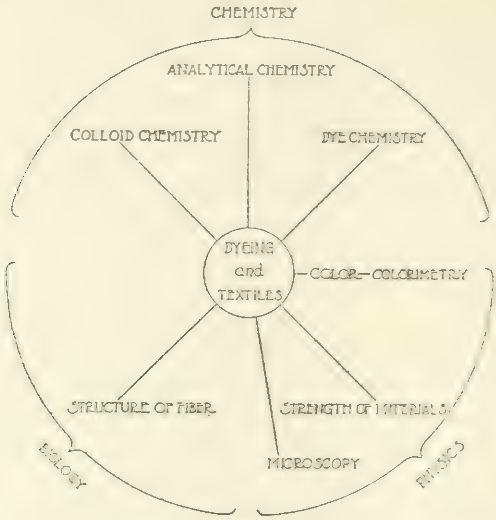


FIG. 1

maintenance and operation. It may be mentioned here that when a laboratory is under consideration by the executive of a company, the matter which usually concerns his mind are these physical details, and he is often greatly concerned with the planning and cost of the building and equipment, a matter which, as will be shown later, is quite secondary to the internal organization of the laboratory as regards effect on the work or even from a financial point of view.

The laboratory should be housed in a convenient, special building. It is very advisable that all research work under the same general direction should be conducted under the same roof, since only in this way can good cooperation between the departments be obtained, and the facilities and organization of the whole department be available to all the workers. In technical research, where it is often necessary to install model plants on a small scale, this cannot always be carried out, but, as far as possible, a research laboratory should be a real building and not merely the name for a number of scattered departments at some distance from each other.

It is a mistake for a factory to house a research laboratory in some abandoned building designed for other purposes. The annual cost of research work, as will be shown later, is very high in comparison with the cost of the building itself. The greater part of that expenditure is on the salaries of the men carrying out the work, and any inconveniences or disadvantages which may be caused by their working conditions and surroundings can easily depress the production to an extent which renders such economics very unprofitable. The cost of the research man, in fact, is so high that it is worth while to provide him with the very best facilities for carrying out his work, since, provided money is not actually wasted on useless ornaments, these facilities will always be inexpensive in comparison with the total expenditure on the work.

Research laboratories are almost always too small, and it is really desirable that, in designing such a laboratory, some system of construction should be chosen in which expansion can be obtained by the duplication of units. This is, of course, a very difficult thing to arrange, especially in the details of the laboratory, but, nevertheless, it should certainly be aimed at by the architect, since whatever the size of the laboratory when it is designed, it is safe to prophesy that within a very few years expansion will be necessary, and if direct expansion is not possible, this will take the form of detached groups of men working in other places, an inconvenient and uneconomical arrangement.

The cost of moving in research work is not always realized. The cost of moving into a new building will be approximately half the total cost of the building, since the men will actually not be working again at full speed in less than six months, and, as a general rule, the annual expenditure is equal to the cost of the building and equipment. It is important, therefore, in designing a laboratory to arrange, if possible, that expansion may take place without any considerable rearrangement. An aid to this is to make the internal divisions of a laboratory movable as far as is possible, and while the laboratory itself should be of fireproof construction, it will be convenient to make partitions of composition board and wood wherever the fire risk does not prohibit this. In this way, rooms can easily be subdivided, combined or rearranged.

Everything that has been said as to the necessity for the provision of a satisfactory building applies also to the question of equipment, but with even greater force. It is an economic error to allow expensive men to be short of the apparatus which they require for their work. As a general rule, men will not ask for apparatus which they do not need. There are a very few men who might be considered to be apparatus collectors, and who seem to have a real anxiety to surround themselves with all forms of scientific apparatus, whether they have any use for them or not; but with the exception of these men, who are limited in number, it may be taken that when a research worker asks for apparatus he needs it, and must have it in some form or other to continue his work.

The total cost of equipment for a physical laboratory represents about two months' cost of operation, and, if economies are to be made, it is clear they should be made in limiting the amount of work undertaken and the consequent cost of operation, rather than in depriving the employed workers of the necessary tools for their work.

From various sources of published information, as well as from personal experience, it is possible to form an estimate of the cost of a research laboratory per scientific worker employed, taking the term "scientific worker" to cover all graduate men working in the laboratory. It might seem that there would be very great variation in the cost, but, provided that we confine ourselves to laboratories of the physical and chemical type, there is a surprising agreement between the different figures, which show that cost of building and equipment for a laboratory will be between $3,000 and $4,000 per man; it may be taken therefore that the first cost of a laboratory will be about $3,500 per scientific worker employed. From the same sources the annual cost of maintenance of such a research laboratory appears to be slightly lower than the first cost. Probably $3,300 per man would be a fair estimate of the cost of maintenance, and of this we may take 60 per cent. as representing salaries and wakes and the other 40 per cent. all other expenses.

Let us attempt to apply the principles which have been laid down for the design of an industrial research laboratory, applicable to a specific industry, in such a form that they would be available for the directorate of the industry to understand to what they are committing themselves in establishing a research laboratory, and how to proceed in order to do so.

We may select as an example of a specific industry one of a technical manufacturing type dealing with engineering processes, handling chemicals, and also involving certain biological considerations; such an industry, for instance, as textile dyeing or the manufacture of leather goods. Exactly the same principles, however, would apply to industries of quite a different kind. Thus, an industry in which there are no biological considerations will not require some branches of a laboratory; it may need to substitute others in their place. For some industries, physics is of no importance and chemistry is of far more importance.

Let us, however, in order to be specific, consider the question of a plant whose business consists in the dyeing of textiles. Let us suppose that the industry is making a turn-over of $1,-000,000 a year, of which 10 per cent. is net profit, and that the directors have decided that, in order to improve their product and extend their business, possibly to diminish costs, they will at the outset undertake an expenditure of $15,000 a year on scientific research. Now, let us consider what they can do for this.

In the first place, we can decide at once how many men they can get. On the basis of $3,000 per man, they should be able to get five men for $15,000, but with very few workers in the laboratory, the cost per man will be somewhat higher, and it will be safe to assume that only four men can be obtained for the $10,000 available for salaries. The cost of the building will be about $10,000 and equipment about $5,000. Taking the basis of $2 per square foot for building as a rough approximation, we shall have a building with 5,000 square feet of floor space, or, dividing this into three floors, a building about 40 feet square. The work of the laboratory may be analyzed according to the chart shown in the figure. Dividing into the three main divisions of chemistry, physics and biology, we shall get the following sections for the work: In chemistry, we shall require an analyst and dye chemist who must understand organic chemistry, and a colloid chemist who will study the relation between the fiber and the dyes. In physics, we shall have work to do on the testing of the strength of materials and especially on colorimetry and the measurement of absorption. In biology, we shall require a man who understands the vegetable and animal fibers, their structure and their bio-chemical properties. We shall also require work on the staining of fibers and photomicrography. This will give us the chart shown.

Now, we can not hope, of course, to represent all these departments by separate men, since we can afford to have only four men, and in addition to the departments shown we must have one practical dyer having actual works experience. Our men may be grouped somewhat as follows: Our organic chemist can look after analytical chemistry as well; that is, we must get a man having experience in organic chemistry and some good knowledge of dyes, who can specialize in the study of dyestuffs and on their analysis, but who also can do what routine analytical chemistry it becomes essential for the laboratory to carry out. We may expect our colloid chemist to be a bio-chemist and to take care of the microscopy. The physicist may understand colorimetry and, at the same time, know enough general physics to be able to look after questions involving the strength of materials. We have thus accounted for three of our four skilled men, and the fourth must be the practical dyer, who should also be the director of the laboratory and should have a good training in dye chemistry and general chemistry, with a considerable knowledge of colloid chemistry and fibers, and some knowledge of physics. Thus, the staff of our laboratory will be completed by the director, who will be a chemist who has had works experience in dyeing, and who must be given this works experience before the laboratory is commenced if a fully trained scientific research man is not already available from the works. It is of no use to take a man from the works who is not fully trained in research methods and in sympathy with scientific work, and if such a man is not already available with a knowledge of dyeing, then the best available man must be obtained from a university or elsewhere and given the works experience to learn dyeing before the construction of the laboratory is attempted.

The amount available for the salaries of these men will be about $10,000 a year, which must be distributed as seems advisable with regard to the men actually chosen. The sum should be sufficient to obtain fairly good men, as a commencing salary.

We will next consider the structure of the laboratory itself. It must be remembered that we have three floors, each of them containing about 1,600 square feet. Of these, one will be required for the library, office and the dye room, which will be a small edition of a works department containing small model machines in which all the works processes of dyeing, washing and drying can be carried out. This may occupy about half the ground floor, the other half being taken up by the library, staircase and the laboratory office, which in such a small laboratory may be united with the library. The next floor will be devoted to chemistry and may be divided into two or three rooms, while the top floor will be used for physics and will contain rooms for ordinary physical work and for colorimetry. It will also probably be used for microscopy, since it is inadvisable to have microscopes and similar instruments exposed to the fumes of a chemical laboratory.

An exactly similar design to this can be made out for any other industry, the factor of size being determined by the expenditure which it is proposed to make, and the work being dissected in accordance with the demands of the particular industry in question. Space must always be kept for a small replica of those plant operations on the investigation of which the laboratory is working, since it will often be necessary to prove the plant operations under the direct control of the men in the laboratory and under conditions which can be rigidly maintained at any required point.

Now, let us consider what returns may be expected from the work of this laboratory.

The work of an industrial research laboratory may be classified in three divisions:

A. Work undertaken on the initiative of manufacturing divisions for the inprovement of operations, for the lowering of cost, or in order to locate manufacturing difficulties.

B. Work undertaken with a view to the development of new materials or of entire, new processes. This may be initiated by the management, by manufacturing sections, by sales divisions who see the need for such materials or processes, or by the director of the laboratory or his assistants.

C. Work which deals with the fundamental theory of the subject the results of which, if successful, will lay a foundation for the expansion of the industry as a whole, along lines which usually can not be foreseen when the research work is commenced.

The work classified under Division A is, of course, common to all industrial laboratories, and many research laboratories in connection with manufacturing plants confine themselves almost entirely to problems arising from the manufacturing division.

Class B includes a large portion of the work of industrial research laboratories, and the best known successes of such laboratories are included in this division. A typical example is the development of the drawn wire tungsten filament by the research laboratory of the General Electric Company, a research which, although originating from a general research on the properties of rare metals such as would be classified under Division C, developed into a study of tungsten with the direct purpose of obtaining a satisfactory filament lamp from the metal. Another example is the manufacture of indigo by the Badische Company. Such researches usually have their basis in some more fundamental work; the industrial work on indigo, for instance, was made possible by the original chemical work on the structure of indigo carried out in the German universities, which was applied on a manufacturing scale to the preparation of the dye.

More rarely do research laboratories work on subjects classified under Division C, that is, on the fundamental theory of their subject. Yet those who do achieve the most conspicuous successes—the work of Professor Abbe on the theory of the microscope, and, indeed, all the work on applied optics at Jena—come under this heading. The great success of the Zeiss Works is directly due to the attention paid by Abbe to the development of the fundamental theories of optics. At the General Electric Laboratory at present much attention is being paid to the emission of electrons from hot bodies, and from this work there have already developed the Coolidge x-ray tube and the Kenotron high frequency transformer, while the possibilities of application are as yet only just beginning to be realized.

In a study of the work of a special research laboratory all the work done during the year was analyzed out from a classification of the work of each part of the laboratory, and the proportionate expense which should be charged to each class of the work was found.

This analysis showed that Division A, that is, work done for the manufacturing departments, corresponded to about 15 per cent. of the work of the laboratory; Division B, work on new materials, 47 per cent.; Division C, or fundamental work, absorbed 27½ per cent., of which 22½ per cent. was devoted to the scientific work and 5 per cent. to the accompanying educational work, while work for the assistance and information of the office force is estimated at 5½ per cent.

Now, considering this division of the work of the laboratory, it will be agreed that, if proper coordination exists between the laboratory and the management of the company, work classified under A and B will certainly be reasonably remunerative, although not necessarily so completely so as to pay the dividends on the investment in the research laboratory, which is commonly expected from such an investment. The same may not appear true in the case of Division C, the fundamental work, which in the hypothetical case discussed would represent nearly a third of the total expenditure of the laboratory; nevertheless, it is probable that this section of the work would be likely to prove the most remunerative of all, and the way in which this can best be illustrated is by some examples.

Let us consider the graded examples of theoretical work in relation to their application in industry.

First, let us take the case of such work as that done by Professor Abbe on the geometrical laws which govern the formation of images by lenses. The connection between this and the manufacture of lenses is so obvious that it is at once manifest that the discovery of any new principle in the theory of lens optics will react immediately upon construction in some way, either in the form of a new product or in cheaper forms of construction.

Next, let us consider work on improved methods of testing such, for instance, as the work done by the various bureaus of standards or research on analytical methods. Here it can be seen that only the possession of an accurate method of testing will enable the manufacturer to improve his product, and to guarantee the similarity of product made at different times. Consider, for instance, the improvements in electrical measuring methods and instruments which have made available the standardized electrical equipment which is now so familiar to every one.

In the third place, we may take as an example such research work as the study of the relation between inductance and capacity in alternating electrical circuits, which has had such an immense influence upon the design of alternating current electrical machinery. At the present time, of course, this is a recognized fundamental portion of electrical engineering.

Lastly, let us consider such work as that of the universities on the photo-electric effect, the diffraction of x-rays by crystals, or the emission of electrons by hot bodies. Of these, the last has already found extremely important commercial application, the second one is being adopted by several industrial research laboratories in making a study of the structure of metals, alloys and other crystalline substances, while the first, as far as I know up to the present, has not found any industrial application, and yet, it may safely be prophesied, will be of importance to industry within the next ten years.

It is almost impossible to name any class of physical or chemical scientific work, from the physics of the atom to structural organic chemistry, which will not sooner or later have a direct application and importance for the industries.

Work in a research laboratory bears a certain analogy to placer mining for gold. A man washing gold can make a living by steady, hard work, but nobody would take up placer mining with the intention of making a living by the everyday washing. Everybody hopes to find nuggets which will give them a good profit, and possibly even a fortune. In the same way a research laboratory can produce results equivalent to a large amount of its expenditure by steady work, but from a commercial point of view research is undertaken in the hope of the occasional valuable discovery rather than for the steady output of small details.

The analogy can be carried somewhat further. Just as in placer mining it is of no use looking for nuggets, and any miner who neglects the routine washing in search of nuggets is likely to starve before he finds them, in the same way a research laboratory can not look for discoveries. It can only carry on its everyday work on the problems presented to it, and hope that when some possibility of a valuable discovery presents itself it may recognize it in time to take advantage of the fact.

There is, however, one direction in which this analogy breaks down. When a man finds a nugget, he knows its value and its value is definite and certain; in research work this is not the case. Discoveries which are thought to be valuable when made often prove worthless, while others which appear to be of no value eventually turn out to be profitable, and frequently the value of a discovery is not under the control of the laboratory because the adoption and exploitation of it may be in other hands.

It is sometimes thought that in order to put an industry into a state of complete efficiency from a scientific point of view all that is necessary is to establish a laboratory and to employ a scientific staff to carry out research work. It is quite possible, however, for such a laboratory to have no influence whatever upon the general policy of the company, and only a very slight influence upon its manufactures, the value of a laboratory depending very greatly upon the closeness of its cooperation with the other departments of the company.

It is often felt that small industries can not afford to support scientific research, but this argument is exactly as if it were suggested that small industries can not afford to support advertising. The object of spending money on research, for a small industry at any rate, is not to support the research but to be supported by it, and it is scarcely an exaggeration to say that the smaller a business is, the more important is it that it should make use of scientific research to the greatest extent possible.

A small business is at a disadvantage in comparison with a large one in regard to all its cost charges. In the purchase of raw materials, in manufacturing, and in selling, its cost per unit of output tends to be larger than in the case of big businesses, but, on the other hand, it is at a real advantage in regard to flexibility and enterprise. Any large business must neccessarily be cautious and conservative. The amount at stake is so large that the penalty of error is heavy. Consider, for instance, the mere cost of allotting half a page in a catalogue of which three million copies are to be printed. It is clear that no business man will allow the introduction of a new article into a catalogue for which such an edition is necessary unless he has reason to believe that the demand will be sufficient to pay the cost involved. That is, the machinery of a large business is adapted for the sale of things for which there is a large demand, but it is difficult for it to introduce articles for which the demand will probably be limited and doubtful. Every large business is anxious to improve its goods, since it knows perfectly well that the penalty for failure to do this is extinction, but it necessarily moves with greater caution and more slowly than a small business can do. It is this very fact, rightly grasped, which enables the small business to get its start and grow in spite of the advantage in regard to cost possessed by its larger competitor, and the growth of a small business will depend upon its supply of ideas for new products and new methods to a far greater extent than will that of the big manufacturing concern making staple products. Small businesses can therefore make far more use of a research laboratory and get a much bigger percentage return for the expenditure than any big company can hope to do. In the small business, in fact, a research laboratory closely associated with one of the high executive officers should begin to return a profit within a few months of its establishment, whereas in the case of a large company it may be years before a research laboratory can be considered to be financially successful.

The greatest difficulty in the establishment of a research laboratory in a small business is that any research laboratory will depend for its value upon the quality of the men at the head, or, if the laboratory is really small, of the man at the head, and a small business often feels that it can not afford to pay even one good scientific man. The solution of this in a technical business might be that the research man should also be an officer of the company, so that his cost is borne not only by the scientific work but also by the value of the executive position which he holds.

It may be objected that an investigator would not as a rule prove a capable business man, but there really seems to be no particular evidence for this common belief, and there are many examples of men trained in science who have proved extremely good administrators. The classic example is, of course, the organization of the great Zeiss works under Professor Abbe, but in many cases it will be found that the technical industries are directed by technical men who were themselves directly concerned with development and manufacture rather than with financial or business direction.

When the question with which this paper starts was put to a chemist much experienced in research work, and he was asked what he would say to an executive who requested information as to how to proceed to establish a research laboratory, he answered without hesitation that he would tell him to search until he found a suitable man to be director of it, and then leave it to the man to establish the laboratory. There is no doubt very much truth in this view, and the success of a laboratory must stand or fall in great measure by the quality of the man in charge of it. But it is often desirable for business men to come to some conclusion about research when they have in mind no man suitable to undertake the formation of a laboratory for them, and it is in the hope of aiding technical or business executives in such a position that the present paper has been written.

THE ROMANTIC ASPECT OF NUMBERS

By Professor S. E. SLOCUM, Ph.D.

UNIVERSITY OF CINCINNATI

THE events of the past few years have made it clear that the mind of man is still a primitive organism in spite of its scientific veneer. This is confirmed by the fact that many of our most fundamental activities pivot around certain time-honored emblems and symbols inherited from an age when few could read or write, such, for instance, as the cross and triangle. Moreover the use of symbolism is an important factor in modern business, as the whole psychology of modern advertising is based on this ancient principle of using some particular device to stand for an idea. Evidently the value of symbolism consists in presenting an idea in such an impersonal form that each may interpret it in accordance with his own individual ideas and experience. Moreover, certain emblems call forth ideas or sentiments to which it would be impossible to give universal expression. Consider, for instance, the varying emotions called forth in a mixed audience when the Star-Spangled Banner is played or displayed. In religion especially, where ideas are frequently of such a nature as to transcend ordinary expression, symbolism has always found extensive use. Thus the symbolism used in the Scriptures is such as to make a universal appeal, independent of race or age, whereas dogmatic theology, at least as regards its formal expression, is necessarily a function of the particular time and place in which it originated.

The symbol which has always stood foremost in religion is the cross. Its most ancient form is the swastika, which has been found in the relics of the bronze age, and was common to races as widely separated as the Hindoos, Persians, Chinese, Japanese and the Indians of both North and South America. Subsequently this pagan emblem of good luck was invested with all the spiritual significance of the Christian religion, while to-day, as the Red Cross, it embodies the humanity of all the world. The triangle is another survival of primitive symbolism. In fact, the modern Red Triangle, inscribed with the trilogy "Spirit, Mind, Body," is exactly the symbol used by Pythagoras over twenty-five hundred years ago as the emblem of his pagan school of philosophy.

The symbolism developed by the pagan nations of antiquity shows clearly their materialistic tendencies and beliefs. The most extensive source of such symbolism is that found in the literature of the Greeks. Thus in the figurative language of the Greeks, Mount Ætna was the forge of Vulcan; and the moōn was the chariot of Diana; while in the last book of the Odyssey Homer tells us that while the Greeks were overwhelmed with sorrow for Achilles, the sea became violently agitated, which Nestor interpreted as the coming of Thetis and her nymphs to lament the death of her son. The most characteristic expression of this mystic symbolism is found in the Grecian oracles which were the purest fiction of the imagination, interpreting at the dictates of fancy the rustling of the leaves of the sacred oaks, or the dashing together of the bowls suspended in the sacred grove.

The ancient customs of all races show a belief in the action of numbers on the course of human events. Thus from the time of the calling of Abraham, Egypt found a mystic significance in the letters of the word Nile, the numerals represented by these letters making 365, the number of days in the year. The Persians also found the same meaning in the word Mithras. The Greeks had no number system properly speaking prior to the Trojan War, which occurred about 1200 B. C. At an early date, however, certain numerals were regarded as endowed with peculiar virtues. Thus Greece had her 7 sages; the world its 7 wonders; 7 great captains united before Thebes; every 7 years was supposed to determine a change in the nature and temperament of man; in a serious illness the 7th, 14th and 21st days were regarded as critical; while the 70th year was considered the most fatal to old men. The numeral 12 was also used as the symbol of completeness, as applied for example to the 12 signs of the zodiac; the 12 labors of Hercules, etc., and still persists in our division of day and night into 12 hours each; the division of the year into 12 months; and the commercial use of dozen.

Probably the numeral 12 was originally chosen as a standard unit because it contained so many small factors, as this is the reason why it is still retained as a base in spite of the efforts to replace it by the metric system. All primitive nations found fractions very difficult, and even the Egyptians, who were most proficient in fractions, used methods that were very long and cumbersome. It was a great advantage, therefore, to have a standard unit which could be divided into parts without giving common fractions, and 12 was such a number, as $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$ and $\frac{1}{6}$ of 12 were all integers. The numeral 5 was also used, this being the symbol of the Egyptian god Apis, and represented in Egyptian hieroglyphics by a five-pointed star. This latter symbol we have also inherited from the past, and it appears to-day in the stars of our national emblem. These two units, 12 and 5, appear to have been combined by the Babylonians in their so-called sexagesimal system, in which 60 is the standard unit or base. Evidently the practical reason for the choice of 60 is that it contains so many small factors that it can be subdivided to a much greater extent than 12 without involving the use of common fractions. This unit 60 is another element of our ancient heritage, appearing in our division of time and of angular measurement into 60 minutes and 60 seconds.

In developing their number symbolism the Greeks were empirical, making the material facts conform to their theories. For instance, Empedocles added a fourth element, earth, to the three elements, air, fire, and water, recognized before his time, because the moral virtues were four in number, namely force, temperance, prudence and justice. Similarly, Hippocrates regarded the numeral 5, representing the five senses, as the symbol of health; and Plato regarded the numeral 3 as representing the three faculties of the human soul, namely intelligence, will and memory, in the belief that this three-fold division appeared in the body as head, trunk and limbs, and in morals and art as the good, the true and the beautiful. Again when two warriors met in combat, the Greeks believed that the one whose name had the most letters in it would be the victor, this being regarded as the mystic reason why Achilles triumphed over Hector.

As the ideas of the Greeks became more definite and scientific they were impressed by the fact that number is the manifestation of thought in the material universe. In particular they were struck by the numerical intervals of the musical scale, from which they inferred that nature had imposed similar mathematical laws on the course of natural events. In particular they saw another expression of the same law in the intervals of the planetary system, and because of this similarity they spoke of the "music of the spheres," not as a poetic fancy but as a mathematical relation. Here again appears the numeral 7 associated with the 7 tones of music, the 7 planets known to the ancients, the 7 Pleiades, etc.

The highest development of Grecian number symbolism appeared in the system originated by Pythagoras and his school. The distinguishing feature of this system was the association of certain physical attributes with the properties of numbers.

For instance the Pythagoreans regarded 7 as the maiden's number because the sum of the digits in successive multiples of 7 produced all the other digits; for example, $7 = 7$; 14 gives $1 + 4 = 5$; 21 gives $2 + 1 = 3$; etc. Similarly 8 was the symbol of death since the sum of the digits in successive multiples of 8 decrease successively by 1; for example, $8 = 8$; 16 gives $1 + 6 = 7$; 24 gives $2 + 4 = 6$; etc. For the same reason 9 was regarded as the symbol of immortality since the sum of the digits in successive multiples of 9 remains constant; for example, $9 = 9$; 18 gives $1 + 8 = 9$; 27 gives $2 + 7 = 9$; etc. In short, numbers were regarded as the cause of events, and numerical operations as having their counterpart in the operation of natural laws. Numerals were regarded therefore not merely as passive symbols but as active principles of good and evil, capable of reproduction and combination by mathematical operations.

This Greek principle of number symbolism is in strong contrast to the Hebrew use of numerals in a figurative sense. The ancient Hebrews were unscientific to the last degree, and numbers had no special significance to them except as associated with certain events and occasions. For instance, the doctrine of the Trinity gave prominence to the numeral 3, and in consequence this numeral came to be naturally associated with Deity without the numeral itself being regarded as possessing any intrinsic virtues or having any causal significance. Thus the incident recorded in Genesis 18, where Abraham received three angels and worshipped one, calling him Lord, has been taken to indicate that the threefold apparition symbolized Deity to him, but there is no evidence in support of this view, because in the next chapter it appears that on the following day two angels appeared to Abraham's nephew Lot and he also worshipped one, calling him Lord. The fact is that all the ordinances and doctrines of the Old Testament were highly symbolic, using not only numerals but also including colors, objects, events and persons, regarded as antitypes in the prophetic sense, but at the same time there is no evidence anywhere in Old Testament literature that any of the intrinsic properties of numbers were even known, much less regarded as exerting any mystic influence on human destiny. The nature of the number symbolism in the Old Testament is apparent in the use of the numeral 7. The doctrine of the six days of creation followed by the rest from labor on the seventh was perpetuated in the division of time into the week of 7 days, naturally regarded as signifying the perfection of works. As the bow in the cloud, the sacred emblem of the divine covenant, revealed

7 primary colors, there was additional reason for regarding the numeral 7 in a generic sense as the symbol of completeness. The Hebrews must also have recognized a divine sanction for the figurative use of this numeral such for instance as appears in Pharaoh's dream of 7 years of plenty and 7 years of famine and its actual fulfillment; in the 7 plagues imposed on the Egyptians for their refusal to free the Israelites; in the efficacy of the 7 priests bearing 7 trumpets who encompassed Jericho 7 times to its destruction; in the fact that the child raised by Elijah sneezed 7 times; in the direction to Naaman to bathe 7 times in the Jordan; and in the 7 times 7 or 49 years which intervened between the years of Jubilee; while a further sanction to the symbolic use of this numeral was given by Christ himself in his injunction to forgiveness "not . . . until 7 times but until 70 times 7"; in casting 7 demons out of Mary Magdalene, and in the 7 words on the Cross.

This primitive aspect of sacred number symbolism, however, must not be confused with the figurative meaning given to the same numerals in New Testament literature, which shows many traces of Greek influence, especially in the mystic number symbolism used in Revelation. The importance of the type figured in Old Testament teachings, as distinguished from that of the numeral associated with the type, is apparent in such connections as the 3 days' journey of Isaac into the wilderness; and the 3 days spent by Jonah in the whale, as symbolizing the death and resurrection of Christ, the number 3 in each case being merely incidental to the type. Again the number 12 in Scripture gained its significance from the 12 patriarchs from whom sprang the 12 tribes. Its use in the New Testament may be referred in each case to this original meaning, as for example in the 12 foundations and 12 gates of the Holy City; the 144,000 of the redeemed Israelites; the 24 Elders, etc., even its use as applied to the 12 Apostles signifying the substitution of the new dispensation for the old. The numeral 40 is also conspicuous in the Old Testament, although its use is not such as to make it apparent what it signified. Thus the flood descended for 40 days; Saul, David and Solomon each reigned 40 years; the Israelites wandered 40 years in the wilderness; and Moses, Elijah and Christ each fasted 40 days.

When the New Testament was written the Hebrews had outgrown their isolation and were in close contact with Greek and Roman civilization. In fact the greater part of the New Testament was written in Greek. The effect of this Grecian influence is nowhere more apparent than in the mystic character given to number symbolism, which is especially manifest in the Apocalypse of St. John. In this remarkable vision, numbers appear with great frequency and always with a cryptic meaning. To simply enumerate the more important instances of such usage, the number 4 is applied to the 4 beasts, the 4 angels, the 4 corners of the earth, and the 4 winds of the earth. 7 is applied to the 7 churches, the 7 spirits, the 7 stars, the 7-branched candlestick, the 7 lamps of fire, the 7 thunders, the 7 trumpets, the dragon with 7 heads and 7 crowns, the 7 seals, the 7 last plagues, and the 7 golden vials. 12 appears in the 24 elders, interpreted as the 12 patriarchs and the 12 apostles; in the 144,000 redeemed, representing 12,000 from each of the 12 tribes; in the crown of 12 stars; in the 12 foundations and 12 gates of the Holy City, and in the 12 angels at the gates; in the length of the city, 12,000 furlongs; in the height of its wall, 144 cubits; and in the 12 manner of fruits of the tree of life. The periods of time specified are equally cryptic, as used, for instance, of the 1,260 days of prophecy; the 42 months of the Gentiles' dominion; the 42 months of the dragon's power; the hour, day, month and year during which the 4 angels should slay $\frac{1}{3}$ of mankind; the 10 days of tribulation; the time, times and half a time of the woman's concealment; and the $3\frac{1}{2}$ days that the dead should lie unburied.

During the Middle Ages the attempt to reconcile the doctrines of Christianity with the classical philosophy of the Greeks resulted in the development of a school of thought called Scholasticism. Naturally the book of Revelation with its highly figurative language appealed strongly to the Schoolmen, and for centuries afforded a fertile field for speculation. One of the foremost in applying the properties of numbers to theology was the noted ecclesiastic Alcuin, who followed the example of the Greeks in investing numbers with certain physical attributes. For instance, he applied 6 to the Deity because he regarded 6, like the Greeks, as a perfect number since the sum of its divisors is $1+2+3=6$; while 8, being an imperfect number, he applied to the descendants of Noah, the number of persons in the ark being 8. Instances of this form of Scriptural interpretation are abundant. Tertullian said that these numerical details were imposed by sovereign wisdom and should not be regarded as trivial. St. Isidore of Seville wrote a special treatise on the numbers mentioned in Scripture, while St. Jerome and St. Hilaire also used this form of interpretation. St. Augustine was perhaps the greatest master of arithmology, developing the idea in his work "On Music," and in his theological works. It is interesting to note the nature of the symbolism he employed. 3 he regarded as a divine number and 4 as a terrestrial number, their sum, 7, applying to creation. The sum of 7 and 3, or 10, he regarded as signifying knowledge of God and creation, and 40 as signifying the accomplishment of all the works of the law. An instance of how St. Augustine applied these properties of number to Scriptural exegesis is found in his interpretation of the 38 years of the paralytic mentioned in John 5:5, namely, that since 38 lacked 2 of being 40, it implied that the man lacked the accomplishment of all the works of the law by 2 items, love of God and love of man.

St. Ambroise, the spiritual guide of St. Augustine, regarded the 40 days of the flood as representing a regenerating baptism. In the 24 elders of Revelation he saw the mystic properties implied in the factors of 24, namely 1, 2, 3, 4, 6, 8, and 12. Thus 1 signified God; 2 the two testaments; 3 the Trinity; 4 the four gospels; 6 the perfect number applied to creation; 8 the beatitudes or virtues; and 12 the apostles. Pope Gregory regarded the 5 talents of the parable as representing the 5 senses of man used for his salvation; the 2 talents as the union of intelligence and work; and the 1 talent as intelligence unused. The man of 5 talents by doubling his charge made 10, a perfect number.

In England, St. Adhelme, Bishop of Sherborne, wrote a treatise in which he reduced every use of 7 occurring in the Bible to an application of the 7 gifts of the Holy Spirit. Another famous English churchman, the Venerable Bede, also made a careful study of number symbolism in the belief that God had ordained all things with number, weight and measure.

This universal belief in number symbolism held in common by the Fathers of the Catholic Church is enshrined to-day in the ritual of the Church. Thus the Church venerates 7 gifts of the Holy Spirit; recognizes 7 capital sins and 7 virtues; and has instituted 7 sacraments, 7 canonical hours, and 7 psalms of penitence.

One of the most interesting and characteristic illustrations of Medieval interpretation of Scripture in terms of number symbolism is found in a commentary on the work of Prudentius, published anonymously in the ninth century, A.D.* The reference is to Genesis 18, which relates that Abraham with 318 servants made war against 4 kings and overcame them. To understand the commentary it is necessary to bear in mind that to medieval writers 3 symbolized the Trinity, 4 was the

* "Commentaire Anonyme sur Prudence," par John M. Burnam, Paris, Picard et Fils, 1910.

terrestrial number, 6 the perfect number, 8 stood for the beatitudes or perfection of faith, and 10 for the decalog or perfection of works. To bring out the characteristic features of this example, the Latin original is given as well as the English translation.

> Per trecentos fidem Sanctæ Trinitatis accipere possumus, et ita iungendum si noverimus quid possint: iste numerus id est CCC Tau littera quæ figuram crucis Christi ostendit sine dubio exprimitur: X vero et VIII perfectionem operum cum fide Sanctæ Trinitatis designant. Sexies enim terni vel ter seni X et VIII conficiunt. Hoc itaque bellum Abrahæ contra IIII reges allegorice significat bellum virtutum et vitiorum. Pater ergo fidei et prima via credendi Abram pro fratre suo Loth contra IIII reges dimicavit et vicit non in multitudine exercitus sed in trecentis X et VIII vernaculis expeditis. Sic et unusquisque nostrum pro anima sua tamquam Abraham pro fratre contra IIII reges id est contra spiritales nequitias spiritale bellum gerat cum trecentis X et VIII vernaculis id est cum auxilio Sanctæ Crucis et perfectione bonorum operum atque fide Sanctæ Trinitatis.

A free translation of this passage reads:

> By 300 we are accustomed to understand faith in the Holy Trinity, and the context in this case verifies this meaning. This number CCC is the Greek τ, a letter which undoubtedly represents the cross of Christ. X and VIII, I believe, denote the perfection of works with faith in the Holy Trinity. Six taken three times, or three taken six times, make the X and VIII. And so this war of Abraham against the four kings allegorically signifies the war of the virtues and vices. Thus the father of truth and original belief, Abraham, contended for his brother Lot against four kings, and conquered not by virtue of a large trained army, but with 300, 10 and 8 light-armed servants. Just as each one of us contends for his soul, so Abraham contended for his brother against four kings, that is, waged spiritual war against spiritual iniquity with 318 servants, namely, with the aid of the Holy Cross, the perfection of good works, and faith in the Holy Trinity.

Whatever one may think of such interpretations in general, the fallacy in this particular case is obvious, for although the letter τ was actually used to represent 300 in the so-called Alexandrian notation of the Greeks, this notation was invented in the third century B.C., long after the time of Abraham, as well as long before the cross had gained its significance as a Christian emblem.

The most conspicuous use of number symbolism in the Scriptures and the one which has always exerted the strongest fascination by reason of its evident challenge to intelligence is the passage in Revelation 13:18, which reads:

> Here is wisdom. Let him which hath understanding count the number of the beast; for it is the number of a man; and his number is six hundred threescore and six.

To the medieval theologians the meaning of this reference was a never-ending source of speculation, while during the Reformation it became one of the most valued weapons in their theological arsenal.

For example, Bossuet, Bishop of Meaux, ascribed the number 666 to the Roman emperor Diocletian, persecutor of the Church. The true name of Diocletian, he said, was Diocles, taken from his mother Dioclea, and which he Latinized on his accession to the throne. Writing the name in the form Diocles Augustus and adding the Roman numerals which appear, the result is 666 as indicated below:

D = 500
I = 1
O
C = 100
L = 50
E
S

A
V = 5
G
V = 5
S
T
V = 5
S
666

Another famous instance was the interpretation given by Stifel, a notable (and notorious) mathematician of the sixteenth century. Stifel was an Augustinian monk who, following Luther's example, became a Protestant minister, and who ascribed his conversion to the fact that he noticed that the number of the beast applied to Pope Leo X. This he proved like Bossuet by writing the title in the Latin form LEO DECIMVS and adding the Roman numerals which appear. M he rejected, because, he said, it clearly stood for "mysterium." Adding the remaining numerals, the result is L + D + C + I + V = 656, and as this number is 10 less than the given number 666, he asserted that it distinctly implied that it referred to Leo the Tenth.

However absurd these particular attempts at interpretation may appear, the wording used by St. John is such as to make it evident that he really referred to some particular person, and probably used a symbolism familiar to a certain sect of his followers. The remarkable fact is that the meaning of this reference was forgotten almost as soon as written, and remained an unsolved riddle for eighteen centuries; while a still more curious circumstance is that in one year, 1835, four men, Benary, Fritzsche, Hitzig and Reuss, discovered independently that it actually referred to Nero.

Apparently none of these men, nor any one since their time, has made any application of this discovery, although it seems reasonable to suppose that it might serve as a key to the entire code of Scriptural symbolism. It is worth while therefore to determine as nearly as possible the actual significance of its use.

Writing in a period of persecution when such a reference to Cæsar if made openly would mean not only the sacrifice of his own life but also the destruction of his writings, it seems natural to suppose that St. John would conceal his meaning by putting the reference in a form that would be understood only by the disciples. The Revelation was written in Greek, but the mistake made previously to 1835 was in always trying to interpret the number in terms of Greek or Latin numerals. Using the title in its Greek form but writing it in Hebrew characters, it becomes

קסרנרון

In the number notation of the Hebrews these characters have the values

ק = 100, ס = 60, ר = 200, נ = 50, ר = 200, ו = 6, ן = 50,

the sum of which gives 666. Additional evidence in support of this interpretation is given by the fact that some ancient versions gave the number as 616 instead of 666. Writing the title in the Latin form, Emperor Nero, that is, leaving off the last letter and giving the remaining letters their Hebrew equivalents as above, the sum is 616.

The only direct evidence tending to establish the date of St. John's vision is a statement by Irenæus to the effect that it occurred at the end of the reign of Domitian, which would place the date at 95 or 96 A.D. Irenæus was a disciple of Polycarp, the Christian martyr, who was himself a disciple of St. John, and his statement therefore has a certain weight. However, Irenæus seemed to be ignorant of what was meant by the number of the beast, and from internal evidence in St. John's writings scholars have come to the conclusion that he was mistaken in regard to the date he assigned to their authorship.

The uncertainty as to the date to be assigned to Revelation is due to the fact that it is written in very rugged Greek, whereas in the Gospel of St. John the diction is far more polished. It is known that St. John died about A.D. 98 at the age of nearly 100, and if, as Irenæus said, Revelation was written in A.D. 95 or 96, near the close of his life, there would be no possible explanation of the difference in style except by assuming that the two writings were of different authorship. To explain this discrepancy it has been suggested that Revelation was written not during the reign of Domitian as emperor but when he was City Prætor or Judge, about the year 67 A.D. Naturally a judge might well be responsible for the exile of St. John to Patmos, and Irenæus, knowing that Domitian was responsible, made the mistake of placing the act in his reign as emperor instead of during his term as prætor. As the last 30 years of St. John's life were spent at Ephesus in close association with Greeks, the earlier date assigned to Revelation would account perfectly for the more fluent style of his later writings.

To determine how far this explanation fits in with the supposition that Antichrist referred to Nero, turn to Revelation 17:10–11, where we read:

> And there are seven kings: five are fallen and one is and one is not yet come; and when he cometh he must continue a short space. And the beast that was and is not even he is the eighth, and is of the seven and goeth into perdition.

Now compare this statement with the chronology of the Cæsars during St. John's lifetime, which is as follows:

Augustus Cæsar	31 B.C.–14 A.D.	Birth of St. John at beginning of Christian Era.
Tiberius	14–37	
Caligula	37–41	
Claudius	41–54	
Nero	54–68	First persecution of Christians.
Galba, Otho, Vitellius	68–69	Military aspirants to the throne.
Vespasian	69–79	
Titus	79–81	
Domitian	81–96	Second persecution of Christians.
	98–100	Death of St. John.

With the exception of the three military chiefs, Galba, Otho and Vitellius, who were never actually seated on the throne, we have here a list of eight kings, fifth of whom is Nero, in whose reign occurred the first persecution of the Christians, and eighth of whom is Domitian, in whose reign occurred the second persecution. In Revelation the reference to Antichrist has always been interpretated as his personification in a man, and if, from the standpoint of the disciples, Antichrist was personified in Nero, he was no less so in Domitian, who was hardly less severe in his persecution. In fact St. John says of the beast (Rev. 13:7) that "it was given unto him to make war with the saints and to overcome them"; and in 17:8 refers to Antichrist as "the beast that was and is not and yet is."

The meaning of all this becomes intelligible if the eight kings referred to means the eight Cæsars who ruled during St. John's lifetime. "Five are fallen and one is" puts the date of Revelation in the reign of Vespasian, A.D. 69–79, which agrees perfectly with the theory that the exile of St. John occurred in the prætorship of Domitian, about A.D. 69 or 70. "One is not yet come and when he cometh he must continue a short space" would then refer to Titus, who ruled for the short space of two years. "And the beast that was and is not, even he is the eighth, and is of the seven and goeth into perdition" becomes Domitian, the persecutor of the disciples.

With this key, nothing could be clearer than the meaning of the seventeenth chapter of Revelation. For the same reason that induced St. John to conceal the name of Nero, the name of Rome is also concealed by calling it Babylon, which ever since the Captivity had been the Hebrew synonym for civic wickedness. To make his meaning unmistakable, St. John personified Rome under the guise of a woman sitting on seven mountains, the classic seven hills of Rome, and "drunken with the blood of the saints and the blood of the martyrs of Jesus." And then referring to the great fire which occurred during the reign of Nero, or prophesying of the second great fire which occurred in the reign of Titus, he says in 18: 17–19 that "as many as trade by sea stood afar off and cried when they saw the smoke of her burning saying 'what city is like unto this great city . . . for in one hour is she made desolate.'"

If this evidence may be said to establish the date of Revelation, many of the references become clear, and give a basis for further interpretation which has so far been lacking. The popular interest in the book now manifest may therefore be an indication that this remarkable vision will no longer be wholly unintelligible, nor its study fruitless.

The various instances cited above serve to indicate the important rôle played by number symbolism in the intellectual development of mankind. Wherever mind has reacted to the stimulus of natural phenomena the number concept has resulted as the inevitable expression of the laws governing the material universe. The properties of number, first accepted as a fact, in process of time came to be regarded as symbolic, and only in modern times has the mind been able to grasp their true significance as one aspect of the great principle of functionality.

REMINISCENCES OF ALASKAN VOLCANOS[1]

By WILLIAM HEALEY DALL
SMITHSONIAN INSTITUTION

THE first author to take up the subject of Alaskan volcanos systematically was Constantine Grewingk in 1850.[2] He gathered from all previous accessible sources such data as existed on record, and his work is the classical source of such information. Later Tikhmenieff in his "History of the Russian-American Company"[3] added such supplementary reports as had been obtained by the navigators of the company's fleet on the Alaskan coast. The more important of these observations were incorporated in the chapters on Geology and History of my "Alaska and its Resources"[4] in 1870. Now that the national Geographic Society has taken up the subject of Alaskan Volcanos it seems well to put on record the scattered observations which I had been able to make during my field work for the U. S. Coast Survey, 1871 to 1880, and for the U. S. Geological Survey, 1885 to 1899.

The southernmost volcano of the Alaskan coast was named by Vancouver Mt. Calder and was regarded by him as a conspicuous peak about five thousand feet high. Later observers have found difficulty in identifying it among the other peaks of the northern part of Prince of Wales Island, and if really a volcano, it appears to be extinct and has perhaps lost in height since Vancouver's time.

The best known of Alaskan volcanos is Mount Edgecumbe on the northwest side of Sitka Sound rising from Kruzoff Island, and a most conspicuous object for navigators. It was named by Cook in 1778, after the well-known elevation on the south coast of England. It is a low flat-topped mountain with gentle slopes, the summit occupied by a crater some two thousand feet in diameter, the edge of which rises to a height of 2,855 feet according to observations by Davidson in 1867. From the summit deep gorges radiate which give rise to an equal number of torrents, and which remain filled with snow after the latter has melted from the intervening prominences of reddish volcanic material. The result is a very striking radiately striped cone of white and red, which once seen is never

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Beitr. zur Kenntniss der Nordwest-Küste Amerikas, mit den anliegenden Inseln." St. Petersburg, Karl Kray, 1850, 1 vol. 8°.

[3] St. Petersburg, E. Weimar, 1861–3; 2 vols. 8°, in Russian.

[4] Boston, Lee and Shepard, 1870, 1 vol. 8°.

forgotten. It is said to have emitted smoke in 1796, but this is the only record of activity in historic times. It is associated with Indian legend as the home of the mythical "Thunderbird" from whence that monster issued to prey on whales. It has been many times ascended by Russian parties, as well as by Davidson in 1867, and a party from the Western Union Telegraph Expedition in 1865.

Various high mountain peaks of the St. Elias Range have been at times regarded as volcanic and the trail of mist which frequently projects from the lee side of such peaks has been taken for steam, but later observations have shown these views to be erroneous.

The high mountains, including the St. Elias and Alaska ranges, which are arched about the Gulf of Alaska, have as a keystone the only volcano in the territory which is situated at any great distance from the sea; namely Mt. Wrangell[5] which still maintains an intermittent activity.

The long line described by the Alaska peninsula and the Aleutian Islands, marking a line of weakness in the earth's crust through which plutonic forces have operated since Jurassic times, affords a splendid field of volcanic activity. Two classes of volcanos are in evidence in it: one comprising the typical volcanic cones rising to a considerable height, with evenly sloping sides and snowcapped summits; the other low and wide craters. The former are largely composed of volcanic ash and cinders, the latter of basaltic lavas. Beside these there are massive eruptions consisting of volcanic rock, syenitic, andesitic or porphyritic, of which a large part of the islands is composed. In the entrance to Sanborn harbor in the Shumagin Islands, the syenitic rock is seen penetrating from below the crevices in an arch of the Mesozoic schists, and in 1871 I found in the central ridge of the island of Unalashka a core of the same material. This observation has since been confirmed by the researches of Professor Jaggar, and pebbles of the same rock were collected in 1895 by Dr. George F. Becker, of the U. S. Geological Survey, at Iliuliuk Harbor. The greater part of the rocks of Unalashka Island are eruptive clay porphyries.

Two of the most striking peaks in the territory are found on the western side of Cook Inlet, named by the Russians Iliamna and Redoubt mountains, the latter from the fortified post on the Kenai peninsula opposite. In 1895, with Dr.

[5] Baron von Wrangell, formerly governor of Russian America, well known for his scientific publications and explorations, spelled the last syllable of his name with a double "l," which accordingly should be retained in the cases of the geographical features named for him.

St. Augustine, or Chernabura, Volcano, Cook's Inlet, Alaska, from the S.S.W. twenty miles distant. July, 1895.

Becker, we entered Tuxedni harbor near the foot of Iliamna. Here the shores rise abruptly, some thousands of feet of Mesozoic limestones wonderfully carved by the weather into turrets, castellated crags, and grand cathedral arches, which in the clear gray twilight of an Alaskan summer night presented a sublime spectacle. The depth of water is very great and we anchored with difficulty close to the shore. At the head of the harbor is a wide point, really an old Mesozoic beach uncovered by the elements, on which lay scattered ammonites, *Inoceramus* and other fossils of that ancient time. Nothing could be seen of the peak from this point, but beyond it was a small rocky bay from which we learned hunters had a trail up to the flanks of the volcano where they went for bears.

Only from the opposite side of the inlet can a good view be had of the beautiful snowwhite cone, 12,066 feet high, as measured by the Russians. It has never been ascended, and on numerous occasions has been recorded as active. On the occasion of my last visit in 1899, the spruce forest on the opposite shore of the Kenai peninsula, for many square miles, had been killed by the masses of ashes which had proceeded from an eruption which had occurred since my previous visit.

The Redoubt volcano, 11,270 feet high and a very similar cone, is situated about thirty miles to the north and east of Iliamna and has a similar history. No ascent of it is known to me.

In the southwest corner of the inlet off Kamishak Bay rises the brown cone of St. Augustine or Chernabura, the latter name meaning "black fox," a Russian nickname for the black-cowled Austin friars. This has been active within recent years. Formerly there was a boat harbor where the Aleut otter-hunters left their kayaks while they watched for their prey from the cliffs, but some years previous to our visit of 1895, when the mountain was ascended by Dr. Becker, an explosion which broke away part of the wall of the crater filled the harbor with fragments of lava and masses of ashes.

Further to the southwest the peninsula is studded with peaks some of which are volcanic; Alai and Chiginagak are the most prominent, but little is recorded of them.

While surveying in Port Moller in 1874 for the Coast Survey, the western edge of Mt. Veniaminoff was visible from the sea with intermittent clouds of steam and blackish smoke puffing from the invisible crater at intervals. This locality I found one of the most fascinating for a geologist. The volcano in the distance, the abrupt slope toward the Pacific, the long slope toward Bering Sea, as in all the peninsular region;

Bogosloff Island, massive eruption, from the beach of the new island, Grewingk, three miles N.N.E., August, 1895.

great slabs of Mesozoic rock near the sea level sculptured by the presence of elegant fossil scallops and ammonites; the alluvium of the beaches surmounted in places with extensive shell heaps of prehistoric people, from which I picked up several interesting archeological relics, but had no time to excavate; and on a small flat point interbedded with lignite and Tertiary shales, hot springs with a temperature of 140° Fahrenheit, in which were large leathery algæ and to my amazement some water beetles skipping over the surface of water too hot to bear the hand in. Here too we shot caribou from our triangulation stations till our vessel's rigging looked like a butcher's shop with the hanging carcasses; bears were seen along the shore fishing for salmon; and on the sandbars near the entrance of the bay a herd of red-eyed yellow walrus bellowed continually.

Further westward rises the cone of Katmai volcano, from which a few years ago came the storm of ashes which devastated the island of Kadiak, and of which interesting accounts have appeared in the *National Geographic Magazine.* It is, or was, when I saw it, a cone of the typical kind, apparently about 5,000 feet in height, snowcapped and smoking. It had not been ascended at that time. The next in the line is the quiescent Pavloff volcano. Westward from it are several others apparently volcanic, and northwestward from the head of Volcano Bay, we observed, when becalmed off Vosnessenski Island in 1880, a remarkable phenomenon. On the skyline was apparently the edge of a crater from which projected upward a series of pinnacles like the teeth of a comb; as nearly as could be measured with a sextant about 200 feet high and about 40 feet in diameter at the base, shaped singly like a very tall champagne bottle, and over a dozen in number. These were probably formed by the ejection of small blobs of lava from small apertures along a crevice, cooling as they fell, until the pinnacle was built up. They are known to the natives by the name of the Aghileen pinnacles, and were mapped by me on the Coast Survey chart of 1882.

Northwest from the western end of the Alaska peninsula is the small volcanic Amak Island, composed of a low cone with the crater nearly obliterated and its fires extinct. This was occupied along the shore by myriads of walrus when I visited it in 1868, and their curiosity led them to come surging around our boat, diving under it, and rising at oar's length with distended funnel-shaped nostrils, red eyes, and tremendous tusks; a situation we found disconcerting, though they offered no violence.

PEAKS OF SHISHALDIN AND ISANOTSKI LOOMING ABOVE THE FOG ON UNIMAK ISLAND, about thirty miles distant from a point south of Unimak; from a sketch made on shipboard in 1865, by Frederick Whymper.

The island of Unimak off the end of the peninsula is perhaps the most volcanic of the larger Aleutians. The voyager to the islands *via* Unimak Pass is apt to make as his first landfall, the magnificent cone of Shishaldin rising above the banks of fog. Many times as I have seen it, I never fail to be impressed by its sublimity. If the weather be favorable, one may see by its side the lower black contorted mass of Isanotski, all that is left from a tremendous explosion of the early part of the last century. Its shattered bulk and frowning black crags form an extraordinary contrast with the tall pure white cone of Shishaldin. The latter rises nearly 9,000 feet, to the 5,525 of Isanotski. The third volcano of prominence on the island is Pagromnaia, or the Thunderer, a broad dome of about the same height as Isanotski but with very gentle smooth sloping sides, and near the shore. Shishaldin steams gently from a point slightly below the apex. It is some twenty miles inland over rough lava beds. It has never been ascended. In the *Bulletin* of the Société de Geographie for December, 1873, p. 568, an account of a supposed ascent of this mountain is given by a traveller in these regions in 1871. He was accompanied only by some natives of Unalashka who I was careful to interview on their return to Iliuliuk, and they assured me that the mountain ascended was Pagromnaia and not Shishaldin, and that the party did not approach within many miles of the latter mountain. This shows how careful one should be in identifying one's mountain.

The next large volcano to the westward is the crater of Akutan on the island of the same name. It is low, probably not over 4,000 feet at any point, and is said to have a smaller cone and crater within the larger one. It is constantly active, and frequently at Unalashka I have heard loud reports sometimes kept up for hours at regular intervals, which were said to be the work of Akutan. Once I timed them and found the intervals about eight minutes long. It sounded like distant discharges of heavy coast artillery.

On the island of Unalashka is the volcano Makushin, which is inactive. It has been ascended by Davidson in 1867 and by many others. Even the crater has been the object of a mining claim for the deposits of sulphur existing there. This mountain is reached from Makushin Bay west of Iliuliuk, by a trail between the two villages, over the center of the island. An amusing story is connected with this trail. The company leasing the seal islands, to haul seal skins from the killing grounds of St. Paul island, brought up some mules by a vessel which touched at Unalashka after a long and rough passage. The mules were put ashore to recuperate and one wandered up the trail. Two Aleuts (who had never seen any land animal bigger than a sheep) were coming over to Iliuliuk. At the ridge of the island they met the mule, who, possibly rejoiced at the sight of a human being, lifted up his voice mightily. The cliffs re-echoed it. The Aleuts believed it was his Satanic Majesty, fell on their knees and prayed audibly. It was perhaps the first instance of a mule promoting prayer!

At the northwest head of Captains' Bay is a small, extinct, but beautifully preserved, volcano about 3,000 feet high. While making my survey of the bay, I ascended it, in 1874. The crater was complete; the portion near the walls full of black contorted columns of lava, recalling the trees in Doré's illustrations of Dante's Inferno. At the bottom was a little lake, and a small gray fox trotted among the spiky tongues of lava. This is named the Pistriakoff peak, from the puffins (Pistriaki) which nest in its walls.

I will pass over with bare mention the most interesting oceanic volcanos or rather massive eruptions, Bogosloff (St. John the Theologian) and Grewingk. Their history has been fully elucidated by Dr. C. Hart Merriam in the report of the Harriman Alaska Expedition. These masses are thrust up out of deep water. Coming down from the Arctic in the Coast Survey schooner *Yukon*, in October, 1880, we met terrible weather in Bering Sea. For sixteen days we were buffeted by living gales, with brief windless intervals which the heavy sea rendered still worse. We crept up in the fog to the entrance of Captain's Bay, but were swept by the currents to the westward and had to put to sea again, all hands worn out by the constant buffeting. In the middle of the night the watch, who had not been told of Bogosloff, was shocked to see the black mass rise out of the fog only a few cables' length away, and the men became very nervous. We decided to run for shelter as soon as it was light, trying for Chernoffski Harbor. Our only chart was dated 1795, and among the numerous rocky bays we had to find Chernoffski entrance, the only safe harbor, or come to grief. With dawn the fog cleared, the gale still blowing from the northeast. We took departure from Bogosloff under a goosewinged foresail alone, and all hands were on deck. To the westward rose the bluff end of Umnak, with a long reef stretching toward us, over which the great combers rushed in a sweep of foam, striking the foot of the cliff with a noise like thunder, and mounting two hundred feet to its very verge. It was a sight to make any seaman's blood run cold. While watching it, the fog above parted for a few moments and we saw the snowy cone of the Vsevidoff volcano, on Umnak island, resting on the clouds, the image of perfect peace.

We made Chernoffski safely and later found that, on the old Russian map, the position of Bogosloff had been fixed from Chernoffski, so our course had been the correct one; but on the modern maps the position of the volcano was about 30 miles in error, so that we were in good fortune to have used the ancient survey to lay our course. The glimpse of Vsevidoff at such a dramatic moment was the only one had in many voyages. Usually the mountain hides its whiteness under an impenetrable mantle of fog. The Russians regarded it as less high than Makushin, but little is really known of it. I may add that only from a considerable distance at sea is the apex of Makushin differentiated from the non-volcanic peaks with which it is associated.

On the island of Umnak there are four volcanic vents beside Vsevidoff. Of these Tulikskoi on the north and the River volcano (Riecheshnoi) on the western end of the island are the most noted, but none rises to any considerable height, practically nothing is known of them and no ascents of either are on record.

Beyond Umnak lie the Islands of the Four Craters (Chetirisopochnoi). Little is known of them, except that in the hot, dry, solfataric cave of one of them was the mausoleum of which the romantic story is told in the Smithsonian Contributions to Knowledge;[6] while the mummies themselves form part of the collection of the U. S. National Museum.

To the westward again volcanic vents are numerous but hardly known, until we come to the island of Atka, where, on its northern projection, is situated the nearly extinct vent of Korovin, about 5,000 feet in height. Around it are grouped several lesser cones, Sarycheff, Sergieff, Konia, and the volcano of the Springs (Klucheffskaia). With my assistant Marcus Baker I visited the latter in August, 1873. The springs are situated high up on the flank of the peak and the Russians formerly maintained a rude sanitarium here for rheumatic and skin diseases. The water I found to have a temperature of 164° F., and it contains sulphur, lime and alum in solution. The water issues as small geysers and deposits a clay-like material of varied and brilliant colors, red, brown, yellow, light blue, and various shades of gray. The natives utilize this material to color the walls of their houses, and it was said to be reasonably permanent. The amount of water is not great and the natives stated that it had perceptibly diminished within living memory. The springs are on a bench or plateau, about

[6] No. 318, pp. 40, pl. 10, 1898, 4°.

five miles from Korovin Bay, and reached from the head of an inlet making up from the old harbor, and into which a rather large stream discharges.

West of Atka a volcano called the White Peak is said to exist on Adakh Island, but we saw nothing of it. A series of sextant angles on the north peak of Tanaga Island, said to be volcanic, gave a height of 7,108 feet, and, to the southwest, the wholly volcanic island of Garéloi (Burnt Island) about 5,500 feet, but these measurements were dependent on positions which may be incorrect, and the peaks may be higher. Grewingk from Russian sources gave them a much greater height. Off these islands, in a thick fog on our return voyage we heard for hours a series of heavy reports, like the discharges of great guns, and the Russians have reported violent activity among them during the last century.

The last active volcanos of the Aleutian chain of which we have knowledge are found on the Island of Seven Craters (Semisopochnoi) where more or less eruptive action was reported to be continuous in 1873. We caught only glimpses of the island when the prevalent fog lifted. Beyond this on the island of Little Kyska, at the entrance of the fine harbor surveyed by me in 1873, is a magnificent wall of tall slender vertical basaltic columns, like the pipes of an immense organ, which yields nothing in impressiveness to Staffa or Stromboli.

Westward of the Seven Craters the islands are composed chiefly of clay porphyry or schistose rocks, as far as observed, and there is no record of volcanic action. Northward in Bering Sea the Pribiloff Islands are wholly volcanic. On St. Paul, Miocene sandstones are included in the rock torn from the sea bottom, and contain numerous fossils.[7] When we reach Norton Sound, the islands of St. Michael and Stuart are composed of basaltic outflows, but no vent is visible in the low dome-like hills in the interior. A part of the mainland coast opposite these islands is of the same character.

Pinnacle Island, on the southeast corner of St. Mathew Island in Bering Sea, is believed to be similar in origin to Bogosloff. It has a deep gash running longitudinally through its crest, and in this fissure we thought, in 1880, we saw at night a glow as of a fire; but this may have been illusive.

In the Yukon region and northward, I know of no volcanic vents or lavas reported, but in the line of the Aleutian chain the field for the vulcanologist seems unparalleled. Even the great arc of the Japanese archipelago can offer less of interest in the form of volcanic activity.

[7] See "Fur Seals and Fur Seal Islands of the North Pacific Ocean," Part III., 1899, Gov't Printing Office, Washington, D. C., p. 539, *et seq.*

THE PROGRESS OF SCIENCE

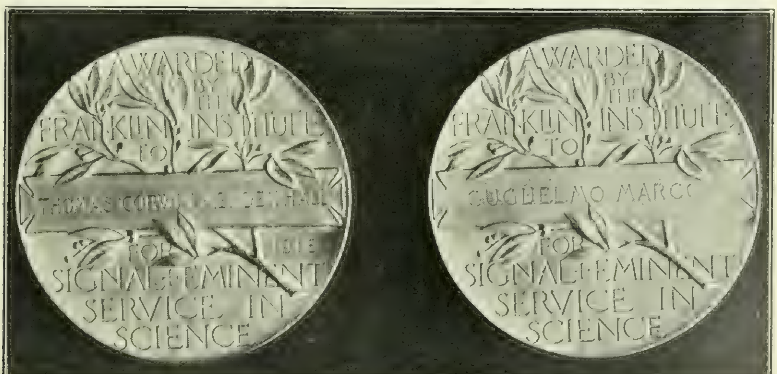
PRESENTATION OF THE FRANKLIN MEDAL TO SIGNOR MARCONI AND DR. MENDENHALL

THE Franklin Institute made the annual presentation of its Franklin Medal, in the auditorium of the institute on May 15. This medal, founded in 1914 and awarded to "those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the institute, have done most to advance a knowledge of physical science or its applications," was awarded to Signor Guglielmo Marconi, electrical engineer and member of the Italian Senate, and to Dr. Thomas Corwin Mendenhall, physicist, of Ravenna, Ohio.

The award to Senator Marconi was made in recognition of his "brilliant inception and successful development of the application of magneto-electric waves to the transmission of signals and telegrams without the use of metallic conductors." The award to Dr. Mendenhall was made in recognition of his "fruitful and indefatigable labors in physical research, particularly his contributions to our knowledge of physical constants and electrical standards."

Count Macchi De Cellere, on behalf of the Royal Italian Government, received the Franklin Medal for Senator Marconi, and addressed the institute when the medal was presented to him. Upon the presentation of the medal to Dr. Mendenhall, he addressed the Institute on the subject of "Some Metrological Memories."

Guglielmo Marconi was born in Bologna in 1874, and carried out his first experiments in connection with his system of wireless telegraphy at Bologna in 1890. These attracted the attention of Sir William Henry Preece, electrician-in-chief of the English Postal Telegraph, who tested the apparatus with success in England; soon afterward, in cooperation with the Italian Ministry of Marine, Signor Marconi succeeded in sending messages from Spezia to a steamer 15 kilometers distant. In 1899 he established wireless communication between France and England across the English Channel. Signals were later transmitted by his system of wireless telegraphy across the Atlantic Ocean, from Poldhu, Cornwall, to St. John's, Newfoundland. In December, 1902, he was able to announce the establishment of wireless telegraphic com-



THE FRANKLIN MEDAL.

GUGLIELMO MARCONI.

On January 18, 1903, there was sent, by Signor Marconi, from the wireless station at South Wellfleet, Cape Cod, Mass., to the station at Poldhu, Cornwall, England, a distance of 3,000 miles, the message—destined soon to be historic—from the President of the United States to the King of England. This photograph was taken by A. B. Phelan exclusively for *McClure's Magazine* immediately after the sending of the message.

munication by his system between Canada and England, and in January, 1903, he transmitted a message from the President of the United States to the King of England, inaugurating wireless connection also between Cape Cod (Mass.) and Cornwall.

Thomas Corwin Mendenhall was born in Ohio in 1841. He was professor of physics at the Ohio State University from 1873 to 1878, at the Imperial University of Japan from 1878 to 1881 and again at the Ohio State University from 1881 to 1884. Dr. Mendenhall was president of the Rose Polytechnic Institute from 1886 to 1889, superintendent of U. S. Coast and Geodetic Survey from 1889 to 1894 and president of Worcester Polytechnic Institute from 1894 to 1901. At the International Electrical Congress held in Chicago in 1893, Dr. Mendenhall was chosen one of a committee of five delegates, to formulate definitions for the fun-

THOMAS CORWIN MENDENHALL.

damental units of electrical measurement: the ohm, the ampere, and the volt. The members of this committee were Ayrton, Mascart, Mendenhall, Rowland and von Helmholtz, and the definitions agreed upon are known as the "International electrical units."

THE SOLAR ECLIPSE OF JUNE 8

FROM the earliest times of which there is record a total eclipse of the sun has excited wonder and been the occasion of omens and portents. Now that its cause is understood, it is still a striking occurrence, not

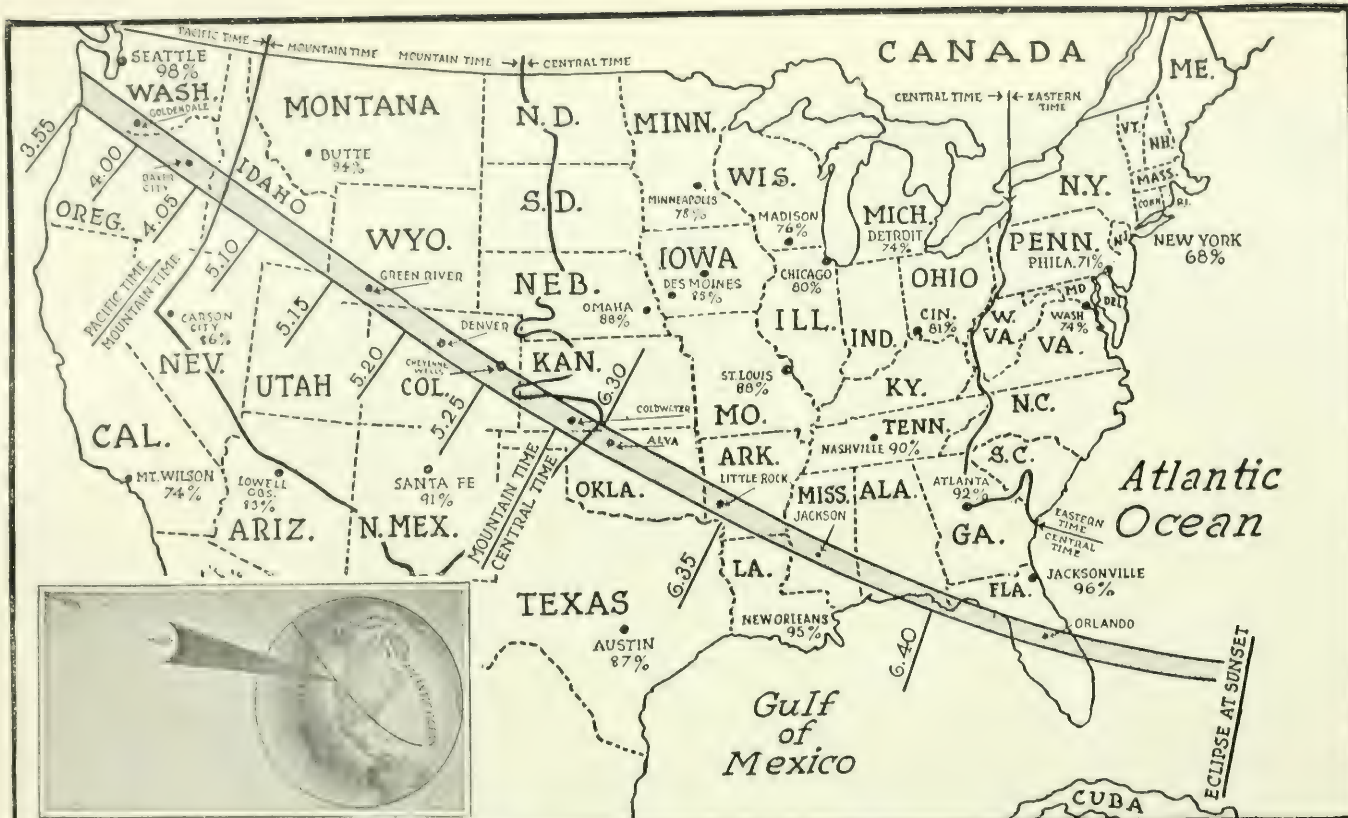


Chart from the *American Review of Reviews*, showing the path of the moon's shadow (track of totality) across the United States. The figures adjacent to the eclipse path show the standard "Summer" Time at which totality began. Outside the path of totality a partial eclipse was visible all over the United States. The percentage of the solar disk that was covered by the moon is shown at several places on the map. The diagram in the lower left corner shows how the moon, coming between the sun and the earth on June 8, blocked the sun's rays and cast a shadow on the earth.

only to people who witness its dramatic phases, but also to men of science who study its phenomena. The event is so rare, the duration is so short, the distance that must often be traveled to reach the place of observation is so great, the difficulties of arranging apparatus in an unusual place are so considerable, the chance of a cloudy sky is so disastrous, that unusual interest is excited even among astronomers.

The eclipse of June 8 was notable in that the shadow passed across the whole United States from Washington to Florida. Not for a hundred years will a total solar eclipse be visible over so large an area of the country. Though the shadow was rather narrow, the time of totality not long and the sun somewhat too near the horizon, the opportunity for observation in the Northwest was very good. The war, however, prevented the presence of any expeditions from abroad, and American observatories are much distracted from their regular work by existing conditions. It is also the case that photography has permitted the solution of many of the problems of special interest and that this can now be used in many directions apart from an eclipse. New problems, however, always arise and scientific men are now interested in the Einstein theory of relativity, according to which rays of light from the stars should be subject to deviation by gravitation when passing close to the sun, and this may be determined by photographing the sky about the sun at the time of a total eclipse.

Expeditions to the Northwest were sent from the Lick, Mount Wilson, Yerkes, Naval and other observatories and from the Smithsonian Institution and the Weather Bureau. The Chamberlin Observatory of the University of Denver is only eight miles from the middle of the shadow. The best account of the eclipse that has appeared is in a press dispatch prepared by Dr. W. W. Campbell, director of the Lick Observatory, who has now observed six total eclipses of the sun.

The Crocker Expedition from the Lick Observatory was stationed at Goldendale, Wash., situated exactly on the central line of the eclipse path. Dr. Campbell states that a few of the twenty-six photographs secured with cameras of focal lengths from eleven inches up to forty feet have been developed, and the details of coronal structure are recorded with admirable sharpness, showing that the earth's atmosphere was in a tranquil state. Four cameras of fifteen-feet focus, using plates of 14 x 17 inches, were used to record the brighter stars in the regions immediately surrounding the sun to detect, if possible, the displacements required by the Einstein hypothesis and to determine the existence of bodies such as the hypothetic planet Vulcan in the vicinity of the sun. Two spectrographs gave images of the stratum of green coronium gas enveloping the sun, and the general spectrum was recorded in good strength with two spectrographs.

The weather conditions at Goldendale were most dramatic. The prospect for a clear sky was apparently hopeless during the whole day, but a very small area of blue sky free from clouds with the sun as its center appeared exactly at the center of the total phase when all other parts of the sky were clouded. This region cleared not more than a minute before the beginning of totality and the clouds again covered the sun within less than a minute of the passing of the shadow.

THE CONSERVATION OF PLATINUM

THE country is and for many years will be urgently in need of platinum in its industrial work and must now have it for war purposes. It is believed that aside from the large amount of platinum metals in the form of manufactured jewelry, a large part of which is in private ownership, there is less than twenty-five per cent. of the normal stock of unmanufactured platinum in this country available for the needs of the war. In an effort to fill the immediate pressing needs of the government in its war program, the War Industries Board has ordered that seventy-five per cent. of the stock of platinum in the hands of manufacturing jewelers be commandeered and also the complete stock held by refiners, importers and dealers, but this, it is said, will only fill a small gap and that temporarily.

The American Chemical Society has issued an appeal to the people not under any circumstances either during the war or afterwards to use platinum jewelry, but to conserve this metal, now priced at five times the cost of gold, for the exclusive use of the chemical and other necessary industries. The first purpose will be to obtain a sufficient supply of platinum for the needs of the war, and then to retain the production of the future for the industries. It is claimed that even before the war, as a result of the craze for platinum in jewelry, the highly important work of the chemists had been curtailed and research work, especially in the universities, handicapped by inability to meet the constantly rising price for platinum.

A movement among the women of the country to discourage platinum in jewelry has been initiated by the American Chemical Society. The Women's National League for the Conservation of Platinum has been formed as a national organization, with Mrs. Ellwood B. Spear, Cambridge, Mass., as chairman. State councils have been formed in fourteen of the leading states of the Union and even the efforts of college women have been enlisted. Already throughout the country thousands of women have signed the following pledge: "I will neither purchase nor accept as gifts jewelry and other articles made in whole or in part of platinum so that all possible supplies of this precious metal shall be available for employment where they can do the greatest good in the service of our country, and I further pledge my influence to persuade others to take the same patriotic stand."

Dr. Charles L. Parsons, secretary of the American Chemical Society, states that platinum ought not to be used in jewelry either in war time or in time of peace. It is too greatly needed for the development of chemical science and industry. The Russian mines, from which 95 per cent. of the platinum comes, are reported to be nearly exhausted, and these are now virtually in German hands. The United States has not enough for its probable war needs and, as the jewelers now use over 50 per cent. of the supply that comes into commerce, they must be held responsible for its scarcity.

SCIENTIFIC ITEMS

We record with regret the deaths of Frederick Remsen Hutton, honorary secretary of the United Engineering Society and long dean of the faculty of engineering at Columbia University; Charles Christopher Trowbridge, assistant professor of physics in Columbia University, and of Joseph Deniker, the distinguished French anthropologist.

In honor of Professor Emeritus John J. Stevenson, who held the chair of geology at New York University from 1871 to the time of his retirement from active service in 1909, the building to be occupied by the Faculty Club has been named Stevenson Hall. It was presented to the university at the commencement exercises on June 3.

THE SCIENTIFIC MONTHLY

AUGUST, 1918

THE MECHANISM OF LIGHT EMISSION

By Professor E. P. LEWIS

UNIVERSITY OF CALIFORNIA

IN THE SCIENTIFIC MONTHLY for February, 1917, Professor Guthrie gave an interesting account of the development of the electromagnetic theory of light. He explained how it had been demonstrated that light waves are very short electric waves similar in all respects except size to the electric waves used in wireless telegraphy. The latter are emitted from conductors of finite size in which electric charges oscillate, and may be several miles in length; the former are radiated from small negatively charged particles called electrons vibrating in molecules or atoms, and are measured in millionths of a millimeter. So far as the theory of light transmission is concerned, there is reason to believe that our knowledge has approached finality. There seems to be no acceptable alternative to the conclusion that light is due to wave motion in the hypothetical medium called the ether, concerning which we may never know more than we do now, but which it seems necessary to postulate as the seat of electrical and magnetic phenomena.

We may, however, hope to learn much more than we now know concerning the processes in matter which cause the radiation and absorption of light. Under the term light, we must include the invisible radiations which lie on both sides of the narrow range of frequencies or wave-lengths which are included in the visible spectrum—the short ultra-violet and X-ray radiations on one side and the longer infra-red waves, often mistakenly called heat waves, on the other. Electromagnetic theory and the effect of a magnetic field on radiating sources (the Zeeman effect) make it certain that the shorter light waves, at least, are set up by the periodic displacements of electrons in the atom. The frequencies of vibration must be determined by the forces in the atom due to the number and arrangement of the positive and negative charges in it, hence the problem of radiation is intimately connected with that of atomic structure, and this in turn with all the properties of matter; and it is also dependent upon the relationship between matter and ether which makes possible the interchange of energy between the two. Hence the mechanism of radiation is a subject of great importance—in fact, probably the most important and the most interesting of the problems which confront the physicist to-day.

Some general facts concerning radiation are familiar to all. We know that most luminous sources are very hot—red-hot at a moderate temperature, white-hot, that is to say emitting all colors, at very high temperatures. From this we may infer that heat is the cause of radiation in such cases, and that the colors emitted depend upon the temperature. Since heat is energy of molecular motion, we might jump to the conclusion that the agitation of the molecules sends out waves in the ether just as the jumping of a trout sends out waves in water. But unfortunately such a simple explanation seems insufficient, for a high temperature is not in all cases necessary to produce luminosity. The reader may recall some familiar illustrations of light emission by sources which are not hot. Many substances phosphoresce brightly at ordinary temperatures or even at such low temperatures as that of liquid air. The glowworm emits light of colors which are not radiated by carbon or a metal until it reaches white heat. The aurora glows brightly in the atmosphere at elevations where intense cold prevails. On the other hand, air and many other gases and vapors do not emit visible radiation even when heated to the highest degree. It is evident that other causes than energetic molecular motion may cause radiation. Our next inference might be that light is due to the vibrations of atoms within molecules which may not themselves possess much translatory energy, but this hypothesis proves insufficient in the case of monatomic gases, such as helium and mercury vapor. There seemed to be no explanation possible so long as it was assumed (without any rational basis, as we now see) that the atom is indivisible and unchangeable. No progress was possible until the discovery of the electron and of the atomic disintegration characteristic of radioactive processes proved the complexity of atoms.

In general luminous sources emit waves of many different lengths and frequencies of vibration, each frequency corresponding to a different color. In order to analyze the light into its components, which is the first step toward obtaining a definite knowledge of what takes place in the source, the use of some form of spectroscope is necessary. What follows will be made clearer by the description of a simple form of spectroscope, to recall to the reader how the light is analyzed and what is meant by the "lines" of a spectrum. The light from the source is focused on a narrow slit, through which it passes in a divergent beam. A lens placed in this beam forms an image of the slit on a screen placed at the proper distance. If a prism is introduced into the path of the light, the beam will be refracted toward the base of the prism, and the deviation will be different for each color. If only one color (frequency) is present in the light, a single refracted image of the slit, of that color, may be thrown on a screen or a photographic plate. If two or more colors are present, there will be two or more images of the slit in different positions. These slit images are known as spectral lines. If the light is white, there will be an infinite number of slit images, corresponding to the infinite number of shades of color in white light, forming a continuous spectrum. If certain colors are removed by placing color screens in the path of the light there will be gaps in the spectrum, called absorption lines, corresponding to the absent slit images. Incandescent solids all give continuous spectra, with radiations extending beyond the red, and also beyond the violet at very high temperatures. Luminous gases and vapors, however, do not usually emit all colors, but only a finite number, giving rise to a corresponding number of bright lines. A series of observations by many investigators, and finally the work of Kirchhoff and Bunsen, about 1859, resulted in the recognition of the capital fact that no two elements have the same spectrum, that is, lines corresponding to each other in number and position. This makes the spectroscope an important instrument for the identification and discovery of elements in terrestrial and celestial sources, and serves also the important purpose of giving us significant data for the study of atomic structure and the relation between matter and ether which causes the emission and absorption of radiant energy.

In 1814 Fraunhofer, an optician of Munich, observed that there are many dark lines in the spectrum of the sun. The explanation was found, but not fully grasped, by Foucault in 1849, who discovered that a pair of very close dark lines in the solar spectrum corresponded exactly in position with two bright lines emitted by luminous sodium vapor, and that if sodium vapor is placed in the path of white light the vapor absorbs the same colors, giving rise to dark lines like those in the solar spectrum. Sodium vapor in the sun's atmosphere causes these lines. Later investigation has shown that many thousands of lines in the solar spectrum correspond in position with the bright lines emitted by a number of metallic vapors, which proves that these metals exist in the sun. Further investigation has confirmed the fact that the vapors of many elements will absorb some at least of the colors which they emit when luminous. Stokes, the English physicist, pointed out the acoustical analogy. Sound waves from a tuning fork will cause a neighboring fork of the same frequency to vibrate, but will have no effect on a fork of a different frequency, and a large number of such resonating forks would form an effective screen to the sound waves by thus absorbing their energy. This suggested the possibility of a further acoustical analogy. A tuning fork emits sounds of but one frequency (analogous to the unknown case of a luminous substance emitting but one color of light), but most musical instruments, such as pianos and organ pipes, emit simultaneously a number of sounds of different pitch. The overtones emitted by a piano wire or an organ pipe always have frequencies which are simple multiples of that of the fundamental tone. If the same were true of light sources, the wave-lengths of the lines of a given element should be simple fractions of the length of the longest wave. This is not true in any case. Some elements, such as iron or uranium, have thousands of lines, chaotically arranged, so that the emission centers not only radiate a wider range of frequencies than is emitted by a piano when its entire keyboard is struck, but none of the simple numerical relationships between the frequencies are found, as is the case with the piano. It is inconceivable that any simple body, such as the hypothetical round, smooth, hard atom of kinetic theory, could emit such a complex system of radiations. There is no escape from the assumption that the atom is a very complex body, not the ultimate indivisible unit of matter which it was once, without proper foundation, supposed to be.

The first step toward a definite theory of atomic structure which would help to explain the facts consistently was the discovery by Zeeman in 1896 of the effect of a magnetic field on a radiating source. He found that if a flame colored with sodium is placed between the poles of a strong electromagnet, when the latter is excited each spectral line, when viewed at right angles to the field, is split into three components, which are plane-polarized. When viewed in a direction parallel to the field, each line is split into two components, which are circularly polarized in opposite directions, that is to say, the ether motion is like that of right- and left-handed vortices. H. A. Lorentz, of Leiden, pointed out that he had developed a theory which would explain this phenomenon, based on the assumption that light emission is due to vibrations or revolutions of small electrified particles in atoms. In the absence of a magnetic field the displacements would be in all directions (unpolarized) and all of the same period. In accordance with familiar electro-magnetic laws, the magnetic field will retard the motion of the particles moving in one direction, will accelerate the motion of those moving in the opposite direction, and will have no effect upon motions parallel to the field. Thus the three plane-polarized components are accounted for, and also the circular polarization of the doublet, this being merely the ether vortex motion viewed end on. Quantitative measurements showed that these particles are negatively charged and have a mass about one eighteen-hundredth that of a hydrogen atom. This identified them with the cathode corpuscles, the nature of which had been discovered by J. J. Thomson shortly before. These small particles, to which the name electron has been given, are likewise discharged from negatively charged metals when illuminated by ultra-violet light, and from incandescent metals. They are apparently constituents of all substances, and play an important rôle in many physical phenomena.

The radiation from incandescent solids is undoubtedly due to the displacements of the electrons in the atoms, but these atoms are crowded so closely together and their agitation at high temperatures is so chaotic that it is difficult to picture exactly what is going on or to account for the wide range of vibration frequencies—practically an infinite number—represented in the radiation. Spectroscopic observations show that the spectra of all incandescent solids are identical in the sense that they are continuous and that the relative intensities at different wave-lengths are the same for all sources at the same temperature. As the temperature rises the intensity increases for each wave-length, but more rapidly for the shorter waves, the limit of which creeps toward the violet as the temperature rises. All solids above absolute zero emit radiations giving a continuous spectrum. The spectrum of a cold body, such as ice, lies entirely in the infra-red. The shortest waves emitted by a piece of red-hot carbon are red, the other colors appearing in succession as the carbon becomes white-hot. It is evident from these facts that a large proportion of the radiation from any solid source lies in the infra-red and is useless so far as illumination is concerned, and that the useful fraction increases with the temperature. From the nature of the case, it is impossible to avoid this waste in the use of any solid source. One of the great practical problems awaiting a satisfactory solution is the discovery of vapors or gases which may easily be made luminous by the electric current and which will emit radiations lying mostly in the visible spectrum. The mercury lamp is the most successful of this type so far discovered, but the disagreeable color of its light prevents its extended use. Various more or less empirical laws concerning the distribution of intensity in continuous spectra have been found, and some success has been obtained in correlating these laws with general theoretical principles. Planck has in recent years deduced the most successful formula for the distribution of energy in the spectrum of a black body, based partly on the laws of probabilities and of thermodynamics and electromagnetism, partly on the bold assumption that energy can not be radiated in a continuous stream, but only in definite units, the magnitudes of which are proportional to the frequencies of vibration, the proportionality factor being known as Planck's "wirkungsquantum *h*." He assumes that the radiation is due to atomic oscillators, the electrons, but he has not explained how these electrons can have such a wide range of frequencies or given any definite physical reason why the "energy quantum" law should hold.

In the present state of our knowledge it is hardly worth our while to discuss the radiation of solids or the quantum theory further, but in considering the simpler case of the radiation of gases and vapors we shall find that experimental facts suggest some definite conclusions which may serve as the basis of plausible theories. The first of these, which goes back to the early days of spectroscopy, relates to the nature of the emission centers of the two types of discontinuous spectra, bands and lines. In the latter the lines are generally at some distance apart and arranged irregularly, although in some of the simpler spectra groups of lines ("series") have been found which are arranged with some regularity and are connected by more or less simple mathematical relations. Bands are composed of groups of lines, those in each group very close together and at intervals which increase regularly in going from the well-defined limit called the "head" of the band, where the lines are most intense, and closest together. It was found by Mitscherlich about 1862 that many compounds, such as calcium oxide, when made luminous by a flame or a feeble electric discharge give characteristic band spectra, hence such spectra must be due to the undissociated molecule of the compound. Very intense electric discharges will in every case cause these bands to disappear and the lines of one or both the constituents of the compound to appear. It has since been found that many elements also, such as nitrogen, iodine and carbon, give band spectra when excited by a feeble electric discharge, but line spectra with the more intense discharges which may be assumed to dissociate the molecules into their constituent atoms. From such evidence we may feel fairly certain that luminous vapors in the molecular state, whether elements or compounds, give band spectra, while emission centers in the atomic state give line spectra. Some vapors, however, which certainly have monatomic molecules, such as mercury, give band as well as line spectra, so that we are compelled to look for a further ground of differentiation. The most obvious is to assume that the difference is due to the electrical state of the particle. For example, it may be that band spectra are characteristic of uncharged molecules, whether monatomic or polyatomic, while line spectra may be due to charged atoms, or ions, the charges arising from the loss or gain of electrons. There is direct experimental evidence which favors this view, although this evidence is sometimes ambiguous.

Lockyer was the first to call attention to the fact which is now evident to all observers that spectra are not the unchangeable things they were at first supposed to be. For example, a metal vaporized in a hot flame may have a simple spectrum containing relatively few lines in the hottest part of the flame, while in the green cone, which is not at such a high temperature, but where great chemical activity and a greater degree of ionization exists, a larger number of lines may be observed. The arc spectrum of a substance contains still other lines, while the spectrum of the spark discharge between terminals of the same metal usually contains many lines which do not appear in the arc spectrum, and some arc lines may be suppressed. In general, with changes in vapor density, pressure, temperature, or the mode of excitation, lines belonging to one group may weaken or disappear, others may be strengthened, and new lines may appear. It is evident that significant changes take place in the emission centers, and that, since radiation is an electromagnetic process, these effects must be due to changes in the electrical condition of these centers. Lockyer advanced the revolutionary hypothesis that the energetic excitation due to very high temperature or intense electrical discharges might cause dissociation of the atoms into basic elements, but until the discovery of the electron such a hypothesis could not be reconciled with accepted views.

Some general inferences regarding the electrical state of the emission centers may be derived from familiar facts. When a feeble electric discharge is passed through some compound vapors, such as those of the halogen compounds of mercury, a band spectrum is obtained which is characteristic of the compound, so that the emission centers are certainly the molecules. At the same time the conductivity of the vapor for the electric current shows that there has been some kind of ionization, or separation into charged components, and apparently the only way that this can happen is by the splitting off of electrons from the otherwise unchanged molecules. The emission must accompany either the separation or the recombination of the electrons. Luminous vapors giving band spectra appear, from their conduct in an electric field, to be uncharged, hence we may infer that usually band spectra are emitted during the process of neutralization accompanying the return of an electron. Again, the conduct in an electric field of vapors giving line spectra indicates that they are always positively charged. Phenomena previously referred to indicate, however, that groups of lines which behave differently with changed physical conditions must be due to different types of emission centers. If the emission centers are positively charged atoms, the only possible differences would appear to be in the magnitude of the residual positive charge, due to the loss of one, two, or more electrons. Some light has recently been thrown on this subject by researches on "positive" or "canal" rays, especially by those of Stark and of J. J. Thomson. The spectrum of a gas is usually obtained by passing an electric discharge through it when it is sealed at low pressure in a "vacuum" tube. If a hole is drilled through the negative electrode (the cathode) it is found that at very low pressures a luminous beam is projected through this opening on the side opposite the positive electrode. This beam is deflected by electric and magnetic forces, and from the magnitude and direction of this deflection it may be determined from elementary electrical laws that the luminous particles are positively charged and that they are of the magnitude of the molecules or the atoms of the enclosed gas. It appears that the positive ions in the conducting gas are accelerated by the strong electric field near the cathode, are projected with great velocity through the hole, and by collisions with the molecules of gas on the other side are excited to luminosity and excite luminosity in the stationary gas. From Thomson's researches it appears that, with few exceptions, no molecules carry a negative charge, or more than one elementary positive charge. Very few atoms acquire a negative charge, but they may acquire several positive charges. Stark arrived at similar conclusions by a spectroscopic method, which gave definite information regarding the number of positive elementary charges carried by emission centers giving different groups of spectral lines. In some cases more than one interpretation is possible, but in general these results are in harmony with the view that band spectra are emitted by neutral molecules or atoms—line spectra by positively charged atoms; that the emission centers of arc and flame lines are singly charged atoms; that the enhanced or spark lines are due to emission centers having two or more elementary charges. Thus we find substantiation for Lockyer's early views. There can be but little doubt that differences in line spectra are due to differences in the degree of electrical dissociation.

This raises the question of the number of electrons in a given atom and the number which it can lose. The greatest number of lost electrons shown by Thomson's experiments was eight, in the case of mercury, and usually it does not exceed three. Radioactive phenomena, however, give us reason to believe that the atoms of the heavier elements at least contain many electrons and also many separable and positively charged units. Uranium, for example, by the successive explosive losses of these positive particles (alpha rays) and electrons (beta rays) passes through the stages of ionium, radium, and the successive transformation products, and probably in the end becomes lead. Thus great complexity is certainly true of the radio-elements, and it is probably true of the elements of smaller atomic weight, which are either not radioactive or else disintegrate so gently and slowly that we have not discovered the fact. It seems reasonable to assume that the atoms of all elements, except possibly hydrogen and helium, which may be the elementary units, are complex structures built of a number of positively and negatively charged particles, the number diminishing until we get to helium, which probably has a single alpha particle nucleus, and hydrogen, which probably has a single nucleus. The problem of atomic structure is concerned with the number and relative arrangement of these particles in the atom, and the problem of radiation with the causes and nature of the disturbances of the system which cause the emission of light waves.

If the electrons which emit radiation revolve in orbits about the atoms, as indicated by the Zeeman effect, the nuclei of the atoms must be positively charged in order to hold the electrons in their orbits; and if the emission centers are as a whole positively charged, one electron or more must have been completely detached from the system, while the radiation is due to those left behind. In order that these orbits may be stable, we must, in the light of our present knowledge, assume one of two hypotheses—the electrons must either be held in equilibrium at a definite distance from the center by some sort of elastic force which it is difficult to account for, or the velocities of the electrons and the radii of their orbits must be so adjusted that there exists an exact balance between the centripetal and centrifugal tendencies, such as that which prevails in the solar system. But if the electrons radiate they must lose energy, and if they lose energy they might be expected to fall into the nuclei as the moon would fall into the earth if it continuously lost kinetic energy. Either hypothesis involves difficulties. J. J. Thomson elaborated the idea that the atom is a sphere of uniformly distributed positive electricity, in which electrons are imbedded in such fashion as to be subject to quasi-elastic (but really electric) forces which cause them to vibrate when displaced. Opposed to this there is the Rutherford atom. The weight of experimental evidence, chiefly radioactive, seems to favor the latter. The alpha particles of radioactive substance, which after their positive charges are neutralized become atoms of helium, have an atomic weight four times that of hydrogen. They are projected from their parent atoms with tremendous velocities, and in their progress through air at ordinary pressures ionize from sixty to one hundred thousand molecules, producing twice as many ions, and yet they travel in almost perfectly straight lines, and only at the end of their path, where their velocity has been greatly reduced, do they show any marked evidence of deflection or reflection by impact with molecules. The molecules of nitrogen and oxygen are about eight times as heavy as the alpha particles, and it is evident that if the latter struck these molecules squarely, as they must do to produce ionization of the Thomson molecule, they would be scattered in all directions. Such would not be the case with the Rutherford atom or molecule. In general the alpha particles go unimpeded through the open structure, usually missing the very small positive nucleus, but occasionally producing ionization by detaching electrons near which they pass. On rare occasions an alpha particle will go so close to the nucleus as to be subjected to a strong deflecting force, as in the case of a comet passing through the solar system and getting near the sun, only in the latter case the force would be attractive, while the positive nucleus will repel the positive alpha particle. These effects are shown clearly in photographs taken by C. T. R. Wilson of the path of alpha particles in air, the tracks being made visible by the trail of fog particles due to condensation of water vapor on the ions. Rutherford obtained further proof in favor of his hypothesis by measuring the angles of scattering of alpha particles passing through thin films of metals. In this case the scattering is greater than in air, because of the greater number of atoms encountered in a given distance and their greater mass. The relative number scattered at different angles can be exactly calculated on the assumption of a definite number of elementary positive charges concentrated in the nuclei of the atoms. The results show very conclusively that the number of these elementary charges, or more properly the excess of positive over negative charges, does not exceed half the atomic weight, the number growing relatively less with increased atomic weight—for example, as indicated in these and other experiments, the excess of positive charges in the nucleus of calcium, of atomic weight 40, is 20; in that of gold, of atomic weight 197, the number is 79. Space does not permit giving in detail the mass of evidence supporting this remarkable conclusion, but it seems convincing, and has already formed the basis of a new chemistry, in which the atomic number (the excess of positive charges in the nucleus) takes the place of atomic weight as the significant factor determining the chemical properties of the substance.

If we accept the Rutherford atom, it seems necessary to eliminate quasi-elastic forces and to assume that equilibrium of the electrons which must associate themselves with the nuclei to form neutral atoms is maintained solely by rotation in circular or elliptic orbits. The existence of a large number of electrons moving in such orbits increases the difficulty of accounting for equilibrium, particularly when we consider losses of energy by radiation, which should result in constant readjustments. Further, if uniform rotation is accompanied by radiation (as we might expect from electromagnetic theory) the atom should constantly radiate. Atoms do not normally radiate, however, but only when subjected to a violent disturbance which temporarily upsets equilibrium. We can readily account for three definite frequencies accompanying such perturbations of a single electron. Superimposed on the circular motion there might be vibrations radial, tangential, and normal to the orbit, and if uranium, for example, of atomic number 92, has 92 such electrons circulating about it we could account for 276 spectral lines in this way. As a matter of fact, uranium has many thousand lines in its spectrum, and it seems beyond the powers of the human mind, with our present knowledge, to imagine the atomic structure which would account for the observed facts and emit radiation in accord with the accepted laws of physics.

Bohr has formulated a hypothesis applicable to the spectra of hydrogen and helium in which he boldly departs from some of these laws. He accepts the Rutherford atom, and assumes that hydrogen has a simple nucleus of one positive charge about which a single electron revolves. According to accepted laws, which associate radiation of waves with accelerated motion of electric charges, the electron revolving in a circular orbit should emit waves, for it is subject to centripetal acceleration. Bohr assumes that this law does not apply within the atom, although the ordinary laws of electrical attraction hold the electrons in their orbits. A further radical assumption is that there are a number of possible "stationary" orbits, of different radii, in each of which the electron may move under conditions of equilibrium. An external disturbance may cause the electron to jump from one orbit to another, and during this transition radiation is emitted amounting to one of Planck's energy quanta, that is the difference between the kinetic energies of the electron in the two orbits is radiated with a frequency which is determined by the relation that the frequency multiplied by Planck's "wirkungsquantum," the mysterious constant h, is equal to this energy. There must be as many possible orbits as there are lines in a series. Bohr deduced an expression for the frequencies of the principal lines of hydrogen like Balmer's empirical formula, which had been known for some time, and which expresses with great accuracy the positions of the lines in several series including the principal lines of hydrogen. With equal success Bohr applied his hypothesis to the case of helium, with two nuclear charges and two detachable electrons, one of the latter being detached, but he could not solve the problem in the case when both electrons are retained. The problem for other atoms is likewise too difficult to solve.

Some years ago Laue showed that the X-rays are diffracted in passing through the regular space lattice of atoms in a crystal, producing diffraction patterns on a photographic plate similar to those observed in looking at a distant light through a fine-meshed handkerchief. This proved that the X-rays are due to waves. The Braggs showed that these waves could be reflected from the atomic planes in crystals, and Moseley, by an ingenious application of this principle, was able to determine the lengths of the stronger characteristic waves emitted by different metallic targets when bombarded by cathode rays. He discovered the remarkable fact that the square roots of the frequencies of the principal lines are proportional to the ordinal numbers, increasing by unity in passing from one element to the one of next highest atomic weight. Siegbahn has extended Moseley's results to the heaviest element, uranium, with atomic number 92, and downward to sodium, of atomic number 11. The known elements of smaller atomic weight fill the remaining places down to hydrogen, of atomic number 1, and there are but six gaps in the entire series, to be filled by possible discoveries of new elements. These results are consistent with the numbers referring to nuclear charges determined by Rutherford and others. Bohr's theory likewise leads to the conclusion that the square roots of the frequencies should be proportional to the nuclear charges. Any single line of evidence suggesting these relations might be regarded as highly hypothetical, but the cumulative effect of several kinds of diverse experimental evidence is to produce a feeling of confidence amounting almost to certainty that the nuclear theory is correct, although there is still uncertainty as to the relations of the radiating electrons to the nuclei. If the frequencies of vibration of the electrons are proportional to their frequencies of rotation, which seems highly probable, the extraordinarily high frequencies of the X-rays, several thousand times greater than those of ordinary light, indicates that the emitting electrons lie in orbits very close to the nucleus and practically forming a part of it, which are excited to radiation by displacements due to intense electron bombardment, while the electrons emitting ordinary light, in numbers sufficient to neutralize the charge of the atom as a whole, lie in orbits of relatively large radius. In both cases, if Bohr's hypothesis is correct, there are a number of possible orbits for each electron, and radiation is emitted only in passing from one to another. This hypothesis fits the cases of several groups of lines in the spectra of hydrogen and helium with astonishing accuracy, yet it leaves much to be explained and involves the acceptance of notions which, to say the least, are difficult to reconcile with principles which have seemed to us to be firmly established. In the case of such a simple structure as that assumed for hydrogen, how can we account for the number of stationary orbits demanded? What determines the frequency of the radiation emitted when an electron passes from one orbit to another? It would seem to be necessary for the electron to know in advance what orbit it will finally adopt. How shall we account for the thousands of other lines in the spectrum of hydrogen which the hypothesis fails to account for, and for the continuous spectrum? These things seem to demand a greater complexity than that assumed by Bohr. Stark has lately found that the spectral lines of hydrogen and of a few other elements are split up into many components when the radiating gas is in a strong electric field, in such a way as to strengthen the suspicion that more than one electron takes part in the radiation. It does not seem impossible that the nuclei of both hydrogen and helium may be built up of smaller positive units than the alpha particle and the assumed simple hydrogen unit, with electrons combined with them, so that the resultant nuclear charges are respectively 1 and 2. So far, however, there is no experimental evidence pointing to the existence of a smaller positive electron than the hydrogen nucleus.

There is another possibility which can not be overlooked, although there is little experimental basis for any clear-cut hypothesis—a static atom, that is, one in which the electrons are normally at rest in a condition of static equilibrium, held in place by quasi-elastic forces which set up vibrations when the electron is slightly displaced. Such an atom would probably better suit the chemist than the Rutherford atom, for how can we imagine two atoms in which the outer rings of electrons, the "valency" electrons, are in rapid rotation, ever entering into permanent relations with each other in the molecular state?

But we are unable to account for such quasi-elastic forces in the open structure demanded by radioactive phenomena, and it is impossible to imagine electrons stationary in space, with nothing to hold them apart from the neighboring attracting positive charges.

It is evident that we have far to go to reach a complete explanation of light emission, but the experimental developments of the past few years, the circumstantial evidence based on many different lines of attack, give us reason to hope that we may solve the problem qualitatively at least, that is, decide definitely between the Rutherford and the static atom, and possibly in the simpler cases, such as that of hydrogen, arrive at a fairly complete solution of the problem. A complete quantitative solution of the general problem we can hardly expect. The astronomer can not solve the problem of three bodies in such a system as that of our sun; how can we expect to solve the far more difficult problem of the motions of the swarm of mutually attracting and repelling particles in the atom?

THE STATUS OF SEALING IN THE SUB-ANTARCTIC ATLANTIC

By ROBERT CUSHMAN MURPHY

BROOKLYN MUSEUM

SEALING on the coast of Patagonia, the Falklands, and the islands north and east of Cape Horn began during the third quarter of the eighteenth century. Alexander Dalrymple, writing in 1775, reports that there was at the Falklands an abundance of "Sea-Lions[1] 25 feet long and 19 to 20 round," and also fur seals in "such numbers that they killed eight or nine hundred in a day with bludgeons on one small Islot." Shortly after the American Revolution, New England and British sealers extended their hunting still farther afield, at first to South Georgia, twelve hundred miles east of Cape Horn, and then to the South Orkneys and South Shetlands, well beyond the sixtieth parallel.

The naturalist George Forster, who accompanied Captain James Cook on his renowned voyage toward the South Pole in the year 1775, had written prophetically of the possible exploitation of South Georgia, although even his farsighted imagination had failed to picture the rapid strides which adventurous commercialism would make. "South Georgia," wrote Forster, "besides being uninhabitable, does not appear to contain any single article, for which it might be visited occasionally by European ships. Seals, and sea-lions, of which the blubber is accounted an article of commerce, are much more numerous on the desert coasts of South America, the Falklands, and the New Year's Islands, where they may likewise be obtained at a much smaller risk. If the northern ocean should ever be cleared of whales, by our annual fisheries, we might then visit the other hemisphere, where these animals are known to be numerous. However, there seems to be little necessity to advance so far south as New Georgia in quest of them, since the Portuguese and the North Americans have of late years killed numbers of them on the coast of America, going no farther than the Falkland Islands. It should therefore seem probable, that though Southern Georgia may hereafter become important to mankind, that period is at present so far remote,

[1] Sea-elephants (*Mirounga leonina*).

Photographs by the Author.

An American Sealing Vessel, the brig Daisy, of New Bedford, Mass., at anchor in the Bay of Isles, South Georgia. In the foreground is a wandering albatross (*Diomedea exulans*) upon its nest.

and perhaps will not happen, till Patagonia and Tierra del Fuego are inhabited, and civilized like Scotland and Sweden." Forster's reference to the possibility of the northern ocean being "cleared of whales" indicates at least that he was not obsessed by the "fallacy of the inexhaustible."

Scarcely a quarter of a century after Forster's visit, sealing at South Georgia had reached its height, and in 1800 Captain Edmund Fanning in the *Aspasia* of New York, one of eighteen sealing vessels at the island, secured the season's prize

American Sea-elephant Hunters at work at the head of Possession Bay, South Georgia, March, 1913.

A "Cow" and a "Pup" Sea-elephant sleeping at the Bay of Isles, South Georgia, December 30, 1912. Both animals are characteristically scratching, or brandishing their flippers. The bird is a skua gull (*Catharacta antarctica*).

catch of 57,000 fur seal skins. This record was never again equaled, although the hunting evidently continued, for, when the Russian explorer, Bellingshausen, sailed along the blustery, uncharted south coast of the island in December, 1819, he met with two English three-masters in one of the fjords. These ships had already been there four months, or through the southern winter, and had carried on a profitable business. But when James Weddell, less than five years later, came to South Georgia, he found that seals of all kinds had become "almost extinct." Weddell's account contains much historical information, and the following portion is well worth quoting:

[Cook's] official report regarding the island of South Georgia, in which he gave an account of the great number of sea-elephants (called by him sea-lions), and fur seals, found on the shores, induced several enterprising merchants to fit out vessels to take them: the elephants for their oil, and the seals for their skins. These animals are now almost extinct; but I have been credibly informed that, since the year in which they were known to be so abundant, not less than 20,000 tons of the sea-elephant oil has been procured for the London market. A quantity of fur seal skins were usually brought along with a cargo of oil; but formerly the furriers in England had not the method of dressing them, on which account they were of so little value, as to be almost neglected.

At the same time, however, the Americans were carrying from Georgia cargoes of these skins to China, where they frequently obtained a price of from 5 to 6 dollars a-piece. It is generally known that the English did not enjoy the same privilege; by which means the Americans took entirely out of our hands this valuable article of trade.

The number of skins brought from off Georgia by ourselves and foreigners can not be estimated at fewer than 1,200,000.

Of seals at the South Shetlands, where Weddell's two crews killed "upwards of 2,000" sea-elephants during the same voyage, the sagacious mariner writes in an economic vein worthy of a later age:

The quantity of seals taken off these islands, by vessels from different parts, during the years 1821 and 1822, may be computed at 320,000, and the quantity of sea-elephant oil, at 940 tons. This valuable animal, the fur seal, might, by a law similar to that which restrains fishermen in the size of the mesh of their net, have been spared to render annually 100,000 furs for many years to come. This would have followed from not killing the mothers till the young were able to take the water; and even then, only those which appeared to be old, together with a proportion of the males, thereby diminishing their total number, but in slow progression.

Since 1825 fur sealing at the southern Atlantic islands has been a decadent commerce. As the prey became scarcer, the brave fleets of the early days gave way to lonely, prowling schooners which poached from the fur seal rookeries of the Falklands, or reaped the meager harvest of a few seasons' repletion at South Georgia. Fur seals are believed to have been practically exterminated at the latter island about 1874, but rumor has it that a New England vessel made a small, illegal catch there in 1907. About the middle of February, 1915, some Norwegian whalers discovered a single fur seal on the beach near the eastern end of South Georgia. This forlorn veteran was promptly knocked on the head, and so the tale ends.

A Bull Sea-elephant swimming away from the observer, and about to enter the kelp fields of the Bay of Isles. South Georgia, January 6, 1913.

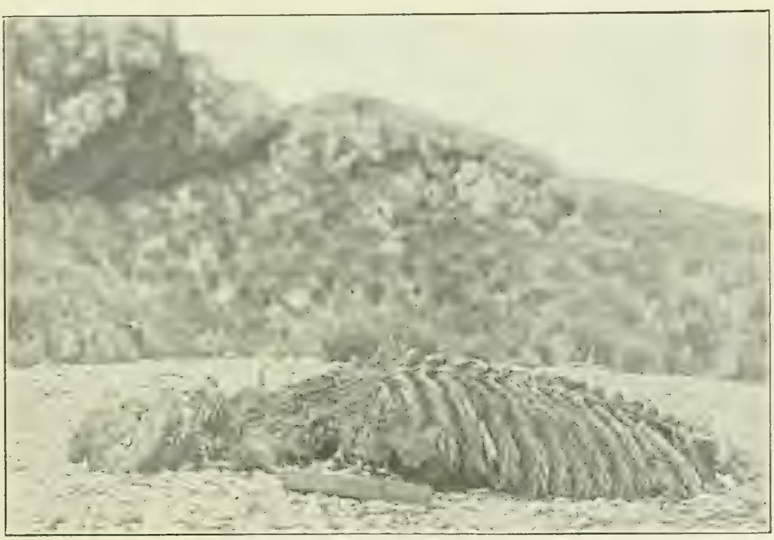
A New Bedford sealer about to lance a Bull Sea-elephant at the Bay of Isles, 1912, and March 14, 1913. 1,641 sea-elephants were killed at this island by the crew of a single American sealing vessel.

The story of the sea-elephant is not unlike that of the fur seal. The species was cleaned out successively on the South American coast, the Falklands, Tristan da Cunha, and the South Orkneys and Shetlands. At South Georgia persistent killing pushed it so near the verge of utter extinction that in 1885 the crew of a Connecticut schooner during ten weeks of the breeding season (September to January) was able to find only *two* of the animals. From before that date, however, until after the beginning of the twentieth century, the seat of the "elephant oil" traffic was transferred from the south Atlantic to the fresher islands of the Indian Ocean, and so the species was given an opportunity partially to regain its foothold at South Georgia. During the last few years hunting has been resumed there, not only by occasional sailing ships from American ports and elsewhere, but also by one of the South Georgia whaling companies, which, through the employment of steam vessels and highly efficient methods, has made extensive inroads upon the male sea-elephants after the end of the breeding season, as many as 6,000 bulls having been killed during one summer.

In taking sea-elephants, the hunters plan first to drive the animals as near to the water as can be done without risk of their escaping. After this they are clubbed, lanced, or shot, or all three if necessary. Sometimes they can be frightened and sent bounding toward the sea by the sound of small stones rattled in an iron pail. If, however, they prove too sluggish or refractory they are often treated with the most revolting brutality; anything seems to be permitted which will urge them beachward and so lighten the labor of carrying blubber.

The old American method of utilizing the blubber is wasteful in every stage. After the slain "elephant" has been allowed to bleed thoroughly, the hide is slit lengthwise down the back, and then transversely in several places from the dorsal incision to the ground. The flaps of hide are next skinned off, and the remaining investment of white blubber, which may have a maximum thickness of about eight inches, is dissected away from the underlying muscle and cut into squarish blanket-pieces. The animal is then rolled over and the same process repeated on the ventral side. Thus the hide, and the considerable amount of blubber which clings to it, are lost at the start.

The blanket-pieces of the blubber are hauled to the water's edge to be strung on short ropes called "raft-tails." These are towed to the anchored ship where each laden raft-tail is looped about a hawser which extends from bow to stern, and the blubber is permitted to soak for forty-eight hours, or thereabouts, until the red blood corpuscles have been practically all washed away. During the soaking process a certain proportion of the oil is lost, and, moreover, flocks of ravenous "Cape pigeons" (*Petrella*), and other ubiquitous sea birds, feed upon the floating fat with an interminable hubbub, both night and



THE STRIPPED CARCASS OF A SEA-ELEPHANT, WHICH HAD BEEN KILLED ONE OR MORE YEARS EARLIER, lying on the South Georgian beach. Thousands of seal remains, in all stages of slow decomposition, tell of the former slaughter and of the wasteful methods.

THE THREE STAGES IN THE DISPOSAL OF A SEA-ELEPHANT, according to the method of the American sealers. The upper photograph shows a bull sea-elephant which was lanced by the writer at the Bay of Isles, South Georgia, on February 17, 1913. The second picture illustrates the removal of the hide, which is cut off in small flaps, leaving the blubber exposed. A curved knife with an eight-inch blade is used in skinning, and, by means of a long, sweeping stroke, the hide is cut away as closely and cleanly as possible. The lower picture shows the carcass completely stripped of its dorsal blubber, which has been dragged to the adjacent cove. The carcass is now ready to be rolled over so that the hide and blubber of the ventral surface may be removed in the same manner. Photographs by Captain B. D. Cleveland.

day. When the blubber is hauled on board it is cut into narrow strips called "horse pieces," and is afterwards "minced." The mincing differs from the same process in sperm whaling only in that the fat is cut very finely with hand knives. At this stage an additional loss of oil occurs, particularly if the temperature of the air chances to be well above the freezing point. Finally the minced blubber is "tried out" in the familiar deck try-works of the old whaling type. There is so little residue or "scrap" from boiled sea-elephant blubber that the Heard Island sealers of last century used to calculate "a cask of oil from a cask of blubber."

The method as practised by Norwegian whalers at South Georgia is more economical, inasmuch as the chunks of sea-elephant blubber are left attached to the skin, and loaded into a steamer's hold, after which the cargo—hide, fat, blood, dirt and all—is dumped into steam try-works at the whaling station and reduced to oil and slag.

During fifteen months of 1914–1915, 850,000 gallons of sea-elephant oil are said to have been exported from South Georgia by the Norwegian whalers. The sea-elephants can not long withstand such a toll as that, and the question as to whether the magnificent species is to be perpetuated will depend upon protective legislation which, it is to be fervently hoped, the British government will see fit to enact after the war. The difficulties and expenses of the modern whale fishery at South Georgia make it almost impossible for any species of whale to be completely extirpated, however persistently it may be chased, but the unfortunate sea-elephants have no such hope of preservation. Slow, unsuspicious, gregarious, they can be hunted profitably until the last one has gone to his ancestors and the tragedy of the antarctic fur seal is repeated.

PRINCIPLES AND PROBLEMS OF FISH CULTURE IN PONDS

By DR. R. E. COKER

ASSISTANT IN CHARGE SCIENTIFIC INQUIRY, U. S. BUREAU OF FISHERIES

FISH as living animals have essentially the same general requirements for growth and propagation as poultry or pigs. As animals living in water, however, they present their needs to us in a so much more obscure way that our problem in providing the proper conditions is relatively complex. We have to meet most of the requirements for successful rearing of fish by very indirect means, and in so doing we have to be guided by a knowledge of general principles and the application of common sense, rather than by any explicit rules.

The ordinary needs of fish, flesh or fowl are: air, water, food, cleanliness, exercise, shade, protection of adults and young from enemies and disease, some control of numbers in proportion to available space, proper conditions for breeding, and care of young. Looking at these requirements severally, we are at once confronted with a striking point of difference between fowl culture and fish culture. *Air,* or more strictly *oxygen,* is freely supplied by nature to animals. With the fish the oxygen problem is paramount, and the fish-farmer must give first thought to the maintenance of a favorable oxygen supply in his pond. Without food the fish would live for days or weeks; without oxygen, it would suffocate in a few hours.

Oxygen

Here is an excellent illustration of the fact that many of the requirements of fish are supplied by indirect means. Before we can proceed intelligently, we must know how the fish gets the oxygen necessary for its existence, that is to say, by what processes the oxygen supply is maintained in a natural body of water. This is one of our problems in its broad aspect.

Two processes are continually depleting the oxygen supply: The respiration of animals and the decomposition of various materials. In warm weather, too, the water will hold less oxygen, and it is accordingly the more necessary that the supply of oxygen shall then be added to continuously and abundantly.

How is the supply of oxygen maintained in a body of water? There are two principal means, one of which takes care of itself, but which is not entirely adequate for the purpose in small bodies of water.

First we are concerned with the interchange of gases between the surface of the water and the air. Birge has aptly employed the term "respiration of lakes," suggesting that the lake or pond breathes through its surface. He and others have shown how the oxygen supply thus derived is distributed through the body of the lake, and how this distribution is affected by temperature, seasons, winds and other factors.

As regards the propagation and rearing of fishes in self-contained ponds, we are led at once to certain very practical questions. What should be the size, the form, the depth and the relative proportion of deep and shallow waters in the several units of our pond system, or of our single pond if there can be but one? Obviously, for a wintering pond we must provide for storage of oxygen to carry over the winter; but in spring, the season of renewed activity, spawning, and the beginning of life for a new generation, the deep winter pond, now depleted of oxygen, proves ill-adapted for quick recuperation, since the warmer surface waters fail to carry the absorbed oxygen to the bottom. This is the season when the natural ponds and streams are accustomed to broaden their margins and flow out over the surrounding lands, and most of the fish in spawning activity are observed to follow the waters outward and to deposit their eggs in places more or less removed from the customary banks of the stream or pond. They find inducement to this outward migration, perhaps, in the warmer temperatures prevailing in the shallow overflow waters, or, perhaps, in the better conditions of oxygenation which may prevail at least temporarily.

Since it is being attempted to suggest rather than to outline problems, it may be in place to mention without comment two unrelated, but very interesting, facts. It is in the middle or late spring that the Bureau of Fisheries expects and receives the most numerous reports of unexplained mortalities of fishes in closely confined lakes. The other interesting fact is this: For two years, at our Fairport station, the effort to get the buffalo fish to spawn in artificial ponds failed. Last year, Mr. A. F. Shira, the director of the station, made the experiment of causing the pond to flow out gradually over a considerable area of ground just as the temperatures were developing when

Part of a group of ponds for fish-culture experimental work, at the United States Fisheries Biological Station, Fairport, Ia.

spawning could be expected. The buffalo fish acted just as they do in nature; they moved out into the shallow waters and spawned—doubtless the first buffalo fish to spawn in controlled ponds. Whether temperature or oxygen supply, or both, or something else is responsible for phenomena such as these, it is evident that the fish-culturist must look to the student of the physical conditions of enclosed waters for guidance in the construction and the control of ponds.

Just as the trees and the small plants and the grass are continually breaking up noxious gases in the air and replenishing the supply of oxygen, so in the water the submerged vegetation plays an important part in maintaining the oxygen supply for fish. In fact, they are probably the principal dependence for oxygen in ordinary fish ponds. In a very large lake where there are high waves and pronounced wind-driven currents, rolling movements, and upheavals, the vegetation plays a less part. The smaller the pond, however, the more essential are the submerged plants. Plants serve another useful purpose in taking care of the noxious carbon dioxide which is given off by animals in breathing and which is formed by the processes of decomposition.

In selecting plants for the pond for the purpose of oxygenation, it must be kept in mind that plants do not possess this function except in the presence of sunlight. The large lilypads which are so esthetically pleasing, but which, being at the surface, can contribute little to the oxygen supply of the water, form a deep shade that must diminish the oxygen-producing capacity of other plants living in the water beneath. It is evident that submerged vegetation is wanted and preference may be given to those plants having an abundant growth of narrow leaves, or to those with foliage so finely divided as to be needle-formed or brush-like. Consideration must be given, too, to the species which remain green during the winter or which are the earliest to give rise to new growth in the spring, so that there may be the most effective production of oxygen at a time when it is so important to the breeding fishes, and when the surface absorption of oxygen is normally less adequate.

Here, then, is a problem which has scarcely been attacked. What species of plants are the most effective oxygenators, under different conditions and at different seasons? The experienced and observant fish-culturist has somewhat definite ideas, and his judgment in the matter is very valuable, but I think that very little has been done in the way of experimental determination of the questions just stated. We ought to know, as precisely as we can, the relative oxygenating values of the different species of aquatic plants—for wintering ponds, for spawning ponds, and for rearing ponds.

Food Supply

The fish must have food and, under ordinary conditions of fish-culture, the food naturally produced in and about the pond is the principal dependence. Obviously, the productiveness of a pond in fish is directly limited by its productiveness in food;

An Experimental Pond, maintained under the conditions of a farm fish pond.

hence, fish-culturists often say that the whole problem of fish culture is one of food supply. It may well be so, since this is not a single problem, but a complex of problems.

Biologically speaking, the food problem starts with the plants, as the source from which, or through which, all animal food must come. Plants form the basis of food supply—large plants or microscopic plants, green plants or dead plants, or the finely divided plant remains constituting the detritus. To what extent do plants, living or dead, enter directly into the food of fishes? I venture to say that we know yet very little of this. Only a few years ago, the forage value of plants was considered insignificant. Yet, very recently, an investigator associated with our Bureau, Dr. A. S. Pearse, of the University of Wisconsin, has prepared for publication a report of the food of 32 species of fish from lakes in Wisconsin, and, from one of his tables, it can be found that, with 23 species, plant remains or algae constituted an appreciable portion (one per cent. or more) of the stomach contents, ranging from 1 per cent. to 25½ per cent. If we include silt and débris (probably plant material principally), 25 of the 32 species were plant feeders, and the ratio of such food to the total ranges from 1 to 40 per cent. Other uncompleted investigations of the bureau indicate that vegetable detritus constitutes a substantial, or perhaps the principal, element of diet for fresh-water mussels and for the young buffalo fishes. This is certainly true for many insect larvæ, and other small animals.

Undoubtedly, the direct food value of vegetation to pond fishes, especially to the young, is not inconsiderable; but even more significant is the part which this form of food plays in an indirect way. Generally speaking, as the fishes become older and larger (this is not true of all species, of course), they seek larger and more active prey, entomostraca are passed over for small insect larvæ, amphipods, small snails, etc., these in turn give place to larger insect larvæ, crawfishes and small fishes, and finally, larger fishes and frogs may become the special prey of the "big-game hunters" among the fish. But all the multitudinous members of this complex community of hunters and hunted derive their origin from plant matter. Now, one phase of this general problem of the relation of plants to food supply to which it is desired to direct attention is this: We have very little information as to the relative food values of the different species of plants. Undoubtedly, some species of plants are better forage plants than others. Dr. Emmaline

Moore, of Vassar College, and quite recently a special investigator for the Bureau, has already given us some valuable information about this, and I may be permitted to emphasize the point that, as her investigations show, plants of one species may be foraged upon, while those of a closely related species are left untouched. Presumably, too, some plants, when dead and disintegrated, give rise to a more palatable or nutritious detritus than others; of this we know little, if anything.

These questions of the relative values of plants, viewed either as oxygenators or as food makers, are not of theoretical or scientific interest only. This can be made clearer from an analogy. A stock farmer may have no interest whatever in plants as plants. Nevertheless, he sows alfalfa under certain conditions and burr-clover under others; he knows when and where he wants to plant red clover, and he knows that he never wants to plant sweet clover. All of these legumes are fairly closely related, yet the grower of stock has learned to discriminate between them, to use each to best advantage, or to let them alone, as his purpose may require. The grower of fishes, on the other hand, lets grow what will, practically speaking—and who can now advise him intelligently?

Our problem does not stop with the plants—it only begins there, biologically speaking. Small crustacea, insect larvæ, and molluscs feed upon plants or plant remains, and then upon each other. The problem becomes complex and peculiarly ecological, but its solution may be approached very directly. Here is an insect larva which feeds upon certain things and is preyed upon by certain other forms: it attacks and destroys small fishes and is itself devoured by larger fishes; it feeds upon materials which the fish that we wish to foster can not directly consume, thus adding material to the fish's food supply, while it competes with the fish for other forms and so diminishes the food supply; it destroys certain enemies of fishes, but who knows if it harbors some injurious parasite of fishes? The significance of this larva, and it is not altogether an imaginary one, is evidently not to be appraised as the result of casual observation. A great deal of data must be accumulated, the points of contact searched out in various directions, the evidence carefully analyzed, checked by experiment if possible, and weighed with sound judgment before a just conclusion is reached. Common sense will make the final ruling, but it will be common sense seated upon a secure bench of scientific observation and experiment. It would be an excellent thing for fish culture if one after another of the typical inhabitants of a pond could be taken up for systematic study along such lines as have been suggested.

Since this paper must be kept within reasonable limits and as the ecological rather than the biochemic aspects of fish-cultural problems are primarily in mind, the important subject of the artificial feeding of fishes in ponds must be passed over at this time. More nearly ecological is the question of the fertilization of ponds—the adding to the water of organic or inorganic substances, so as to promote an abundant growth of desirable aquatic organisms, without impairment of the conditions of existence for fish. In this connection, I will merely hint at two very important subjects; that is, the character and composition of the bottom soils and the chemical composition of the water itself. We know that plants and animals have definite chemical requirements, and the requisite substances must come, directly or indirectly, from the soil or from the water. We strongly suspect, at least, that certain chemicals have subtle but significant physiological effects, favorable or unfavorable, upon the growth of aquatic plants and animals—effects that can be discovered not so readily by inference from analysis, as by experimental determination.

So far, we have kept strictly within the confines of the pond itself, but the ecological problems of fish culture extend well beyond the reach even of the highest waves that wash the margins. The sloping banks, the green sward, the meadows beyond, do not these contribute to the food supply of the pond? No one can be doubtful of this after walking around a pond, and noting the small frogs that leap from the banks to be snapped in by a hungry bass, or observing the grasshoppers and crickets resting on the lotus leaves or in the stems of *Persicaria* or of cattails, or watching the dragonflies and mosquitoes and dozens of other insects that pass from bush or grass to pond and back again (if luck is with them). Read the reports of stomach examinations by Forbes and others, and note the extent to which non-aquatic insects and other animals enter into the food of fishes. Mr. H. W. Clark, of the Bureau of Fisheries, tells of trout feeding upon masses of woolly plant lice as fast as they fell from overhanging alders. Professor C. B. Wilson, while working at the Fairport Laboratory, finds a certain dragonfly that, like others, through its larvæ supplies food to fish, but that almost invariably completed its metamorphosis on a hillside slightly removed from the pond, although in order to arrive at this chosen environment after emerging from the pond, it was obliged to cross a dusty road. Professor J. M. Bates writes in *Science* of serious losses of fish in Pine Creek, Nebraska, caused apparently by feeding upon rose chafers dropping from overhanging willows. These are merely typical illustrations showing some of the various ways in which the land environment affects the fish life within the pond.

Doubtless, in due time fish farmers can be given definite and helpful advice, not only about the maintenance of a suitable environment in the pond, but also regarding the provision of a proper environment about the pond.

Association of Species

The judicious association of fishes within the pond is, perhaps, one of the most important questions of fish culture. To one who does not consider carefully the conditions of life in ponds, it may seem, offhand, that the only proper plan is one fish to the pond, yet, in all probability, this is rarely the practical plan of action. By associating two or more species of fish in the same pond, we expect to experience benefits in two directions: first—utilize the available space and food to best advantage, and, second—get the best results from any one given species.

There is nothing new in the idea that the appropriate association of species is for the best interest of the fish it is primarily desired to cultivate. An old and quaint, but very practical, book on the culture of the carp, published more than three quarters of a century ago, advises us to introduce with every 200 brood carp, 20 brood tench and 20 brood jack (pike). We can accept the author's explanation of the service of the pike, which is to check the increase (in numbers) of the carp, though we may be skeptical of the function ascribed to the tench, or "doctor fish," namely, to "act medicinally to other fish, by rubbing against them when wounded or sick."

Two chief principles which should guide us in determining the desirable combinations of fish are these. First, that the associated fish should not too severely compete with each other for food; second, that, under certain conditions at least, one of the groups of fishes should prey upon the others to such an extent as to prevent an excessive increase in numbers.

It would, beyond doubt, astonish a stock farmer to be advised to introduced a wolf into the sheep-fold; but what else should he do if he had no other practicable means of preventing his sheep from multiplying in numbers until the pasturage could no longer support them? If seems to be true that a new pond or lake often produces within a few years fish of particularly large size, and that after a while the fish became much more numerous, but much smaller in size. This is not invariably so, of course; it depends upon the conditions of stocking, but it is easy to see how this may come about. Given at first a reasonably abundant supply of food and a small number of fish, the fish, naturally, thrive and attain rapidly to a large size. The strong healthy fish reproduce successfully and the abundant generations of young, unless soon decimated by enemies, prey so exhaustively upon the available food as even to prevent its growth in formerly normal luxuriance. The introduction, then, by natural or artificial means, of a small number of rapacious fish may lead to such a reduction in the numbers of fish, and such a consequent change in the conditions of competition as to serve the best interests of each and every species within the pond. This is why the German carp growers put pike into the carp ponds.

The control of numbers is an essential condition of success in agriculture, husbandry, or fish culture; but where fish are being reared in ponds it is usually very difficult, if at all possible, to accomplish this end by direct means. Even if the pond is so devised that it may be drained, one can not always draw the pond after each brood is hatched, and to draw the pond may also entail a loss of valuable food supply carried out with the discharge of water.

Unless it be to provide variety, there can be no good purpose served by associating species which have identical feeding habits, and which, therefore, merely compete with one another. If, however, one can group fishes of principally insectivorous with others of principally vegetational diet, it is, obviously to be expected that the pond will yield more fish per acre than if only one half of the existing supply of food could be availed of. One may often, too, wish to introduce a smaller species, which will serve as food for a larger kind that is especially desired.

While the principles of association of fish species which have been outlined may seem almost too obvious to justify discussion, it is remarkable to what an extent they are violated in fact or in intention by persons of high intelligence in all other matters. Every possible species of Salmonidæ is desired in a particular lake. An organization of men, successful in their ordinary pursuits, will want to pour into a pet pond unlimited numbers of bass, pike, pike perch and perch. If a lake frequented for sport fishing is found to contain innumerable small crappie, the plea is for more crappie, on the fatuous assumption that "new blood" is all that is required to make the fish grow large.

The problems of appropriate associations are interesting and very important. Their solution may be attacked most directly by experiment, but also indirectly by studies of feeding habits and of associations in nature. I hope that I do not give an unduly unfavorable impression of the progress of fish cultural science, when I say that we know very little on the subject of proper association. If you wish to produce the greatest quantity of large-mouth bass per acre, what species of fish would you associate with the bass to serve as food for it—or would you leave the bass to itself and trust to cannibalism for the control of numbers? Apply the same question, if you wish, to other species; but who will now supply the answers based not upon opinion, but upon the sure footing of experimental determination?

In concluding, it seems to me that an apology may be due to the readers of THE SCIENTIFIC MONTHLY for presenting a paper which contains so little that is original, and which makes no pretense of adding to the sum total of knowledge. The purpose has been merely to indicate, from one incomplete point of view, a common meeting ground for the fish culturist and the ecologist, the zoologist and the botanist. If this shall lead, in any way, to more frequent meetings upon that ground, the effort of the writer and the time of the reader will not have been wasted.

THE ENGINEERING PROFESSION FIFTY YEARS HENCE. III

By DR. J. A. L. WADDELL

Promotion of Projects

Americans for two centuries have been notorious as promoters of projects. For this habit they have often been adversely criticized; but it should not be forgotten that, were it not for the enterprise, zeal, and courage of such men, our country would not be standing to-day as the acknowledged leader of the world. It is true that promotions used often to be carried to extremes, and that wild-cat schemes were only too common. The almost irrepressible enthusiasm of Americans needed a curb, and it certainly got it soon after the academy appointed a standing committee to pass upon all projects submitted to it involving the expenditure of more than a quarter of a million dollars. Bankers soon dropped into the habit of refusing to consider any large project that did not have the endorsement of the academy. The investigation of the soundness of any project is not done directly by the committee but by an engineer, or a firm of engineers, chosen by the said committee and paid a standard fee by the promoter. No real hardship for the latter is involved by this arrangement, because he is not actually compelled to come to the academy for an endorsement, although, truth to tell, the number of promoters is far smaller to-day than it used to be formerly. On the other hand, a far greater proportion of the schemes submitted to capitalists is materialized.

Working Abroad

Until the beginning of the third decade of the century, American financiers and business men were so interested in the development of our own country that they neglected the fine opportunities which constantly presented themselves for securing work abroad, especially in Latin America, although there was no dearth of American engineers who were eager to go to such countries in the service of any sound corporation. Some of them were willing to do more, for, having the "roving spirit" in their blood, they went as soldiers of fortune to Mexico, Cuba, and many of the South American republics. A few of them made good, but the large majority sooner or later came to grief for one cause or another. It was, as once before stated, the Great War that opened the eyes of Americans to the business opportunities in the countries to the south. At first the failure of our young men to understand Spanish militated greatly against progress in business with the Latin Americans; but a wave of enthusiasm for the study of that language suddenly overtook the country, and soon thereafter a large number of young American men and women possessed a good working knowledge of *la lengua castellana;* and their services were in immediate demand at good salaries.

There existed up to the end of the second decade a condition which acted adversely and seriously against the establishment on a large scale of business relations with foreign countries, viz., the apathy of the American government in protecting the rights of its citizens outside the boundaries of the United States. When Mr. William Jennings Bryan was Secretary of State, he made it plain to our soldiers of fortune and to our financial men that if they invested their money abroad it would be at their own risk, and that they need not look to the United States government for protection, in case of being defrauded of their foreign holdings by any illegal or piratical act of another nation. Such a pusillanimous doctrine was a disgrace to our country! Fortunately, the war taught the Administration the fallacy of it, and brought on a change of heart, with the result that now there is no nation in the world whose citizens are as well treated in foreign countries as are ours. It took years and much effort to accomplish this desideratum; but the result is worth incomparably more than all of the labor involved.

In the development of business relations with all foreign countries our academy has played a leading part, in that through its honorary members, who are always chosen from the most prominent and active engineers abroad, it receives annually therefrom reports concerning the progress of all kinds of engineering works during the past year. Besides, these honorary members have often interested themselves in promoting closer business relations between their countrymen and ours.

Publicity Movements

The publicity movement started by the Cleveland Engineering Society a little over fifty years ago, with the double object of bringing local engineers into touch with their fellow townsmen, and of making the latter conversant in an interesting way with the most important of the current feats of engineering, was gradually taken up by the local technical societies of other cities, until in time our profession became well and favorably known to the general public throughout the country. This movement was and still is fostered and encouraged by our academy through its specially friendly relations with the engineers' clubs and local technical societies which are now to be found in all American cities of any size.

Public Recognition

As the education of engineers became broader, they took more interest than formerly in local, state, and national politics; and because of their superior mental attainments, people soon began to select them as their representatives, at first as mayors and city managers, then as state legislators and governors, and then as U. S. congressmen and senators. Finally, in 1932, a civil engineer was elected president of the United States, thus making our country follow the example set by Cuba in 1912, when it elected General Menocal, a civil engineer of high standing, to the presidency of that republic. Since 1932 two other engineers have occupied the presidential chair at the White House.

Public recognition is truly the main object of engineering endeavor, because engineers more than any other class of people place honor and glory above the "almighty dollar," although it can not be denied that the accumulation of a reasonable amount of wealth is a proper ambition for any technical man.

This brings to a close my observations concerning the main causes of the wonderful advancement of the engineering profession during the last half-century; and now I shall proceed to indicate the most striking improvements which have been effected during that period in the various lines of engineering activity, taking them up in alphabetical order so as to avoid all possibility of criticism for alleged partiality.

Aeronautics

While the flying machine was made a *fait accompli* only in 1907, its perfection into a serviceable means of transportation was hastened by the Great War and by the silent preparation therefor on the part of some of the contestants. As a fighting machine it then reached the acme of perfection, because there has been no real war subsequently; but as a means of transportation for the business of peace it has since been wonderfully improved, and its carrying capacity has been augmented fully twenty-fold. There are now regular lines of passenger airships flying between the principal cities of the North American continent, and a considerable amount of first-class mail and a smaller amount of light express matter travel in the same manner; but it has not proved economical to transport freight through the air.

So great is the air-travel that it has been found necessary to pass stringent laws confining planes going to and from certain places and in certain directions to limited spaces, in order to avoid collisions. However, it has very seldom been found feasible to punish offenders for the infraction of these laws, because, if they escape collision, it is difficult to establish proof of the offense, while if they do not, it is generally unnecessary to penalize them.

Nearly fifty years ago the first flight to Europe was accomplished; and since then some desultory flying across the ocean has been practisced, but nothing of the kind on a commercial scale has yet been effected, in spite of repeated trials. Many of the hitherto inaccessible places of the world, such as mountain-tops and the lands of perpetual snow and ice, have been reached by the airplane; but such trips are fraught with so much peril that they have not become popular. Practically all of them have been made in the interests of science and exploration, only a few of them having proved remunerative through the discovery of deposits of certain rare minerals of value in the arts. The development and perfecting of the helicopter have enabled airplanes to alight with almost no shock in small spaces and to rise vertically from the ground. All the high mountains of the world have been sailed over by the airplane, consequently there is now no place on the earth which has not been visited by man. One of the most useful fields of the aeroplane is in making reconnaissances and preliminary surveys for railroads, continuous photographs of the country being taken, and the mapping thereof being done automatically—of course, in a rather crude manner, but with sufficient accuracy for exploratory work.

Agricultural Engineering

Agriculture as practised in America during the nineteenth century was exceedingly extravagant and crude. Very little scientific study was given to the subject until the state universities about 1900 began methodically to teach agriculture. The universities of the middle west were the first institutions to take hold of the matter in real earnest; and it was an acknowledged fact that the University of Wisconsin doubled the agricultural product of the state in a very few years simply by teaching its farmers the rudiments of scientific farming.

The shortage of food for the entire world during the Great War brought home to the American people the realization of the necessity for more thorough and economic methods of cultivating their soil. About all that could be done during the struggle was to increase the acreage of the crops and work longer hours, with the result that a material enlargement of the output was effected. Some attention, too, was then given to richer fertilization, but it was not until after peace had been declared that a systematic study was made of the problem of really multiplying materially the outputs of the various products of the soil in the different parts of the country. Commissions were sent to China, Japan, India, Holland, Belgium, and some other countries to study intensive farming; the best rotation of crops for the different soils was determined; economic fertilization was thoroughly investigated; the destruction of insect and animal pests was studied and put into practise; the utilization of all farm produce was established so firmly that the waste of anything at all usable soon came to be considered almost a crime; the breeding of domestic animals was reduced to a science; the employment of power instead of human labor, wherever possible, became widespread; the proper housing and care of machinery and tools was made compulsory by law; effective protection against fire and flood was instituted; all the really necessary conveniences and comforts of city life were brought to the farmers' houses; the roads were so improved as to reduce to a minimum the cost of hauling produce to market; and the life of the farmer and his family was made so attractive as to call to the soil the overplus of population which used to render our great cities so unhealthful and make urban life such a burden to the poor.

The production on a large scale of nitrates from the atmosphere, now a government monopoly, has done much to prevent the exhaustion of the soil. The taking over of this industry by the government was a natural sequence of its control of the manufacture and distribution of power, concerning which I have previously spoken at length. All excess power, or that which is not required for other purposes, is employed for nitrate production; and in seasons of flood the hydro-electric-power plants manufacture and store immense supplies of that material.

Applied Chemistry

As indicated previously, the Great War started such a boom of activity in chemical engineering as to make America subsequently independent of Europe not only for all the necessities but also for many of the luxuries of modern life, as well as for war supplies of every description, in case such should ever again be needed. New departments in our universities and technical schools for chemical engineering soon sprang into existence; and that branch of the profession quickly became one of the most popular and lucrative of them all, and has so continued to be ever since. In the economic disposal of sewage and garbage, chemical engineering has played a leading part.

Bridges

Fifty years ago bridge building had truly been reduced to a science; for it had been more thoroughly investigated and written up than any other branch of engineering. For that reason there have not been made in the last half-century as many improvements in this specialty as there have been in most of the others. In 1917, one of the leading bridge engineers of those days stated that the near future would mark the end of long-span bridge-construction, because the increasing scarcity of structural materials and the consequent rise in their price would render their cost prohibitive. As a prophet, he proved an utter failure, because scores of long-span bridges have since been constructed, the longest span being about three thousand feet in the case of the North River Highway Bridge at New York City. His alarm over the growing dearth of structural materials proved to be groundless, because soon afterwards enormous deposits of both fuel and iron were discovered. They were not developed, however, for some years, because the old sources of supply were sufficient, and because expensive lines of transportation were required to reach many of the new deposits.

Time has shown that the demand for a large bridge at an important crossing increases with the development of the adjacent metropolitan communities. Not only is there a continual growth in the keen necessity for lines of transportation over the water, but there is also an accompanying and more than proportionate growth in the wealth of the communities affected. With such increasing wealth there is bound to come a time when the demand for a bridge will far outweigh the obstacle of expense. In other words, the capitalized economic value of the project will ultimately increase to a point where it will more than balance the cost of construction.

The main reason for the existence to-day of so many long-span bridges is the fact that we have at our disposal for their building a truly high alloy of steel. That such is the case is due to the persistent efforts of my grandfather, extended over a period of two decades, in his search for an ideal alloy for long-span bridge building. His extensive experiments in the early twenties, using Mayarí steel as a basis, resulted in the obtaining of alloys having the following elastic limits:

For plate-and-shape steel, to be sub-punched and reamed, 65,000 pounds per square inch; for plate-and-shape steel, to be drilled solid, 75,000 pounds per square inch; and for eye-bar steel, heat-treated, 90,000 pounds per square inch. No material improvement in alloy bridge-steel has since been made, excepting only that it has been found practicable to manufacture heat-treated eye-bars having an elastic limit of 100,000 pounds per square inch.

The use of reinforced concrete for bridges has increased immensely in the past half-century. It is very seldom to-day that any span under 250 feet is built of steel; and reinforced-concrete arches of 350 feet span are not uncommon. A few longer ones have been built, one as long as 460 feet, but they are uneconomic on account of the great expense of erection and the numerous difficulties encountered in keeping the arch rings to proper elevation during construction.

In pier foundations no important advance has been made since the building of the great Mississippi River Bridge at New Orleans, where the piers were sunk 225 feet below low water, and had their bases enlarged by the injection of grouting. The pneumatic process of pier sinking has been somewhat improved, so that it is now comparatively safe for the workmen to operate under a head of 125 feet of water; and in a few cases pneumatic piers have been put down several feet deeper than this.

For certain new railroad lines with the widened gauge, the actual live loads have been increased to Class 85, which means axle-loadings of 85,000 pounds and carloads of 8,500 pounds per lineal foot; but for the standard-gauge railroads the old maximum of Class 70 still suffices, for the reason that it is as large a loading as the old-fashioned type of track will support.

In highway bridges there are no more wooden floors, even in country districts, because the auto-truck loads that are employed in all parts of North America are so great that it is unsafe to run them over any plank floor supported on timber joists. That type of floor system received vigorous adverse comment in the technical press in 1918, but it took a full decade to educate the public to an appreciation of its unfitness for carrying modern highway live loads.

Canals

In no line of engineering in the United States has greater progress been made during the past fifty years than in that of canal building. Immediately after the conclusion of the Great War, work was started on the Bowen Canal, joining Lakes Erie and Ontario and running behind the city of Buffalo, so as to reverse the flow of all the streams and main sewers in that city. The object of the canal is three-fold, viz.: It is a ship canal that accommodates the largest-sized vessels on the Great Lakes; it withdraws the sewage of Buffalo and the neighboring towns from the Niagara River and thus permits the water of the latter to be safely utilized for drinking purposes; and it develops some 750,000 horse-power. Its two lift-locks, each consisting of a pair of balanced steel tanks, some 660 feet long, 70 feet wide in the clear, and 35 feet deep, to contain 30 feet of water, in one the rise being 208 feet and in the other 104 feet, were an innovation in canal building; and nothing like them in magnitude has since been constructed.

Following the completion of this immense work, a series of canals and deepened rivers was begun so as to make it practicable not only for all lake vessels to reach the ocean, but also for a large proportion of ocean-going vessels to pass to the Great Lakes and discharge and take on cargoes at all of the large cities situated thereon.

Simultaneously with these there was constructed by the federal government the Inter-Coastal Canal, extending from the city of Boston to the mouth of the Rio Grande, and continued from there by the Mexican government as far as Vera Cruz. Ultimately it may be extended still farther.

Early in the forties our government undertook the construction of another interoceanic canal, adopting therefor the old Nicaragua route. It required nearly ten years to complete the work of construction.

Again, it was found economical to build on an enlarged scale many barge canals in various parts of the country, so as to lessen the cost of hauling produce, including the Great North-and-South Canal, which extends from the Canadian border to the Gulf of Mexico.

Heating

The development of central heating-plants in cities and large towns which took place during the third decade of the century solved one of the most difficult problems of housing in congested urban areas. In country districts and small towns, where such plants would not be economical, heating by electricity is now usual, in spite of the fact that it is apparently more expensive than the burning of fuel. This is because of the large saving in labor involved by employing electricity—and nowadays man-power is much more highly appreciated and conserved than it was half a century ago.

HYDRAULICS

Important advances have been made in the science of hydraulic engineering during the fifty years past. Late in 1917 one of America's most prominent hydraulic engineers in a private letter wrote as follows:

> The profession is somewhat handicapped by holding conventional views of water instead of a thorough knowledge of the internal workings and nature thereof. . . .
>
> I have found that the hydraulics of the rivers themselves are very vaguely understood. The quantity of water flowing, the water surface elevation at many points corresponding to these volumes, and the length of time in which a change of stage is transmitted over forty or fifty miles of river concerned, are all rather vaguely comprehended; and in many cases text-book formulas instead of observations are used. I find an astounding amount of adventurous design in dams, evidenced by many failures. One of the causes of failure is the lack of understanding concerning the matter of the standing wave, in which water changes from a dynamic condition to one of more nearly static equilibrium. How to build a dam upon a glacial-drift foundation and utilize the full head available, thus conserving the water power, has not yet been clearly worked out.
>
> Perhaps one of the chief faults in such cases is the lack of experimental data, preceding design and construction. In other words, we operate on the patient before we diagnose the case thoroughly. As the years go by we shall emphasize preliminary diagnosis in all engineering matters.

Some five years after the above was written, through the influence of our academy, the American government was persuaded into appointing a well-paid board of three of the country's most prominent hydraulic engineers (including, by the way, the writer of the letter just quoted) to study with a large force of assistants a number of hitherto unsolved questions in hydraulics. The work of that committee extended over a period of seven years; and the results of its investigations are of exceeding value. All the great hydraulic works of the world undertaken since the publication of its report have been based on its findings, and the saving of money resulting runs into the hundreds of millions of dollars.

IRRIGATION

During the early portion of the century, irrigation projects in the United States fell into disrepute, because many of them had proved financial failures. This was due to the promoters having either dispensed with engineers' services altogether or else retained cheap ones who did not possess the necessary ability or experience. On that account it was almost impracticable fifty years ago to find an American banker who would finance an irrigation enterprise, no matter how promising the prospectus might show it to be. But as the country became more and more settled, there arose a demand for irrigable lands that could not be withstood, and irrigation once more came into its own. To-day there is left in our country comparatively little unwatered land that is capable of being irrigated at any reasonable expense. Our irrigated lands are the largest producing, the most reliable, and the highest priced of all the cultivated lands of the country, not excepting even the reclaimed lands of the Mississippi River delta.

Allied to irrigation is the watering of crops by the artificial precipitation of moisture. Early in the century certain credulous persons (as well as a few designing ones) made themselves ridiculous by vainly trying to cause rainfall in the arid districts of Kansas through the firing of cannon and the explosion of bombs. This fiasco made scientific men rather chary of even mentioning the subject of artificial rainfall; nevertheless Chiera Maclen Whask, C.E., in the early twenties proposed to some of his friends that they try to condense the fogs which blow from the Pacific Ocean over the tablelands of Southern California by spraying from above them liquid air carried on aeroplanes. Some experiments made thus by private subscription showed the scheme to be feasible; and it was then undertaken on a large scale by the Department of Public Works and proved to be a commercial success. The method has been followed in several districts along the Pacific coast of South America.

Levees

For about a century the building of levees in the Mississippi River delta was done piecemeal and in a haphazard and desultory manner, with the result that the said levees were being continually broken or overflowed, to the great detriment of the bottomlands for a considerable distance both above and below. The levees were lacking in both height and strength; and they were built in short lengths by different communities. Of course, under such conditions they were without system; and the protected (?) lands were annually in danger of being flooded. This prevented their proper settlement and development.

In the early twenties there was appointed a commission of engineers, first, to report upon the control of the Mississippi River and the reclamation and development of the adjoining lands, including the entire delta, and, second, to attend to the work of the said reclamation and development. It took a dozen years to complete the work, which was all done at the joint expense of the United States government and of the several states wherein the reclaimed lands were located. The products from these reclaimed lands are of a greatness and value staggering to the mind and almost incomprehensible. The soil is exceedingly rich; and most of it bears two crops per annum—in some places three. These lands truly form the garden-spot of the world, comparing in yielding capacity per acre quite favorably with the best of the irrigated lands of the West.

Lighting

Owing to the uniform distribution of power throughout the land, the problem of lighting has become a very simple one, and the farmer as well as the city-dweller now has all the light he needs for every purpose at a reasonable price. Being under government control, all lighting apparatus is kept in good repair and at a minimum of expense.

Materials of Engineering

Very few new materials for engineering work have come into use during the past half-century, but the old ones have been much improved, their scope has been greatly enlarged, and the cost of their production has been materially reduced. Numerous alloys of the metals have been manufactured and employed in the arts upon a commercial basis, including the before-mentioned high-alloy of steel for long-span bridges; the manufacture of hydraulic cement has been cheapened; and the use of timber has been reduced to a minimum. The heat-treatment of steel has increased its strength from two to three fold. Wrought iron has come back into use for many things in the manufacture of which it is superior to steel—for instance, tinned plate, metal employed near salt water, and cylinders for bridge-piers. The Bruntwasler process, developed after long delay in the early twenties, permitted the making of wrought iron directly from the ore, and thus kept the price down to a reasonable figure.

Mining

In this line of engineering the improvements have not been so marked as in most of the other lines. The dwindling supply of gold has forced the adoption of more economic methods of extraction; and the increased demand for iron products has necessitated a cheapening of the mining of the ore as well as of the reduction of the metal therefrom. Most of the improvements in mining consist in the development of economic methods, and especially by working upon a large scale. The drainage of mines has received much attention; and it has been found practicable to operate deeper workings than formerly.

Power

Concerning this matter I have spoken at length before, and I, therefore, have not much more to say upon the subject, except to remark that a large elimination of physical labor has been effected by means of the development of machinery in many ways formerly thought impossible or uneconomical. There is an old saying to the effect that anything which can be manufactured by hand can be manufactured also by machinery; and it seems to have been nearly, if not quite, true.

Railroading

In railroading some fundamental improvements have been made in the last half-century, though not many in the standard-gauge system, which was used exclusively till about 1929, when the first wide-gauge trunk-line was built from Pittsburgh to the Great Lakes so as to carry long trains of ore cars weighing when loaded as much as 8,000 pounds per lineal foot. The gauge was made six and a half feet, and the rails were laid upon a concrete base, but not until after the embankments had come to a final settlement. Since then a number of other railroads have been built in that manner, but they are all used exclusively for carrying heavy freight between terminal points, and not for the ordinary distribution of light freight, which can be handled more economically by standard-gauge lines, especially since they have all been electrified. The last of the steam locomotives went out of commission some twelve years ago. They were found to be less economical in operation than electric locomotives, besides being exceedingly offensive to the traveling public because of their smoke. The building of very long tunnels, in order to reduce the heavy grades that used to exist on our transcontinental roads, rendered the employment of steam locomotives really dangerous to human life. The change in power began by the electrification of lines through such tunnels, and gradually extended so as to cover the rest of the line on which the tunnels were located. Finally, the electrically operated lines proved to be so satisfactory that all lines were eventually electrified.

Considerable expensive railroad work has been done of late years by building belt lines around all large cities, not only to connect the various systems passing through them, but also to divert through-freight away from congested traffic-centers.

Another innovation in railroading was the adoption of the monorail system of transportation, evolved by Charles Whiting Baker and introduced by him in the early twenties, after many trials and tribulations. It is employed generally as a feeder to other railroads and to take the place of the electric railway in those localities where a more expensive type of construction is not warranted. At first the Baker system was operated solely by gasoline engines, but since it was proved to be a success it has sometimes been run by electricity.

Attention has been paid of late years to reducing the noise of operating railroads, and the attempt has proved quite successful.

Another important improvement in railroading has been the installment of automatic block signals, which now work to perfection.

The immense increase in the number of automobiles and the high speed at which they are driven have rendered imperative the separation of grade of streets and roads from railroad tracks, except in a few localities where the automobile traffic is light. It required federal control to establish this innovation; and in securing it the American Academy of Engineers took the leading part. The problem was essentially a financial one; and it was settled by dividing the expense of grade separation upon an equitable basis (which varied for different localities and different conditions) between the railroads, the federal government, and the municipal or state government.

In railroading, as in all other lines of technical activity, the substitution of machine labor for hand labor has effected great improvements—for instance, tie-tamping machines, ditching machines, rail-loaders and unloaders, and track-laying machines.

The old, slow process of surveying railway lines, taking topography and platting to scale on maps by using large forces of men has been very much simplified. Instruments of precision have been designed which traverse the sections of the country under investigation and accurately record on maps and profiles by fixed scales the same data that used to be obtained by employing several field parties. As before mentioned, the aeroplane has been utilized to much advantage in railroad surveying.

The long-discussed question of government operation of railroads was settled by experience obtained during the Great War. It was finally decided thereafter that it would be better to continue to let the railroads operate as previously—but with certain restrictions, as well as certain liberties formerly denied them, rather than to leave them absolutely under government control. The restrictions of the Interstate Commerce Commission had proved to be so drastic and severe that the gross earnings decreased and the operating expenses increased to such an extent that the result was an annual deficit instead of an annual profit. Under continued conditions of this kind, the public refused to invest its savings in railroad securities; and, in consequence, railroad construction throughout the United States came to a standstill. Nor did the roads earn enough money even for up-keep of line and rolling stock; consequently the condition of the systems had deteriorated, wrecks had become common, and more or less general demoralization had ensued up to the end of 1917, when the government assumed control for the period of the war.

Pooling had been prohibited and treated as a crime; but the government itself soon learned that that method of operation was the only sane and economical one possible. Eventually, private ownership with government supervision, cooperation, and support was decided upon as the logical solution of the knotty problem. Experience has proved that it was a wise decision; for now when private investors refuse to lend their money for necessary improvements, the government lends what is needed; a legitimate pooling of interests of competing roads has been adopted; and the officials responsible for results have the opportunity of selecting those extensions which will be most beneficial to the wholesome growth and development of the country, and are in a position to prevent ill-advised duplication and multiplication of competing facilities, such as in times past placed an insupportable burden upon certain railroads and the communities that they served.

Reclamation

I have already referred at length to the reclamation of lands along the Mississippi River. Other minor rivers have been treated in the same manner, swamps have been drained, and sandy places have been covered with fertile soil. The drainage of the immense swamps of Florida and of some of the other Gulf States has thrown open to settlement agricultural lands of untold value and productiveness.

The most elaborate and expensive reclamation project ever undertaken, or even contemplated, is that of New York Bay and the adjacent waters. It was conceived and advocated over fifty years ago by T. Kennard Thomson, a consulting engineer of New York City. After much discouragement, he finally succeeded in getting work started on his immense enterprise; but it has required fully four decades of hard work and untold millions of money to complete less than one half of the original scheme, notwithstanding the fact that, from the commercial standpoint, it has proved a success.

Reinforced-Concrete Construction

The use of reinforced concrete of late years has become far more general than was anticipated fifty years ago; for to-day it seems that almost any construction, large or small, excepting long-span bridges, can be built of that material. During war times, the reinforced-concrete vessel was perfected; and since then that material has usurped the place of steel, stone, brick, and timber in constructions of all kinds. When scientifically and honestly manufactured and used, it is a thoroughly reliable material; and the cost of its maintenance and repair, as compared with other types of construction, is truly a minimum.

River Improvement

In addition to the leveeing of the lower Mississippi River and the reclamation of the adjoining lands before mentioned, a scientific study of the problem of how best to improve the other navigable rivers of the United States was made at the expense of the government and under the management of our academy. A commission of seven expert engineers in various lines was appointed, with instructions to study certain of our great rivers and report upon how best to improve them so as to care for navigation, shore protection, water-supply, drainage, irrigation, and power. All these desiderata were to be duly weighed and evaluated, so as to determine in every case whether each item should be considered or ignored; and, if considered, to what extent. After the report upon each river was completed, the government (through our academy) decided what improvements were advisable for the immediate future, how they should be effected, what works could properly be relegated to the distant future, and what provision should be made for their ultimate accomplishment. Then the improvement was regularly undertaken by the Department of Public Works, which body at times utilized its privilege of calling upon the academy for advice and counsel.

Another river improvement (of a temporary nature, however) that has been undertaken by the federal government of late years is the keeping open during the winter months, by means of ice-breakers, certain navigable waters, including among others the Mississippi up to St. Louis, the Hudson up to Albany, and the Ohio up to Pittsburgh.

The river improvements of our country are by no means completed—in fact one might say that they are merely started; for much yet remains to be done to help the regulation of the flow by building storage reservoirs near the headwaters and thus incidentally irrigating lands and developing power.

Roads

Fifty years ago the extravagance involved in the then-prevalent methods of road construction was simply a crime! From one end of the country to the other the people's money was squandered by incompetent, and often dishonest, county or township supervisors. Many of these men used to claim that they knew how to build roads as well as any engineer, consequently road-construction was hardly considered by our profession as coming within its realm of activity. A reaction began to set in about the end of the second decade, and a certain amount of roadwork was undertaken by some of the state governments; but it took many years to establish road-building upon its present satisfactory basis. To-day the great highways of the country are under federal control, and are handled by the Department of Public Works through its "Bureau of Roads"; and all other road-building comes under the jurisdiction of the various states, each state government having a special bureau therefor. As a result of this arrangement, our common roads are the most perfect of any in the world; and it is universally conceded that they pay for their first cost and upkeep many times over by reason of the fine facilities which they afford the farming community for delivering produce to the main arteries of transportation. Pleasure-travel by automobile, in consequence of our good roads, has become the most popular pastime of the nation; and the reaction therefrom upon the people through enlarging their horizon of acquaintance has been strikingly valuable.

Sanitary Engineering

When one looks back upon the wasteful methods of sewage disposal which governed half a century ago, he can not but wonder how intelligent people—especially engineers—could countenance the discharge of unpurified sewage and waste products of manufactories into the streams and lakes, thus ruining them for water-supply and destroying the fish, besides wasting millions of tons of fertilizer so sadly needed by the farmers.

To-day it is not permitted to turn unpurified sewage into any water-course or lake; and the sources of our drinking water are guarded against pollution by the strictest kind of supervision. The result is that the people have pure water not only to drink but also to utilize in the arts; our lakes, rivers, and streams teem with fine fish, the supply of which is kept up by federal control; and the exhaustion of the country's soil, which was increasing at such an alarming rate a few decades ago, has ceased. Moreover, these are not the only important benefits secured through the adoption of common-sense methods of sewage disposal; because its effect on general health by the reduction almost to zero of certain diseases, which in times past were often veritable scourges, has proved to be a god-send to the community. I speak truly when I state that the consummation of this great economic reform is due primarily to the efforts of our academy, which brought a number of other technical societies, economic organizations and municipal governments into line, and thus induced Congress to pass and put into effect the necessary laws.

Steamships

The improvements in ship-building of the last fifty years have been simply marvellous. Not only are the vessels far larger than they were formerly, but also they are equipped with every modern comfort and convenience for passengers and every facility for the economic handling of freight. Moreover, they are now made almost unsinkable; and the lanes of travel are so strictly followed that collisions of vessels at sea are almost unknown. The signaling between vessels and with the shore has been perfected; and various kinds of apparatus, working automatically, indicate the proximity and direction of other craft, icebergs and the land. No great increase in speed has been achieved, because the economic velocity of travel had already been attained half a century ago. It is true that we now can develop somewhat greater speeds, but it is not economical to do so, except in special cases for the purpose of meeting unusual conditions.

Steel Buildings

In steel-building construction no fundamental advance has been achieved in the last half-century. It is true that we have in New York City an eighty-story building, but it has proved to be a white elephant for its owners. It has been found advisable in tall-building construction to study very carefully in each case all the conditions from the economic viewpoint, so as to determine what will be the best height to adopt when everything is given due consideration.

The Telegraph

Since the discovery of wireless telegraphy some sixty years ago, no fundamental improvement has been made in this branch of technics, unless it be the "teletypograph." By this apparatus there can be produced at any place in the United States or Canada, and also simultaneously at a great number of places, the contents of a typewritten page, the time required for transmission and reproduction being about one second. The message to be sent is first typed with a special ribbon upon a special kind of paper, and then this is run through a pair of rolls similar to those of the old-fashioned clothes-wringer. The distant reproductions are made on similar paper by means of a special ink.

The Telephone

The improvements in telephony of the past fifty years have been mainly in detail, excepting only that the wireless telephone has been perfected. It has not, however, put out of commission the ordinary telephone system in which wires are employed.

It has been found practicable to utilize a wire simultaneously for half a dozen messages without involving any interference; and the recording by phonograph of long-distance messages sent by wire is now not merely practicable, but is truly a paying business-venture. Some bold technical dreamers have lately been talking of recording in a similar manner telephone messages sent by wireless, but thus far nothing has really been accomplished through their experiments.

Tunneling

In tunneling no great strides have been made in the fifty years past. Much longer tunnels have been constructed than were formerly built; but in subaqueous tunnel-work it has not been found practicable to go much lower than one hundred feet below water, although in a few cases that depth has been exceeded by ten or twelve feet. We still have to depend upon compressed air to keep back the water. The freezing process did not prove to be commercially practicable for tunnels, although it has solved some difficult problems in the sinking of deep shafts. Important improvements have been made in the methods of tunnel-construction, and the unit prices of excavation therefor have been brought to very low figures.

Water Supply

No startling innovations in water supply have been made for many years, although a number of valuable improvements have been effected. In addition to the control of the pollution of watersheds previously mentioned, I might call attention to the use of Mayarí steel for pipes, which has increased their strength fully fifty per cent. and their cost in place only from twenty to twenty-five per cent. for the same weight of metal; to the greatly increased efficiency of pumping equipment; to the wonderfully dependable and durable coating for steel and iron, called "Anticorro"; and to the efficient and absolutely unobjectionable modern methods of purifying drinking water.

Conclusion

In drawing this rather lengthy address to a close, I should like to speculate as to what important improvements in engineering will be evolved in the next fifty years, so as, in a measure, to anticipate the retiring address of my distant successor in office when our academy celebrates the one hundredth anniversary of its establishment; but any attempt to do so would certainly prove futile. I must confess that I can not even prognosticate as to whether the progress in engineering during the next half-century will exceed or fall behind that of the one just ended; but this much I can very safely foretell: Whatever the said progress may be, a large proportion of it will be due to the initiative of our well-beloved society, The American Academy of Engineers.

RESEARCH AND THE INDUSTRIES

By DR. P. G. NUTTING

DIRECTOR, WESTINGHOUSE RESEARCH LABORATORY, EAST PITTSBURGH, PA.

According to the older view, an industry is composed of two elements—capital and labor. This is true to-day of the smaller and less technical manufacturing concerns. Capital supplies plant and equipment and covers the lag between expense for material and receipts from sales. Labor prepares and fabricates material according to accepted methods, keeps the plant in order and suggests improvements. The manager may be in the ranks of either capital or labor.

But a large, progressive, modern industry is operated on quite a different plan. *Capital* is represented only by a group of bankers in the dim background. The thousands of technical operatives of all grades representing *labor* follow routine instructions or work to blue prints. The vital part of the organization is the *technical expert,* everywhere directing the various departments, divisions and sections, designing new products, developing new ideas, eliminating troubles, testing raw materials and finished products. Without him the industry would go on the rocks at the first serious works trouble and even in the absence of such would be rapidly outdistanced by progressive rivals. The technical expert may or may not be financially interested in his company—it is immaterial. He is a professional solver of problems and applier of fundamental principles in quite the same sense as a physician or lawyer. He has his own capital invested in his own brain by reason of the expense for his special education and training. He represents a class quite distinct from either capital or labor, much as would a man with a special, unique machine of his own, hired for a special job.

The training of the industrial expert may be in any of a wide variety of different *fields,* ranging from statistics to science. A large progressive concern usually has at least the following separate departments: Accounts, Education, Engineering (including Research), Executive, Export, Legal (including Patent), Mailing, Publicity, Sales, Service, Treasury, Traffic and Works. In each of these (with its divisions and sections) are experts of all *grades,* smoothing out troubles, checking the work of less skilled labor, dealing with outsiders, solving general problems and finally anticipating requirements in the nature of fundamental principles by extended investigations of the principles underlying general problems. Within each grade of each field of expert knowledge individual characteristics come into play and the work may properly be made to fit the man, or rather, the man allowed to cut out his own field of endeavor according to his taste and training.

In relation to *organized knowledge*, the nation as a whole is concerned with its dissemination through education, its increase through research and its application to special problems of all kinds in all fields. The promotion of each is the self-evident course toward the ultimate goal of all our problems solved by experts, the elimination of misguided effort and the rule of common sense everywhere. The large industrial unit stands in precisely this relation to organized knowledge, but chiefly only in selected fields, and in these is concerned not so much with education as with research and the application of the results of research through engineering.

Industrial research is one of the three great classes by which the great bulk of the increase in organized knowledge is made. The investigation of fundamental laws and phenomena is naturally and probably always will be associated with our universities and our greatest teachers and leaders. We look to *university* research to advance our knowledge of the structure of the atom, gravitation, valence, relativity and similar phenomena. Problems in such fields as astronomy and astrophysics, geophysics and terrestrial magnetism are properly the charge of either university or of privately endowed research laboratories. It is the field of *national* research, directly endowed and fostered by national and state governments, to solve problems of general practical interest such as are related to public health, food, forestry, soil physics, road building, animal hubandry, education, the maintenance of standards and the development and conservation of public resources. Such problems fall outside the bounds of both industrial and university research. The existence of a number of privately owned and of cooperative research corporations in a flourishing condition attest the commercial value of research by technically trained experts.

There exists a widespread but fallacious notion that industrial research deals chiefly with cures for works troubles. As a matter of fact that represents but one extreme, the other extreme being the purest of "pure" research and the average being nearly or quite as fundamental as the average university research in physics or chemistry. Industrial research is usually directed along lines of more or less direct interest to the company, but almost invariably leads to results of general or theoretical interest. On the other hand, hardly any research is so "pure" but that it will yield some results of commercial value. In the investigation of difficult industrial problems, it is usually found necessary to continually dig deeper and deeper until the very foundations of the science are reached. Industrial research can not be distinguished from "pure" research, except that in one case it is the scientific results that are the by-products, while, in the other it is the results of commercial interest which are regarded as incidental. In a typical large industrial research laboratory the main line product is a series of reports from the laboratory to the chief of the division; the by-products are scientific papers and patents. It would be difficult to name a piece of research which would not be likely to yield all three classes of results: scientific, technical and patentable.

But research is exceedingly expensive and the results are very uncertain. Why is it that manufacturing concerns are so ready to start and maintain research laboratories, particularly since so much of physics and chemistry has already been worked out? In any industrial plant the need of research work and research men is usually first felt in the need of *improvements in products* and of *utilizing by-products.* The factory superintendent and his experienced foremen have been able to handle the ordinary run of works troubles and make minor improvements. But they find themselves handicapped by the lack of deeper insight into materials and their behavior. Why does one lot of material give good results and the next fail utterly even though chemical analysis reveals no difference? What is the cause of blow holes in castings and how may they be eliminated? The elimination of obscure works troubles calls for expert technical advice and no manufacturing concern can go very far without feeling the need of it. As a general rule the expert with just the required knowledge can not be found or is employed by a rival concern. If the problem is turned over to a private or cooperative laboratory, a solution of their problem may be attained, but they have no further control over the investigator, valuable by-products of the research are wasted and a crop of succeeding related problems must go unharvested. The results are far less satisfactory than when the concern has its own laboratory.

But probably the most urgent *raison d'être* for industrial research laboratories is the constant danger of being out-distanced by competitors. Of two otherwise equal concerns, one of which has plenty of skilled scientific and technical assistance and the other has not, the former is sure to forge steadily ahead of its unprogressive competitor by making more far-reaching improvements and by utilizing waste products. Even bakeries and laundries find research pays in cutting down losses and making improvements in processes. The balance is a delicate one, since the results are cumulative.

The notion that physics or chemistry is "all worked out" can hardly exist except in the mind of the student. As a typical concrete example of industrial research work let us consider the problem of condenser dielectrics. The student has learned the definition of dielectric constant and how to measure it. He knows his electromagnetic theory and the relation between refractive index and dielectric constant. He knows that constant to be an important one in organic chemistry and that it varies with frequency. But the industrial concern wishes to know what is the best dielectric to use in a given kind of condenser. That dielectric must have a high dielectric constant with high dielectric strength and low watt loss. It must be insoluble in certain oils, but soluble in certain solvents. It must be fusible, but must have high melting point and must be stable. Finally, it must be reasonable in price. The organic chemist has a rich field of fats, oils and waxes to cover; acids and esters, halogenated hydrocarbons, ketones and the like to prepare and try out. The physicist must devise new and more precise methods of measuring dielectric constant and of separating the leakage current from the displacement current in the presence of some electrolysis and polarization. All of this physical and chemical research devolves upon the industrial laboratory. The investigator is fortunate if he have a thorough grounding in the elements preparatory for this work. Any problem in this whole field is well worthy of a university laboratory and no problem can fail to yield results of scientific as well as practical interest.

Similar fields of industrial research might be cited without number: leather substitutes, magnetic materials, porcelain, varnish, glass, coke, soap, non-corrosive alloys, tool steel. In each field there are extensive groups of problems each relating to material for a different special purpose and each with its special set of requirements. In each case, the university man, entering industrial research, finds his academic training, even high-grade graduate work, to be hardly introductory to the work in hand. By digging through recent scientific literature he may find a few bits of applicable data and suggestive leads, but rarely more than this. In a few of our leading technical institutes advanced students work on actual industrial research problems and excellent results are obtained. The student takes a keen interest in his work and gets a great deal out of it, the spirit of the whole institution is enlivened and frequently both the student and the concern to which he disposes of his rights reap considerable financial advantages. If the student is careful to clear up the fundamental principles involved, even "pure" science is as rapidly enriched as by any other class of research.

In the broadest meaning of the term an *engineer* is one who applies fundamental principles to practical problems. With a thorough grounding in those principles and a taste for the practical, he rapidly becomes an expert in his chosen field, whether it be bridge-building, designing power plants, making explosives, surgery, copper reduction, banking, ceramics or radiotelegraphy. In order to become an expert it is necessary first of all to acquire a broad general knowledge of all fields related to the one chosen. Upon this must be built a thorough knowledge of the basic principles involved in that field; research is undoubtedly the best and only means of acquiring such knowledge. Then comes the technical training in solving practical problems obtained through actual solution of such problems. Finally, the expert is ready to attack any problem that he may be called upon to solve. The future of the nation depends upon the quality and numbers of its engineers. A first-class engineer is not only an expert in his chosen field, but keeps in close touch with developments in basic principles in his own field and in related fields. It must be admitted, however, that the country is full of men in positions where expert knowledge and skill would be desirable, but who have neither the thorough grounding nor an up-to-date knowledge of their chosen lines of work. May the number become rapidly fewer!

Nearly all our large industrial concerns are now in the hands of a corps of trained experts designing, superintending manufacture in its various branches, writing specifications, testing products, etc., frequently known as the engineering department. Within this department, a natural subdivision is the research division, looking after the more technical and scientific problems that arise. That division is composed largely of physicists and chemists who are experts on raw materials, on testing product, on special products, preparations, methods and processes and on uncovering obscure basic principles and relations. Such a research division falls naturally into two fairly distinct sections, the technical and the scientific. The technical or engineering research section takes care of works troubles and routine testing and looks after the initiation of new works processes. The scientific research section properly looks after the investigation of the larger and more obscure problems requiring more extended research in more or less pure science. The technical research is conveniently located within the works while the scientific research may best be carried on in special laboratories separated from the works and largely under its own management. Technical research requires men with a taste for precision work and an insight into practical problems. Scientific research requires men with subjective fertility of mind and a firm grasp of the fundamental laws and principles of physics or chemistry.

In brief, industrial concerns provide their own research divisions, because (1) the accumulated knowledge of physics and chemistry falls far short of filling their needs and (2) university research fails to provide solutions for most of the larger industrial problems. University research might be largely directed toward problems of industrial moment without being any less scientific than the present average of university research, but the results of such research would always be unsatisfactory. In most cases, further research would be required to bring the results into shape for industrial application and in any case some one concern would wish exclusive rights to their use. It is only fair that the industry reaping the chief benefits from the results obtained should bear the expense of obtaining them.

The great strides in industrial progress are in the nature of improvements in *materials, methods* and *processes* and are chiefly, therefore, the work of chemists and inventors. The physicist investigates and tests the results of both. In the typical group of problems cited above (condenser dielectrics) the chemist develops materials of promise while physical measurements test their worth. The work of the physicist is at least as important as that of the chemist, but the credit will go largely to the former. This case is typical of the vast majority of research problems. The expert called upon to test a new invention is also usually a physicist. Comparatively few valuable results are obtained by either physicists, inventors or chemists working alone.

In the ideal industrial laboratory there must be the closest cooperation between the physicists and chemists and indeed between all members of the laboratory staff. University research must always be done largely through individual effort due to its very nature and to the lack of coordinated time for research by either instructors or students. Some of the earlier industrial and national research organizations are on a similar individual plan. Each high-grade man is given a room or suite of rooms with apparatus and assistants and only his chief (if any one but himself) knows much about what he is doing. There is no regular meeting of the staff for discussion of results and no general assembly other than perhaps a weekly meeting to listen to a lecture by an outsider. The natural result is a tendency to wander into side issues and to become jealous of colleagues through ignorance of their work and objectives.

In some of the more recently organized large industrial research laboratories, cooperation and team work are carried to an extreme heretofore unknown. A system of weekly or biweekly conferences on each of the major lines of research promotes the interchange of ideas and a general knowledge of all the work going on, and thereby secures an excellent spirit of cooperation and comradeship. Each conference is attended by the men carrying on the work, colleagues interested in that work, a member of the patent department and one or more research engineers. The latter look out for patentable material and for results of probable interest in the works. The director is ex-officio chairman and directs the discussion along the most useful channels. Stenographic notes are taken of each conference, these notes being afterward revised, typed, witnessed and filed for reference. Such conferences effectively stimulate ideas and suggestions and keep research directed toward the chief objectives. Such effective team work in scientific research is new, but the results indicate that it has come to stay.

An occasional conference is given over to suggestions for new lines of research. If, after thorough discussion, a suggestion appears sufficiently promising, a grant to cover it is applied for and work initiated. A piece of work lasting a year and costing from two to ten thousand dollars is not to be lightly undertaken or discontinued.

Three forms of general assembly are found to be profitable in any research organization: (1) a meeting to present and discuss the work (scientific paper or technical report) of members of the staff, (2) a journal meeting dealing with the current periodical literature and (3) topical lectures in groups of three to five lectures by some expert member of the staff or outsider on his own specialty, chiefly for the benefit of the younger members of the staff. Men who have joined the staff without much advanced university work are always a problem in the older, larger laboratories. Their advancement can not be as rapid as it might had they a full university training, it is difficult for them to drop out for further university work and, unless some such lectures are provided, the less mature men are liable to stagnate.

The *technical research* wing of the research division of a large concern is properly about equal in size or somewhat larger than the scientific research section and is made up of chemists, physicists and engineers. Their work is necessarily varied in character. It ranges from chemical analyses of raw materials and the testing of products to the elimination of works troubles and the testing and installation of new manufacturing processes. Such work requires men with a taste for routine testing, precision measurements or for the application of scientific data to concrete problems. On the other hand, men with high originality and a tendency to theorize belongs rather in the scientific wing of the research division.

Another function of the research division is to prepare men for the higher executive positions and to train specialists to take charge of special fields of advanced technical research. Men who have had a full academic course, supplemented by several years of research work in an industrial laboratory, make the best of timber from which to select *executives* and high-class *specialists*. There is at present a strong tendency to fill the higher-salaried positions only with university men with research experience and such is the avowed policy of a number of our largest manufacturing concerns. Workmen in the shops may rise to be foremen, but no farther; superintendents, chiefs of divisions and heads of departments must be university men with technical experience.

The best *preparation* for industrial research as a profession is a thorough and broad grounding in the fundamental principles of the field chosen. The student should not specialize too early nor too highly or he will fail to obtain command of related fields of science or engineering. In quantity and breadth of academic preparation the standard to be chosen is about that required for the doctor's degree in our best institutions. The new men preferred at research laboratories are men with doctorates who have published half a dozen scientific or technical papers. Men with less preparation are under a handicap and do not advance as rapidly as a rule.

SUMMARY

The essentials in a successful modern industry are capital, labor and the technically trained expert. Only rule-of-thumb, relatively unprogressive concerns are possible without scientific specialists.

The numerous departments of a large concern require the services of a wide variety of experts. Engineers are experts in the application of organized knowledge. The research division is a branch of the engineering department and consists of two wings devoted to scientific and technical research.

Technical research is devoted to the testing and specification of materials, checking product, initiating new processes and the elimination of incidental works troubles.

Scientific industrial research is devoted to the extended investigations of basic principles and relations to the more obscure and fundamental works troubles and to the development of correct testing methods.

The research division as a whole is, in addition to the above, a training ground for men for the higher executive and technical positions.

The best academic foundation for industrial research as a profession is a broad and thorough grounding in the fundamental principles and relations in the chosen field of activity.

THE TUTORED FARMER

By Professor W. O. HEDRICK
MICHIGAN AGRICULTURAL COLLEGE

THE much preached but little practised educational precept that "learning should be by doing" was never more boldly applied than in the contemporary endeavor to give technical instruction to farmers and farmers' wives upon their own premises. Farm demonstrations, or agricultural extension work as this movement is known, indifferently, acknowledges the truth that farmers are visualists rather than auralists in their methods of learning. The motor car, telephone and cheap railroad rates have of course had their share in making this new instructional scheme practicable, but after all the preference of the farmer for "being shown" rather than "told" is the basis for the new system.

Farm demonstrations as a systematic way of teaching farmers seem to have been first employed by the late Seaman A. Knapp two decades ago in undertaking to show southern farmers how to escape the evils of the boll weevil in their cotton fields. The technique of the demonstration as employed then by Dr. Knapp and as now used by thousands of county agents and extension specialists is the same and consists in doing upon the farmer's farm or in his house the thing which it is desired to teach. Feats of this sort may be applied to any one of the numerous details which make up the farmer's craft, but their purpose is always instructional and their methods are invariably those of performance.

"Putting on a demonstration," as the act of teaching in this way is called, requires the accomplishment by the demonstrator under the actual conditions of the farm process—the thing—tile laying, tree pruning, crop harvesting or what not—which he wishes to make clear, and preferably to a group of farmers since this extends his message. More than 500,000 visits of this sort were made to farms in 1915 by demonstrators, the last year in which records have been tabulated by the Federal Department of Agriculture.

The farm demonstration method of instructing farmers has proved revolutionary in the realm of agricultural education. Formerly the most successful agencies in this sphere were the farmers' institutes, technical bulletins, the agricultural press and agricultural educational institutions. The last three of these still remain, but the institute, for a quarter of a century the supreme method of reaching the adult farmer, has surrendered everywhere its supremacy to the newer method of instruction.

Not only has public authority specialized itself to reaching the farmer by this method of instruction, but railroads, banks and certain manufacturing establishments of prominence throughout agricultural regions employ officials who are devoting themselves to this propaganda. The International Harvester Company, as an instance, "puts on" many scores of demonstrations annually in furtherance of its belief in this method of teaching. The method has been successful, too, in accomplishing its purpose. As is well known, the farmer is the most conservative of men. He still hugs himself with the delusion of personal independence. Dean Bailey, of Cornell, tells the apposite story that on leaving for home after conducting a very successful farmer's institute in western New York he overheard the following conversation between two members of his audience as he passed them outside the doorway. "Well, Sam, how did you like it?" "Oh, I don't know," replied the other, "It hain't hurt me none." In spite of this robust self-independence which grows from the farmer's natural isolation in both a business and a social way, he has taken to this new form of instruction. He attends the demonstrations, as is shown by the statistical report from the department of agriculture quoted above, that in 1915 more than 2,959,700 came to these gatherings. The farmer's approval is shown also by the fact gathered from the same authority that he contributed directly during the year, through his county appropriations, a round million of dollars in support of these demonstrations. Many individual county demonstrators, too, in token of their worth to the contributing farmers, receive vastly larger salaries than colleges or universities can afford to pay.

Furthermore, the farmer is anxious to be taught. Not so long ago but that it is a matter of easy memory, farmers spurned anything savoring of "book farming" as applied to their business. Until 1900 our agricultural colleges were puny affairs. Attendance was not from those who intended to follow agriculture, and as late as 1908 Mr. Prichett, of the Carnegie Foundation, in his annual report, declares concerning these institutions—"they have not yet found themselves." Science applied to agriculture has overturned this situation and the new vocabulary of farming is replete with terms such as these: "bacilli culture," "butter fat tests," "balanced rations," "orchard spraying," "soil liming," "labor incomes," "major performance standardizations" of various sorts, "moisture content," credit associations, etc. Even the most self-confident farmer must admit that he knows nothing about these, and his necessities have rendered him a docile pupil. In addition to this the enormous costliness of contemporary agriculture has forced the farmer to utilize every device to lower expenses. Farms are no longer given away under homestead laws. Quite the contrary—it can easily be demonstrated that farm lands have risen more in price during the eighteen years of this century than during all our previous history. The operator of a costly farm may not wisely omit any helpful teaching which will enable him to make a profit on so much investment.

A demonstration may consist of an object lesson in tiling a field, in kitchen drains and sinks, in the "cold pack" method of fruit and vegetable canning, in how to plant a garden, or in any one or the other hundred additional features of the farm and farm household processes. Usually there is an immediately useful product which results from the lesson—as cans of produce where canning demonstrations have been "put on"—and these go far to create enthusiasm for the belief that education and actual life may be brought close together.

Education "carried to the people" as this is, must necessarily be expensive since, like the "circuit rider" of old, the mentor of this new learning is constantly in the field moving from place to place. Unlike the history of most educational innovations—a history of private sacrifice and initiative until success is achieved, whence adoption is immediate on the part of public authority—the farm demonstration movement received governmental support from the start. An appropriation made by Congress in 1903 for combating the boll weevil in Texas was handed over in part to Dr. Knapp for his demonstrations experiment. Annual appropriations followed from Congress for carrying on what was known as the "Farmers' Cooperative Demonstration Work" in the South and in 1912 appropriations were made for carrying on the same work in the North and West. The Smith-Lever Act of 1914 is the crowning work of government in this great undertaking, and since it not only furnishes the funds, but also the plan of administration for the enterprise some discussion of its terms are necessary.

A sum approximating a half million of dollars was to be distributed among the states during the first year of this appropriation, augmented by half million increases during each of the eight years thereafter. This is a summary of the finances of the great law. Furthermore, since an amount corresponding to the gift to it from the federal government must be raised by each state, one easily sees that eight millions in toto will be available for carrying on the work in 1922–23 and during each subsequent year.

So large an amount as this devoted to a single purpose must needs have unusual administrative machinery and it is insisted by the law that a separate division or school known as the extension school shall be created in each agricultural college through which these funds are handled. A special bureau in the federal department of agriculture to administer its end—the States Relation Service—and the directive apparatus of the new law is complete. The trend which this new extension effort should take is shown by the further provision that "extension work shall consist of the imparting of information through field demonstrations, publications and otherwise."

The county agent, as he is called, is the central figure in this mechanism. He is the immediate representative of the Smith-Lever fund and farm demonstration system to the rural locality; he is the chamber of commerce secretary in the open country; the "heading up" agency for all the organized agricultural activities of the county. In 1916 there were 1,225 farm agents employed in the various counties, and 430 women employed in farm household demonstrations, leaving only 1,695 agricultural counties still unprovided with these representatives.

The county agent, whether man or woman, is first and primarily the farmer's adviser and preceptor. He is the interpreter of the agricultural college teachings and the experiment station discoveries to the farmer. The homely title "farm doctor" was originally thought to be the term which properly characterized him in his attitude toward professional activities. It is usually thought best that he must be a graduate from an agricultural college, but whether educated in science or not, he must certainly be a practical farmer in order to satisfactorily advise. He must have many of the gifts of leadership too, as the further discussion of his work will show.

As an adviser there are no problems pertaining to agriculture which the county agent may not be called upon to solve. A short summary of the typical agent's services shows him engaged in the judging of live stock and seeds, in the encouragement of under drainage, in illustrating the cultivation, pruning and spraying of fruit orchards. Everywhere he advises with regard to tillage, time of crop planting, varieties, nature of cultivation and harvesting methods. He is also the counselor as to when to market, what rotations to pursue, how to secure credit, and the proper use of machinery. The epithet "general practitioner" well describes this cyclopedia afield and the motor runabout and the telephone are his indispensable allies.

But the county agent is more than an adviser, he is also a teacher and, like the practical laboratory man that he is, he believes that pupils learn best when they conduct their own experiments. Through demonstrations, therefore, upon their own premises, he undertakes to see that each farmer benefits from a practical experience. At this point arises what is probably the most cardinal of the pedagogical precepts which have come up in this new species of teaching and this is that the farmer reacts to no other educational stimulii so quickly as through being shown the successful achievements of some neighbor farmer. "Pick up in one place the instance of a successful farm achievement by one farmer and carry it to the farmers in other places," says an experienced demonstrator, "and you will win their confidence and adherence at once." The county agent undertakes to effectivize this "teaching from example."

"To put on a demonstration," therefore, is the county agent's way of making his teaching agriculturally read by as many as possible. Demonstrations themselves are helped by contact teaching of every sort, such, for example, as automobile and train trips to places where good farm enterprises are to be seen. Most customarily perhaps they are "put on" by being arranged for in advance through getting some farmer to make himself a model in performing some farm feat. It may be the growing of alfalfa, or the using of a fertilizer, or the raising of a special variety of animal or grain. At any rate, at the proper time interested neighbors are motored in and the lesson to be taught is presented.

In this work the county agent is frequently helped by the subject-matter specialist furnished through the state college or the federal Department of Agriculture. Since these subject-matter specialists are the "first helps" to county agents, and indeed are sometimes considered to have their whole usefulness through the teaching field that the agents' need furnishes them, a word of description of these specialists is necessary.

Agricultural colleges and departments of agriculture everywhere have upon their staffs these "teachers on mission" as they may be called, representing one or the other of the various college departmental divisions. They are usually of professorial rank in the college and indeed differ from the usual departmental member only in the respect that their work is afield rather than in the class room or laboratory. It is for them to be ready for the summons from the permanent agent in the field to hasten thence with the desired special message. This done, the subject-matter specialist returns to headquarters to await another call.

However, neither of these two forces—the one on mission nor the one permanently in the field—relies solely upon "occasions" to shape their activities. At stated intervals members of both forces assemble together to shape permanent programs or "projects" of work, as they are called, to be carried thenceforth into practical effect. These programs include a wide variety of farm interest and are entered into with the deliberateness and formality of a general staff preparing a campaign. The specialists are indispensable, therefore, to the county man to keep him freshened in information and also to enable him to systematize his attacks on the farm problems which are to be solved.

In the second place, the county agent is the organization promoter of his county. A slight calculation will show that it is a physical impossibility for any teacher to maintain or even to acquire a personal touch with every farmer in a county. Therefore it is indispensable to the county agent that he perfect some other means of transmitting the message than himself, and the organization of his followers is the device. Sometimes it is only a matter of the federation of existing organizations, since in many country communities farmers have already found their way into concerted action and a redundancy of organization is as bad as too much of anything else.

Farmers indeed are becoming conscious of the merits of united action. The Roosevelt Country Life Commission of 1907 suggested "organization" as a cardinal method of improving country life. The organizations suggested have certainly been forthcoming in recent years both of the sort which express the farmer's passionate and immediate desires, such as the milk producer's unions near our large cities, or the nonpartisan league of the Dakotas, but also organizations more firmly rooted in the farmer's needs, such as the granges, farmers' clubs, and the cooperative association of various sorts. Agricultural societies—trade associations they would be called in town—have existed for generations among farmers. Indeed, it is probable that there is no branch of agriculture, however, small or remote but what it is organized more or less closely for educational and promotive purposes. But the present-day attempts to organize farmers by communities in respect to all their interests, and especially to develop in them class consciousness such as that possessed by unionized labor, promise to become the dominant form of organization in the open country in the near future.

The farm bureau, as the variety of organization is called which the county agent promotes, has its members, whether individuals or associations, acting as teachers or sponsors placed in all parts of the county, and at the center a "clearing house" for ideas and teachings is formed available to every one. It is, in brief, the chamber of commerce idea carried into the rural neighborhoods. The bug-a-boo "class development in a republic" which this program arouses resounds feebly against the movement, since the agricultural class already exists and the sole question is should it be organized into efficiency or remain disorganized and impotent. Usually the headquarters of the farm bureau is in the county agent's office in the local courthouse, and here its members meet at intervals to discuss projects or decide upon undertakings in the betterment of the county farming.

The demonstration movement does not expend itself solely upon the farm and farm household, but reaches out in a well-organized way through boys' and girls' clubs to the youth of the farm regions. In both forms of this junior extension work, as this activity is called, the clubs derive their funds and take on a similar administrative system to that of the county agents just described. The end in view is inspirational rather than the immediately practical. Boys' and girls' clubs are auxiliaries to the agricultural schools and endeavor to furnish stimuli of the agricultural sort which will keep young people interested in farming. Nevertheless, in the frenzied farming which took place last spring resulting from the food famine fear, these associations of children became immediately practical, since they took over a large proportion of the school gardens which were then so important. Indeed, the fifteen per cent. increase in agricultural production in 1917 over any preceding five-year average in our history may be attributed in no small degree to the efforts of the extension specialists, both of the junior and senior sort. Congress made large especial appropriations—as did certain state legislatures also—to both these classes of workers during each of the two years since our entrance into the war, and few expenditures seem to have been better warranted or to have given better satisfaction than these.

An educational institution, of such vast proportions and unique scope as that provided by the Smith-Lever Law, has seldom been established upon so small a basis of experience. Much experimentation is therefore inevitable. Already serious problems have arisen as to the proportions of authority between the federal Department of Agriculture and that of the different states. Furthermore, the activities of the teaching staff are too largely shaped by circumstances rather than in accordance with a fixed program. Suitable instructors have been difficult to obtain, not only on account of the inherent difficulties of the new scheme of instruction but also because of the man absorption of the war. Extension teaching in general, however, has proven its merits and has become a permanent part of our educational system, and there seems to be little doubt but that the special form of this new style of teaching which makes use of the demonstration method will find its place and maintain itself in its proper field.

BIRD MIGRATION IN ITS INTERNATIONAL BEARING

By JOSEPH GRINNELL

DIRECTOR OF THE MUSEUM OF VERTEBRATE ZOOLOGY OF THE UNIVERSITY OF CALIFORNIA

OF all natural assets bird-life is least localized. Birds are in large part migratory, and many kinds move over great extents of country according to regular seasonal schedule. They cross boundary lines of all sorts, and traverse territory always in response only to their own critical requirements as regards food supply and climate. Faunal boundaries rarely coincide with political boundaries.

It would seem scarcely necessary here to argue the value to any community of its native bird life. We have come to recognize in wild birds sources of recreation, both physical and mental, of æsthetic appreciation, of practical aid in insect repression, of service in reforestation and spread of useful plants, and of food for ourselves.

The great majority of our waterfowl are migratory; and the pursuit, capture and shipment of these in particular, has meant wage-earning occupation for some thousands of men in the United States, for at least a part of each year. In California alone, according to statistics of the State Fish and Game Commission, wild ducks were sold on the markets in 1912 to the value of $250,000; about one million ducks in all were shot, presumably all used for food; and over one and one half million dollars were expended in the pursuit of these on the basis of recreation—maintenance of gun clubs, traveling expenses, ammunition, etc.

I have here attempted to convey an idea of one of the values of bird-life in terms of dollars; for dollars seem to constitute the only ready measure of value comprehensible to every one. Some of the values of birds just referred to, it is of course impossible to express in connection with the dollar sign. While the total monetary value of birds is not to be figured in hundreds of millions of dollars, as with certain other natural resources, it may properly be asserted, I think, that total disregard or waste of an entire asset of relatively small quantity is just as poor business as disregard or waste of a small part of any large asset.

I hardly need try to demonstrate here my conviction that it *is possible,* without special care, to levy an annual draft upon those birds for which we may have use dead. I will only refer to the biological principle that rate of reproduction has been established at a point in excess of sufficiency to meet the maximum probabilities of casualty. The persistence of the species has been assured, at least under the natural conditions obtaining immediately heretofore. The interpolation of the human factor would seem to have influenced the natural balance on the whole in favor of increasing bird population, this because of the customary destruction by humans of other animals normally predatory upon bird-life. Of course there *are* cases where cultivation of the land by man, or the removal of forests by him, has affected adversely, and inevitably so, the persistence of particular birds; as, for instance, the mountain plover and the passenger pigeon. But there remain very many valuable species which have not been so adversely affected by man's presence and some which have even benefited; and these are the ones from which we can expect contribution to our needs without attention on our part save for regulation of our own rate of draft upon them.

Let it be accepted, then, that bird-life does comprise a natural asset worth conserving, to the end that it may become a thing producing regular annual income. If many of our important species are migratory, how can proper conservation be secured without cooperation between the several countries through which such birds travel during their annual migration? Here in California, in the early days of bird and game legislation, each county of the state formed its own code of laws irrespective of its neighbor. No thought was taken towards adjustment of regulation with a view to conditions throughout the entire state. In 1861, for example, the shooting season for waterfowl and upland game birds in Los Angeles and San Bernardino counties opened on August 1, whereas in adjoining counties it did not open till September 15. The earlier date cut into the nesting season of the birds to the injury of the breeding stock in all the counties. But adjustments have now been made, by which judicious treatment is accorded to the game birds throughout the state, although this has meant the curtailment of shooting altogether in some districts—this, however, strictly in the interests of the state as a whole.

Can there be any less justification for the cooperative conservation of bird-life as between nations?

One of our wading birds, the golden plover, at one time so plentiful at certain seasons along the Atlantic Coast and in the

Mississippi Valley as to be marketed in New York City by the barrelful, repairs during its short summer breeding season to the Arctic coast of North America from Alaska eastward. There it finds safety for its young, as well as adequate food. In late summer the flocks of golden plover, adults and young, start on their southward migration, going first eastward to the Labrador coast, thence to Nova Scotia and the coast of New England; then they undertake a journey of 2,500 miles southwards across the Atlantic Ocean to Brazil, and thence proceed to the plains of Argentina. In the last named country the birds spend their winter time under summer skies, then start northward in the early spring along a course different from that followed in the fall. Passing through northwestern South America and through Central America they cross the Gulf of Mexico, follow up the Mississippi Valley across the central United States and continue on through central Canada to their breeding grounds, on the Arctic Coast. In this annual circuit of more than 16,000 miles, as worked out by the late W. W. Cooke, of the United States Biological Survey, the golden plover comes under the jurisdiction (where any regulations at all exist) of no less than seven different nations.

This particular game bird does still exist, but probably in not one one-hundredth part of its original numbers—for this reason: It happens that the migrant throngs were intercepted without let or hindrance by market hunters at at least one critical point on their annual circuit, the coast of New England. Whole flocks were annihilated without regard to the principle of maintenance of breeding stock. This could not help but injure the supply of plover at all other points in its range.

Again let it be said that there is no doubt but that native birds of any sort can be so treated that an annual crop can be gathered. This has been done from time immemorial with permanently resident species of game birds in Scotland, Holland, and other European countries.

Happily, the laws of the United States are now closely approaching the ideal in their treatment of birds as a national asset. But no one country alone can handle the problem of the migratory species. Migratory birds constitute a common property among nations, and one which should be administered in common and shared with due regard to all the factors involved. An important step has just been taken in this direction. In 1916 there was formulated as one provision of a treaty to be entered into between the United States and Canada a migratory bird clause, under the provisions of which each of the two countries is to adhere to a program of absolute protection of migratory insectivorous birds and of maximum limits of open seasons on migratory game species. The final ratification of this "migratory bird treaty" was completed by our Congress, June 6, 1918; the Canadian sanction had already been formally given some months previously. As far as my knowledge goes this is the first really important accomplishment as regards international agreement in the regulation of bird conservation. It is the beginning of a system which should in all reason prevail among countries throughout the world.

In the birds of migratory habit we have a valuable asset which cannot be administered advantageously in any other way than through international cooperation.

THE HOME OF THE SOVEREIGN WEED

By Professor E. M. EAST

BUSSEY INSTITUTION FOR RESEARCH IN APPLIED BIOLOGY, HARVARD UNIVERSITY

ARE you a worshipper at the shrine of My Lady Nicotine? Have you offered incense with a real Havana? Performed the rite with all its proper ceremony—the tender removal of the fancy label with many misgivings as to whether the offending girdle has left its scar, the careful, deliberate clipping of the end, the final Promethean touch, the first ecstatic inhalation, the contented smile? But no, no smile, this is a serious business. If such has been your lot, and you are not an unworthy devotee, you have realized there is both truth and poetry in the line, "There's peace in the Larannaga," that in the Larannaga or any one of a dozen other brands unsung by Kipling from the Pearl of the Antilles, there is something not found in the baneful product of the average domestic factory.

Whence comes the delightful fragrance of the true Havana article, so different from the tarry odor so often met in the product of other lands? Why does the single isle of Cuba, but ninety miles off Key West, yield a plant unique, characteristic of itself alone? It is a fact, the theme of song and story. But why?

One hears it attributed to some mystic instinct of the grower or to the secret genius of the manufacturer. It is ascribed to the climate, to the soil, to the variety of the plant. I would not have the hardihood to deny all virtue to any of these. Doubtless each is a contributing factor, though they vary greatly in their contribution. But, in my opinion, the really effective agent has never been described. Others may not agree with me, and in truth the cause of such a fugitive, indefinite thing as quality in whatever pleases the eye, ear or palate is difficult to prove. I will give my version of the story; one may take it or leave it.

Four centuries have passed since the white race took up its burden in Cuba, four centuries of war rather lightly flecked with peace. But time has dealt kindly with the island. The American touch has of course improved its ideas of sanitation and education, but the people and their customs remain unaltered. It is true buccaneers no longer ply the Spanish Main, and Spanish misrule—less bad than it is pictured, by the way—is no more; but the pirate still stands behind the counter of the city shop, and the free and independent citizen is fleeced in the same old way by his duly elected public representatives, to whom the city fathers of the same ilk in certain of our own cities might well go for instruction.

During this time the country has been a melting pot for more varied ores than even the United States. The population at the present time is something over three million. The census says seventy-one per cent. is white, a surprising thing to the visitor making his own observations until he learns that the obliging census-taker inquires of each whether he is white or black, and black indeed he must be if he does not reply *blanco*. The educated classes are largely of Spanish descent, of course, but in the mass of the population there is such an intricate mixture of Chinese, negro and Indian that one hesitates even to make a guess as to the origin of a particular individual. For this reason one can not characterize them as a people. They are too varied, physically, mentally and in disposition. Those of Spanish blood and even those having a considerable admixture of Chinese have a marked ability along the lines formerly accredited to the down-east Yankee. They are sharp, shrewd, observant and witty. It is a common saying that the Jew starves to death when within reach of their competition.

But since it is the barefooted inhabitant of the palm-thatched cottage, the representative of the common people, who raises most of the tobacco—indeed all of the tobacco of the finest quality—one can hardly impute to him either uncanny skill or hidden knowledge in bringing it to the forefront of the world's markets. Let us give the tiller of the soil the good word he deserves, for in many ways he is a lovable person, kindly and hospitable, but let us look elsewhere for the reasoning of our riddle.

On the other hand, some considerable credit for the excellence of their product does belong to both the Cuban manufacturer and his workman. The former, keenly alive to the value of a little hocus pocus with the American buyer, plays a very practical tune when he emphasizes the difference in flavor of each vintage, the varied quality of the product of the several districts, or the care with which each blend is made, with a polite but condescending intimation that the way he does it is beyond the ken of ordinary mortals. As a matter of fact, there is a modicum of charlatanry in tobacco judging as in wine judging or anything else of similar type where personal equation is so great. The Cuban manufacturer does take the necessary time to finish every process, no matter how much is required—something his American rival does not always do—but to believe he has kept any business secrets to himself requires more perfect faith than I possess.

But the Cuban cigar maker, that is another thing. He is a master-craftsman, an artist. *His* product is not hammered together like that of the American workman, who bunches his filler carelessly, hides his misdeeds in a binder of no special size or thickness, and finally courts ruin by crushing the whole thing in a mould. Instead, he actually builds his *tobaco,* as the Spanish call it, piece by piece, carefully spreading one small leaf around the other and manipulating them deftly with a single hand, till, perfect in shape and size, it is ready for the wrapper. When, with some paternal pride, he holds it up for final inspection, one can hardly repress an exclamation of admiration at the exactness with which it matches its fellow. Truly in this case the laborer is worthy of his hire.

Were it not that we have somewhat overstated the case of the workman in the states, one might suppose that the key to the problem lay here. But though probably seventy-five per cent. of the American cigars are abominations concocted of the mould and binder, still there are numerous factories working after the Cuban model without obtaining the Cuban result. We must look further.

The climate of Cuba is wonderful, perhaps the most wonderful in the world. No ice, no snow, no wintry blasts. Sometimes a January *norte* bringing a temperature of 50° F. makes the inhabitants pull their garments closer, but the mercury rarely sinks lower. It is continuous spring. No sticky, humid Florida weather, just delightful bracing air somewhere between 70° and 90° in the shade. In the sun it *is* hot; but it is a comfortable, refreshing sort of heat, the kind we in the north get on one or two days in June, when there is wholesome contentment in just basking there carefree and indifferent.

It may be that climatic conditions loom large in the matter of perfecting their tobacco. It is known that an even temperature and a relatively constant humidity are necessary factors for the foundation of high-quality leaf. Their control furnishes the reason for the immense sums spent in Florida and Connecticut on the cotton cloth under which is produced the so-called shade-grown types. And further, it must be an immense advantage on the manufacturing end to be able to handle the cured product at any and all times without being continually on the jump to approach correct conditions by supplying artificial heat and moisture. To be sure, Tampa and Key West have similar climatic conditions, while, with all due regard for the proprieties, their cigars are still those of Tampa and Key West; but we must remember that these manufacturing centers seldom have to deal with a high-grade Cuban leaf, so that a fair comparison can not be made even on the manufacturing end and none at all as to the effect of climate on production of the natural leaf.

But what can we tie to in all this? The grower, the manufacturer, the workman, do their bit, as one might say; the wonderful climate is a mighty factor; nevertheless, as efficient causes of Cuba's preeminence in tobacco, they are not convincing. And varietal difference can be left out of consideration, for the Cuban varieties have been smuggled out again and again and tested in every country under the sun. The answer is that we have considered everything but the "hoyo," and the *hoyo,* the "hole" made by Nature in their limestone cliffs, is the efficient cause. You will recognize the term in the name of the celebrated brand "Hoyo de Monterey," cigars made originally from tobacco grown in the *hoyo* of Monterey. These limestone pits are Cuba's secret, the home of the really fine product. Cuba raises much other good tobacco, and, to tell the truth, much tobacco in her eastern provinces about which the least said the better, but the *hoyos* are the workshops for Nature's best. Why they are but seldom visited by the Havana nicotine magnates and known only by rumor to American tobacco men, I do not know, but I have recently had the pleasure of making a personal pilgrimage to two of the most famous spots and was told there that I was one of the first Americans to make the trip.

We left Havana, three of us, about 6:30 in the morning in a Henry Ford production, fortified only by a single cup of *cafe con leche,* that peculiarly flavored coffee that is really a Cuban institution. We were driven clickety-clack by one of those reckless corner-cutting chauffeurs with which Havana is infested, whose almond eyes betrayed an ancestor from the Celestial Kingdom in the not too distant past, and who nearly brought us to grief at the first turn by running into a native who was trying to get some speed out of his Andalusian mule by screaming, while wielding the goad, "I will beat thee! I will beat thee! If thy skin were that of a holy Saint, still would I beat thee!" Luckily we missed him and sped out into the highway to Pinar del Rio with grins on our faces and curses in our ears.

Though with marvellous ingenuity the infernal chauffeur jolted us squarely through each uneveness in the road, we felt that the trip was "not too bad" as the Cubans have it, when we flashed out from under a long avenue of royal poincianas loaded with their giant beans and our eyes met the fascinating outline of the distant mountains, across long plains dotted with feathery plumes of the royal palm.

We breakfasted, a typical Cuban breakfast of six or eight courses, at San Diego de los Baños in a wonderful inn some centuries old, then on to Pinar del Rio, the center of the tobacco district. From here our way wound up through shale mountains covered with dwarf pines, as different a scene from that of the morning as well might be. Typical Virginia hills they were, and if rifts in the rocks and turns in the road had not given us glimpses of the tropical verdure below, we should have thought we had suddenly been transported there on Suleiman's magic carpet in the moments we had nodded from the effects of somnorific old Sol.

Down again and up like the King of France with his ten thousand men, thirty miles beyond Pinar del Rio we reached our goal, San Carlos del Valle de Luis Lazo, perched on a little plateau at the foot of the limestone cliffs of the Sierra del Camo. Here, thanks to the hospitality of the "squire" of the little village, good old Don Andres Carvallo, we spent the night, and were ready early the next morning for our trip to two of the *hoyos*, Hoyo Valteso and Hoyo Martel, for each of the thousand or so of these places has its individuality marked with a name of its own.

As the cliffs seemed to rise absolutely vertically some four or five hundred feet, there was some speculation as to our ability to make the climb, but we were assured by Higinio, our native guide, that he would take us up one of the easy trails—one used for many years by oxen. As we plodded up the narrow, twisting, stony path, rising at an angle of fully sixty degrees in places, our respect for the climbing ability of the ox increased. In response to our questions, Higinio informed us that it took at least a year to train each ox, schooling him in his task by placing him between two *practicos* that had previously learned their trade. In other *hoyos*, those really isolated by the steepness of the cliffs, they are carried in when quite small calves, and spend their whole lives there before the plow and harrow.

As the top was reached and we peered down, between the trunks of the *palmas de los sierras*, and the branches of the *ceibas* covered with bromelliads and an occasional orchid, we caught our first glimpse of the *hoyo,* a pit in the limestone rock, apparently the crumbling remnant of a cave with the top fallen in. It seemed to cover about an acre, though in reality it was eight times as large. The level floor was dotted with green spots which we knew must be tobacco, though we could have hazarded no such guess from its size, and at one side the curing barn, a palm-thatched affair about fifty by twenty feet, where the leaves are hung to dry before being packed into the odd little palm-covered bundles ready for their journey to the Havana market. The picture was a gorgeous riot of color under the tropical sun, but even so, there was not that peculiar feeling of awe which came when we had cautiously picked our way down and obtained the view from the floor. I have sought for a simile, but have not found it. The *hoyo* is a thing unique. Imagine a prison of limestone cliffs towering abruptly five hundred feet. Above, the southern sun peeping from a cloud-bank of fleecy white, as if inquiring the reason for this third American intervention. At right, at left, in front, behind, the bleak wall, with only here and there a famished palm or green-barked *ceibón* struggling for a foothold, or perhaps a clump of fern and moss screening a soft-voiced dove or a black-coated wrangling Jew bird, the echoes of whose vocal aspirations resounded back and forth. Below, the tidy garden with drooping rows of green broken at times by a spot of pink where a Cuban nettle flaunts its flag of warning. Surely it is a garden of gnomes, where nightly they water their seedlings with a magic essence, coaxing them to distil the fragrance in their leaves, that dead and gone they may fulfill their appointed lot in bringing solace and contentment to the tired business man—really given away at three for a dollar gold, in Havana.

The tobacco, botanically speaking, was in no way different from the same variety grown in Connecticut. There was the same habit of growth, the same shaped leaf, the typical flower. Only the size was something new to our experience. It was dwarf, tobacco in miniature, two feet high at most, with seven or eight delicate little leaves scarcely long enough for a man's size cigar. We saw none of the cured product, but were assured that the yield was about 300 pounds per acre in a good year, and (with considerable pride) "the price, Señor, one dollar and a half a pound at the plantation." When we thought of the 1,800-pound yields of the same variety on the level fields of Connecticut, and glanced at the towering cliffs, emblems of the difficulties here encountered, we wondered why the price was not multiplied by twenty, although, as a matter of fact, it was greatly in excess of that obtained on the island for other tobacco.

We stopped a moment on our way back at a *semillaro,* a place cleared near the top of the limestone cliff for raising seedlings for the *hoyo.* This is done, we were told, because fungus attacks are less likely at the higher altitude. Rather an unkempt place it was, with here and there a yam or taro plant showing that the workmen did not forget their own wants in the midst of their labors.

Back to Luis Lazo and a midday breakfast to which we were duly attentive. Afterwards a visit to several *ensenadas,* tobacco plantations outside the *hoyos* where a primitive sort of irrigation is used. Open troughs radiate from a platform at the water's source—in this case a river—and a patient old nag hour after hour hoists a laden barrel to the center of distribution, a hogshead reservoir some fifteen feet up. The tobacco here was larger and from the agricultural point of view much finer than that in the *hoyo.* The plants were three or even three and a half feet in height and the ten or twelve leaves, characteristic of them, were sometimes sixteen inches long. They were just in the midst of the picking, and we saw leaves in various stages of drying, hanging in the different barns. These buildings, if such they can be called, interested us very much. I do not know whether it has any effect on the quality of the product, but it is clear that these affairs with their long sloping roofs of palm leaves through which the air can pass at any point are ideal for the purpose for which they are intended, provided no torrential rains occur at the wrong season of the year and start the half-cured leaves to rotting. One other thing here was not without its attraction to our northern eyes, as illustrating the efficient use these people back in the mountains make of their natural resources. We were already aware that the royal palm might as aptly be called the people's palm, since it furnishes the Cuban with his entire habitation, with part of his furniture and clothing and, through the intermediation of his pig, with food, yet here was another valuable use right in line with our inquiry. The *tercios* or bundles of tobacco are so neatly packed away in palm-leaf envelopes that they undergo a perfect case-curing and reach the Havana factory practically ready for use. And further, the *tercios* are bound with a native rope, a product of another tree right at hand, the *ceibón.* A very good rope it makes, as strong as hemp and not half so troublesome to prepare.

Regretfully we tore ourselves away from the magic attractions of the mountains and sped to Havana. We had had a glorious trip, a trip of real discovery, one might say, and were duly thankful for the memories we carried with us. Pleasant they were, though rather disconcerting after there was time for thought. We had seen the *hoyo,* the one place in the world where they raise perfect tobacco. But had we pried into Cuba's secret, after all? Again and again came the question, why does the *hoyo* raise perfect tobacco? There is no question about the fact; the manufacturers admit it; the growers take pride in it. The price proves it. If more conclusive proof is wanted, it comes from the *hoyos* themselves. Would such a place as the Hoyo Palenque, surrounded by cliffs over a thousand feet high and reached by seventy separate ladders, have been cultivated for over a hundred years if it did not produce a superfine product? There is but one answer to this, but the reason is not so easy. I believe I have unriddled the riddle, but mark that I only say "believe."

The limestone cliffs give their aid of course, since tobacco must have a slightly alkaline soil. But then lime is not a scarce article in this world of ours and its effects can be duplicated elsewhere. Again, there is the sterility of the peculiar type of sandy soil which makes up Cuba's good tobacco land. It may have unique chemical properties that contribute to the end result. Since they have never been studied carefully, one can not say, but this does not seem a necessary assumption. The fact that there is that agricultural ideal, a perfect climate, backed up by a sterile soil of proper physical constituency, is all that is necessary to account for the generally excellent tobacco of certain areas of the celebrated Vuelta Abajo. Doesn't it seem like an agricultural paradox to attribute the excellence of a product to the sterility of the soil? It is the truth, however. Several years ago it was found that a tobacco plant produces about the same quantity of the essential oils that give the leaves their aroma no matter whether certain of the conditions under which it is grown be good or bad. In other words, if a plant grows to be eight feet high and has leaves twenty-six inches long, it produces only about the same amount of essential oils as when it grows two feet high and has leaves eight inches long, other things being equal. Now it is a noteworthy fact that while Cuban tobacco under shade in Connecticut meets the first of these conditions, the average Cuban plant hardly approaches the second. The Cuban plant is a dwarf, and packs into its small self as much of the essentials of real quality as its giant sister in Connecticut. Here again, however, our interpretation fits Cuban tobacco in general. The conditions are met just as neatly in the *ensenada* as they are in the *hoyo,* so we still seem far off the mark. This is not the whole story, for we must remember that the *hoyo* has and uses all these advantages as a basis upon which to build its own perfecting qualities.

The *hoyo* itself is the secret of the matter. Why do they grow tobacco under shade in Connecticut, Florida and even Cuba? Simply because it conserves moisture and keeps the temperature and humidity constant and high. This the *hoyo* does naturally with its limestone cliffs, having withal the immense advantage of direct rays of the sun at a considerable altitude, factors known to be essential to other crops besides tobacco. And it has the sun when it needs it, enough and no more. From ten o'clock until three it shines directly on the plants, storing up food in the leaves for elaboration during the night, while from dawn until ten and from three until seven, there is indirect light due to the protecting cliffs. It is a stage setting that could not be more admirable from the standpoint of plant physiology, a perfect fulfillment of what are known to be the conditions required by the tobacco plant.

The reason why other countries can not compete with Cuba in producing the fragrant weed, therefore, is not so difficult to see. They may improve their methods of cultivation and manufacture, select carefully their soils and climate, may even imitate conditions artificially with tents and tent-poles; but they can not hope to duplicate the finest product until they find a wizard genius who can transport the ancient *hoyos* far beyond the sea, and train the sun to obey his word as did Joshua of old.

VITAMINES AND NUTRITION

By Dr. H. STEENBOCK

ASSOCIATE PROFESSOR OF AGRICULTURAL CHEMISTRY, UNIVERSITY OF WISCONSIN

SINCE 1912 when Casimir Funk first brought to the attention of the public the hitherto unknown dietary essentials under the collective term vitamines, nutrition experts have felt that they had something tangible to investigate—something the importance of which it was necessary to prove or disprove. As experimentation revealed symptoms attributable to vitamine deficiency, the general public, ever easily impressed by matters unexpected, and matters so vital as to revolutionize the conception as to what constitutes an adequate diet, soon became alarmed. At present it is probably not overstating the situation when it is said that the previously considered all-important attributes of an adequate ration, such as sufficient protein, calories and salts, have probably been slighted by the sudden interest taken in vitamines. Nor is this so very remarkable. Certainly no individuals have been more impressed with the important rôle that vitamines have in the diet than the investigators engaged in this field of nutrition. Only a few years ago students were taught that the body needed energy, to be furnished by carbohydrates and fats, protein, to be furnished by proteins, and inorganic elements, to be furnished by ash. These, together with water, were supposed to constitute the sum total of the dietary requirements of the animal body. Imagine the surprise and chagrin of the nutrition experts when it was found impossible to support the life of an experimental animal, such as the rat, on a ration compounded from these elementary *highly purified* food stuffs. Lack of palatability resulting in insufficient consumption was given as the reason. "How," was it asked, "can an animal maintain itself when the lack of taste to the food leads to loss of appetite?" "Our naturally occurring foods contain esters and ethers which induce better consumption and therefore maintenance." But, on investigation, it was found that a great substantial variation in the taste of the ration by the addition of flavoring extracts of great variety in kind and amount did not improve the nutrition of the animal. Not until there were added small amounts of certain plant or animal tissues or their extracts—now known

1. A pigeon showing a neck spasm in an acute attack of avian beri-beri (polyneuritis) resulting from the consumption of a ration deficient in water-soluble vitamine.

to furnish the vitamines—was it found possible to induce normal nutrition. Certainly the public is to be excused, if, as the result of the enthusiasm of the investigator, it shows undue concern over the vitamine content of the daily diet.

Let us analyze the situation more minutely from the experimental standpoint, so that we can comprehend what is definitely known in regard to vitamines, what physiological disturbances are to be expected if our diet is deficient in them and what with our present mode of living is the probability of a deficiency.

Generally it would be inferred from the term, as Funk implied, that vitamines are substances of an amine nature concerned with vital phenomena. Though certain derivatives of ammonia have been shown to have some of the properties of vitamines, yet of their amine nature there is conclusive proof. Of their relation to vital phenomena there is absolutely no question. Physiologically, vitamines can be divided into at least two types. Both are soluble in water, but only one is soluble in fats. This difference in properties has led to their characterization, respectively, as a water-soluble vitamine and as a fat-soluble vitamine. Though possible, yet in the light of present information it can not be considered probable that either type consists of more than one active component. Chemically, in even an approximately pure form, both vitamines are entirely unknown. Without either kind in the diet, animal life, at least that high in the genetic scale, is impossible.

Curiously enough, the observations of symptoms indicative of a lack of the water-soluble vitamine in the dietary were made on man himself. In the far east, especially in the Malay peninsula, in the Philippines and in Japan, there has been prevalent a disease known as beri-beri. It is characterized by a loss in weight with muscular atrophy, contracture or paralysis. It may run a rapid course, ending in sudden death, due to heart failure, or it may take on a chronic form. On post mortem there is evidence of more or less edema and extensive degeneration of nerve elements. Though these cases were of quite frequent occurrence, economically this disease was first brought to the attention of the civilized world when, during the Russian-Japanese war, a considerable portion of the Japanese army was incapacitated by its ravages. Fortunately,

2. A young female albino rat suffering from polyneuritis due to a deficiency in its diet of the water-soluble vitamine. Note the abnormal curvature of the back and especially in the one photograph an extreme spasticity. This rat should normally have weighed 120 grams; its actual weight was 54 grams. A rat in this condition without treatment will usually die in 10 to 24 hours.

by this time, experimental investigation had already indicated suitable prophylactic treatment, and prompt improvement and final prevention were brought about by providing for more variety in the ordinary oriental diet of white rice and fish.

Beri-beri was put upon an experimental basis when Eykman, a Dutch investigator working in the East Indies, observed that birds fed exclusively on white rice developed symptoms resembling those of human beri-beri. At first they consume rice readily, but anorexia soon ensues. After a period of a few weeks the onset of the disease is indicated by a tenseness of the muscles of the crop; usually then in the course of twenty-four to thirty-six hours more pronounced symptoms appear. When the bird is entirely at rest these may not be so evident, except for a slight unsteadiness of the head, but upon the slightest excitation the head may be suddenly thrown backwards, the feet forwards and the wings flapped violently as the bird makes an effort to regain its balance. These movements cause it to tumble over and over. In these spasms certain muscles are so exceedingly tense that violent restraint may lead to injury. Not all birds in an experimental lot may show these symptoms, variations in the symptoms being caused by the kind of nerve elements affected in the degenerative processes. Some birds may take on a so-called chronic form where the progress of the disease is so slow that death results primarily from starvation. All acute cases can be promptly relieved by the administration of extracts containing the water-soluble vitamine. Complete alleviation of all symptoms in most violent cases have been seen to result three to five hours after the injection of a few milligrams of a concentrated water-soluble vitamine preparation. A bird in violent convulsions often will preen itself, coo, and strut around in its cage six to ten hours after such treatment.

Experimentally, a nutritional polyneuritis can also be induced in the rat. A lack of the water-soluble vitamine in the ration of the growing rat will soon lead to cessation of growth, then to rapid loss in weight and finally to spasms which terminate in death. The oral administration of the water-soluble vitamine, if the respiration has not become too feeble, will terminate the violent symptoms and lead to complete recovery. If the administration of the vitamine is continued, the animal will resume eating and rapidly regain its health and begin to grow. In certain ways the water-soluble vitamine stands in different relations to the reproducing animal than other food constituents. When the ration of a nursing animal is poor in

3. The same rat 23 hours later after the oral administration of an alcoholic extract of 3.4 grams of wheat embryo. It was now able to sit quietly in normal position and resume eating its former vitamine-deficient ration.

good proteins or poor in certain mineral elements such as lime, normal milk will be produced at the expense of body tissue. Such a process, which sooner or later results in the depletion of the reserve of the mother, gradually manifests itself in her appearance. When, on the other hand, the ration is low in its content of water-soluble vitamine the mother may maintain herself in fine condition and the young will grow, but may suddenly become neuritic and soon succumb.

Deficiency of a ration in the fat-soluble vitamine is indicated by symptoms not so specific or so dramatically manifest. A young rat will fail to grow, and a mature rat will fail to maintain itself just as would happen if there were a deficiency of suitable protein, ash or available energy, but in addition these rats are predisposed to a purulent conjunctivitis which usually leads to permanent blindness. So general is this condition that it might be taken as pathognomonic of this dietary deficiency if it were not for the fact that an indistinguishable form sometimes occurs in animals on other rations. In addition, Osborne and Mendel have found that their rations deficient in the fat-soluble vitamine induced the formation and deposition of calculi along the urinary tract. It is barely possible that these two conditions are related, irritation in the eye socket, due to abnormal secretions, preparing the field for the conjunctivitis. That it is an infection is indicated by its response to proper medication.

As these two forms of dietary deficiency can be easily demonstrated experimentally in the laboratory, one may well ask the question—what is the probability that certain cases of recognized or even unrecognized malnutrition in man may be due to an avitaminosis? With respect to beri-beri under ordinary conditions the danger is not very great, if at all existent. It is only when man so modifies the type ingredients in his diet as to depart from the character of *naturally* occurring food materials that beri-beri has ever been known to occur. The oriental suffered from this malady when he began to demand, for esthetic reasons only, that the prepared rice in his diet should be white. As the hulled rice kernel varies in color from a light yellow to almost black, he proceeded by a crude milling process to grind off this variously pigmented pericarp and thus obtained his white or polished rice. Though his esthetic desires were satisfied, his source of water-soluble vitamine had been dangerously reduced in amount; sporadic outbreaks of beri-beri became common. A similar condition of affairs has been reported in Newfoundland where an almost exclusive subsistence on patent wheat flour during a period of scarcity of other foods caused beri-beri. In the milling process where the aleurone layer and embryo of seeds are removed most of the vitamines are removed as well. It is timely to question the wisdom of many of our food-manufacturing processes not only from the standpoint of removal of valuable salts and proteins, but of vitamines as well. Why feed many of the most vitally necessary food constituents having their origin in the manufacture of our food in superabundance to our stock for animal and milk production and feed ourselves on what may look better

4. The same rat 23 days later kept on the same ration, but given daily the residue of an alcoholic extract equivalent to 3.4 grams of wheat embryo dissolved in its drinking water. The rat now weighed 102 grams. At the present time of writing it is in excellent nutritive condition and still gaining rapidly.

5. A female rat and her young raised on a ration rather low in its content of water-soluble vitamine. She became pregnant and raised a litter of four young to a total weight of 66 grams. The nursing young grew rapidly, but suddenly in one day lost 5 grams in weight and showed periods of great excitability. The next day one was found dead, and the others had convulsions as indicated in the cut. Such young invariably develop into normal rats when nursed by a normal rat on a complete ration; otherwise death ensues rapidly.

but nourishes less? Some of our milling processes have been adopted for economical reasons, as in the case of rice the unpolished grain on storage is very liable to become infected with meal worms and its fats are liable to become rancid, but undoubtedly other means could be found to cope with these difficulties. All food materials making up the greater part of the human dietary so far investigated have shown the presence of a generous amount of the water-soluble vitamine. Lack of water-soluble vitamine undoubtedly has not been one of the determinants which in itself has interfered with man's general progress and development.

There has recently come to the attention of the medical fraternity in Denmark and in Japan an abnormal condition of the eyes, a xerophthalmia, in children fed on pasteurized milk or grain milk-substitutes. Monrad and others have made the suggestion that this is due to an avitaminosis. This hypothesis has been tentatively accepted on the basis of experiments with rats such as previously described and because improvement has been found to result upon adding raw whole milk or cod-liver oil, both of which are rich in the fat-soluble vitamine, to the previous diet. Butter fat is very rich in the fat-soluble vitamine. The dairy cow in the tremendous consumption of rough feeding materials rich in the fat-soluble vitamine performs the act of concentrating it in the food for her offspring.

Man probably can not safely restrict himself to grains as his source of supply of this dietary essential, but needs to supplement them with the actively growing and assimilating parts of plants. Leafy materials such as have been investigated up to the present time have been found to contain this vitamine in large amounts. Some roots also apparently contain considerable amounts.

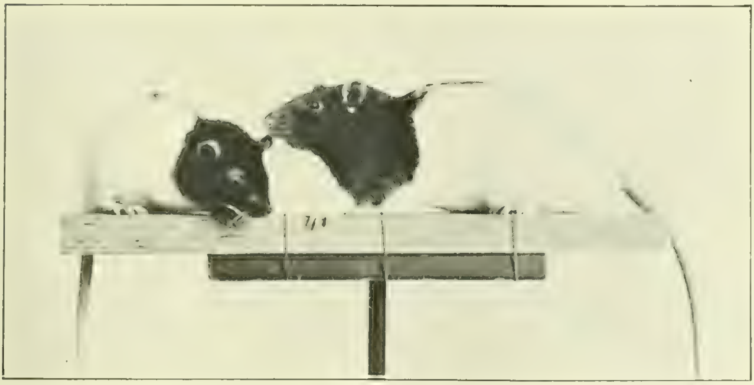
Because butter fat is very rich in this fat-soluble vitamine and because plant fats and the body fats of animals contain but little of it, much has been said in favor of the use of butter instead of butter substitutes. In full realization that but small amounts of the vitamines are required it must be remembered, however, that butter is wholly absent from the dietary of some and at most constitutes but a small part of the total of food stuffs consumed by most people and while little is known definitely of the fat-soluble vitamine content of other foodstuffs, yet enough is known to indicate that sufficient amounts to satisfy all requirements of the body can be carried by other food materials. It is not necessary to value milk especially on the basis of its fat-soluble vitamine content when it is remembered

6. The same rat 77 days later after having had two more litters, neither of which she kept alive longer than a few days. Though slightly longer haired she weighed 25 grams more and was in good condition. Rearing of the young is a process more exacting in its requirements than either growth or reproduction.

that as a source of protein for the animal it has no equal. For this we have no substitute, for it as a source of fat-soluble vitamine we have.

At one time, there was a tendency to associate etiologically other conditions of malnutrition, such as scurvy and rickets, with a deficiency of specific vitamines. Evidence so far presented does not support this contention. These diseases are undoubtedly associated with a faulty intestinal condition not directly referable to an avitaminosis.

In the present emergency in the economic food situation, it



7. Two male rats of the same age. The one on the right—a normal rat—received a sufficiency of the fat-soluble vitamine in its ration; it weighed 262 grams. The one on the left received but little of the fat-soluble vitamine; it weighed 109 grams. Note the inflammation of the eyes and the incrustation of the ears to which rats on a ration deficient in the fat-soluble vitamine are subject. Both conditions, if not too far advanced, can be improved by suitable medication.

is the duty of all students of nutrition to scan the horizon very carefully for indications pointing the way for rational modifications in the selection of nutriments. An individual so adapted as to be able to digest large amounts of food without digestive or other organic disturbances undoubtedly guards himself against a deficiency of any nutrient in his diet. This, in considerable measure, may account for the great capacity for work shown by some heavy eaters. On the other hand, many people are undoubtedly limited in their performance due to a shortage of a necessary constituent. When the food consumption is large there is little cause for concern, but when it is limited in quantity and in variety it is well to realize that any one of the factors, viz., vitamines, protein, salts or energy may limit a man's capacity for work. It might be said that it is unfortunate that man is not gifted with a sense of perception indicating to him the specific dietary needs of his body. He is either hungry or satisfied and ultimately he feels well or unwell. It is sufficient to say that vitamines are indispensably necessary in the diet, but for normal nutrition, if the individual has the opportunity to select his foods as he desires, lack of vitamines should undoubtedly give no greater cause for concern than lack of suitable proteins or salts. There is cause to look forward with considerable anticipation to the economic results which are bound to come with a fuller knowledge of what constitutes the valuable dietetic properties of many food materials individually and in various combinations.

THE PROGRESS OF SCIENCE

ONE HUNDRED YEARS OF THE AMERICAN JOURNAL OF SCIENCE

In July, 1818, *The American Journal of Science and Arts* was established by Benjamin Silliman, professor, as the title page of the first number states, of chemistry, mineralogy, etc., in Yale College. In the century that has since elapsed, the journal has witnessed and been itself a part in the most notable of all performances, the development of modern science. The present editor, Edward S. Dana, the grandson of Silliman, and like him professor at Yale, including mineralogy and other physical sciences in his field, has done well to issue a centennial number of the journal and himself review its history, while other contributors, who have been active in its work, sketch the history of the sciences covered by it. These articles have been made the basis of seven Silliman lectures, to be published by the Yale University Press, in accordance with the terms of the foundation established by a nephew of Benjamin Silliman.

The advancement of science in the past century and its progress in this country are the more notable if we compare the present situation with the humble and almost naïve beginnings of the *Journal*, and contrast them with other forms of human achievement, as poetry, literature, music and the fine arts, which at most have remained stationary, while our political institutions have progressed so little that they permit wars as devastating as those of the Napoleonic era.

The *Journal* was a modest quarterly, but the "Plan of the Work" with which it opens includes an ambitious medley of subjects which indicates so correctly the situation of science a hundred years ago that it deserves to be quoted:

> This Journal is intended to embrace the circle of THE PHYSICAL SCIENCES, with their application to THE ARTS, and to every useful purpose.
>
> It is designed as a deposit for *original American communications;* but will contain also occasional selections from Foreign Journals, and notices of the progress of science in other countries. Within its plan are embraced
>
> NATURAL HISTORY, in its three great departments of MINERALOGY, BOTANY, and ZOOLOGY;
>
> CHEMISTRY and NATURAL PHILOSOPHY, in their various branches: and MATHEMATICS, pure and mixed.
>
> It will be a leading object to illustrate AMERICAN NATURAL HISTORY, and especially our MINERALOGY and GEOLOGY.
>
> The APPLICATIONS of these sciences are obviously as numerous as *physical arts*, and *physical wants;* for no one of these arts or wants can be named which is not connected with them.
>
> While SCIENCE will be cherished *for its own sake*, and with a due respect for its own *inherent* dignity; it will also be employed as the *handmaid to the Arts*. Its numerous applications to AGRICULTURE, the earliest and most important of them; to our MANUFACTURES, both mechanical and chemical; and to our DOMESTIC ECONOMY, will be carefully sought out, and faithfully made.
>
> It is also within the design of this Journal to receive communications on MUSIC, SCULPTURE, ENGRAVING, PAINTING, and generally on the fine and liberal, as well as useful arts;
>
> On Military and Civil Engineering, and the art of Navigation.
>
> Notices, Reviews, and Analyses of new scientific works, and of new Inventions, and Specifications of Patents;
>
> Biographical and Obituary Notices of scientific men; essays on

THE

AMERICAN

JOURNAL OF SCIENCE,

MORE ESPECIALLY OF

MINERALOGY, GEOLOGY,

AND THE

OTHER BRANCHES OF NATURAL HISTORY;

INCLUDING ALSO

AGRICULTURE

AND THE

ORNAMENTAL AS WELL AS USEFUL

ARTS.

CONDUCTED BY

BENJAMIN SILLIMAN.

PROFESSOR OF CHEMISTRY, MINERALOGY, ETC IN YALE COLLEGE, AUTHOR OF TRAVELS IN ENGLAND, SCOTLAND, AND HOLLAND, ETC

VOL. I.....NO. I.

ENGRAVING IN THE PRESENT NO.
New apparatus for the combustion of TAR, &c. by the vapour of water.

New-York:

PUBLISHED BY J. EASTBURN AND CO. LITERARY ROOMS, BROADWAY, AND BY HOWE AND SPALDING, NEW-HAVEN.

Abraham Paul, printer.

1818.

TITLE-PAGE OF THE FIRST ISSUE OF THE AMERICAN JOURNAL OF SCIENCE.

COMPARATIVE ANATOMY and PHYSIOLOGY, and generally on such other branches of medicine as depend on scientific principles;

Meteorological Registers, and Reports of Agricultural Experiments: and we would leave room also for interesting miscellaneous things, not perhaps exactly included under either of the above heads.

For half a century the *American Journal of Science* remained practically our only scientific journal. Then in 1867 THE AMERICAN NATURALIST was established, followed in 1872 by *The Popular Science Monthly*, of which THE SCIENTIFIC MONTHLY is the editorial successor, and in 1883 by the weekly journal SCIENCE. Simultaneously special journals began to appear: in 1875 the *Botanical Bulletin*, the predecessor of *The Botanical Gazette;* in 1878 the *American Journal of Mathematics*, in 1879 *The American Chemical Journal*, now merged with the *Journal of the American Chemical Society;* in 1888, *The American Geologist*, no longer published, in 1887 *The Journal of Morphology*, and so on, in increasing numbers until to-day the files of our scientific journals fill alcoves of a library. The American Journal of Science is now only one in a large group of journals, but it occupies an important place earned not only by its history but also by its present high standard in the publication of scientific research.

HOURS, FATIGUE AND HEALTH IN BRITISH MUNITION FACTORIES

HOURS, fatigue and health in British munition factories is the title of a Bulletin, No. 221, issued by the Bureau of Labor Statistics of the U. S. Department of Labor as the first of a series of bulletins prepared at the instance of the Council of National Defense for the purpose of giving wide circulation to the experiences of Great Britain, France, Canada and other countries in dealing with labor in the production of the largest quantity of munitions in the shortest space of time. The bulletin contains the reprint of eight memoranda published by the British Health of Munition Workers' Committee which was appointed in September, 1915, "to consider and advise in questions of industrial fatigue, hours of labor, and other matters affecting the personal health and physical efficiency of workers in munition factories and workshops." These memoranda deal with Sunday labor, hours of work, output in relation to hours of work, industrial fatigue and its causes, sickness and injury, special industrial diseases, ventilation and lighting in munition factories and workshops, the effects of industrial conditions upon eyesight.

From a perusal of these memoranda it appears that Sunday labor, in the opinion of the committee, is not profitable and that continuous work "is a profound mistake" and does not lead to increased output; that a system of shifts although impracticable in some cases is to be preferred to overtime, since the latter taxes the strength of workers too severely, results in loss of time because of exhaustion and sickness, and curtails unduly the period of rest; that night work should be discouraged, that output can not be maintained at the highest level for any considerable period if the conditions are such as to lead to excessive fatigue and to deterioration in the health of the worker, with a recommendation that hours should not exceed 56 per week for men engaged in very heavy labor, or 60 for men engaged in moderately heavy labor, while 64 should be a maximum.

The committee's study of industrial fatigue and its causes sums up its own studies of hours of labor, emphasizing the importance of regularity of hours and of daily and weekly rests made with due consideration of the character of the work performed. In its report on sickness and injury the committee points out certain injurious conditions which should be guarded against as likely to diminish seriously the efficiency of the labor force "To conserve energy and efficiency is, other things being equal, the way to improve output." The medical examination of all workers before employment is recommended, and it is suggested that factories should provide proper sanitary facilities, safeguard machinery, make arrangements for adequate medical and nurse schemes, etc. The value of first-aid is emphasized.

The report on special industrial diseases gives the causes, methods of prevention and treatment for the principal industrial diseases which have been found to affect munition workers. Particular attention is directed to the importance of adequate lighting and ventilation which are absolutely essential for the maintenance of health and comfort and, therefore, the efficiency and capacity of the workers. Special measures to prevent undue strain upon eyesight and to reduce the liability of accidents to a minimum are recommended.

SCIENTIFIC ITEMS

We record with regret the death of Karl Grove Gilbert, the distinguished geologist of the U. S. Geological Survey; of John Harper Long, professor of chemistry in Northwestern University Medical School; of Stephen Farnham Peckham, known for his work in the chemistry of bitumens; of George M. Searle, formerly professor of mathematics and astronomy in the Catholic University of America; of Richard Rathbun, assistant secretary of the Smithsonian Institution, and of Sir Alexander Peddler, the English chemist.

The Croonian Lecture before the Royal Society was delivered by Major W. B. Cannon, professor of physiology, Harvard Medical School, on June 20, the subject being "The physiological basis of thirst."—The Wilbur Wright memorial lecture of the British Aeronautical Society was delivered in the Central Hall, Westminster, on June 25, by Professor W. F. Durand, chairman of the American Advisory Committee for Aeronautics, scientific attaché to the American Aviation Mission in Europe, and professor of mechanical engineering, Stanford University, U. S. A. The subject was "Some Outstanding Problems in Aeronautics."

The American Association for the Advancement of Science and the National Scientific Societies affiliated with it will meet at Baltimore in Convocation Week. It had been originally planned to meet in Boston, but under existing conditions it was thought best to choose a place as near as possible to the main centers of scientific activity and at the present time large numbers of scientific men are working at Washington. It is planned that the meeting will direct its main attention to the service of science in the present national emergency.

Yale University received by the will of John W. Sterling, of the class of 1864, a distinguished New York lawyer, the residue of his estate, which it is said amounts to fifteen million dollars.—Mr. Hobart W. Williams has given to the University of Chicago property to the value of $2,000,000, part of the income to be used for the development of the school of commerce and administration.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1918

THE TEACHING OF THE HISTORY OF SCIENCE

By GEORGE SARTON

CARNEGIE INSTITUTION OF WASHINGTON

DURING the last two years I have had to lecture on the history of science before a score of American and Canadian universities. In each university center I have naturally met and discussed with most of the people interested in the subject, which has enabled me to gauge pretty accurately the general sentiment concerning it and to figure the prospects of these studies. The present essay is the fruit not simply of this random experience as a lecturer, but also of my experience as a teacher in Harvard, Columbia, at the University of Illinois and the George Washington University. I propose both to clear up some misunderstandings, the further development of which might be more fatal to the history of science than mere indifference, and to answer a question which has often been addressed to me:

> You always lay stress on the importance of the history of science, as the best way of *humanizing* science and giving to it its whole educational value. But how shall we best do it? How should these studies be organized? And what should be the spirit of this teaching? . . .

The main misunderstanding to be dispelled (I will return to it, but I wish the reader to know from the start where I am aiming) is one which is chiefly bred by professors of philosophy. I have had the privilege to talk with many of these after my lectures, and not a few seemed to be surprised at my statement that the history of science had yet hardly been taught. Why! they themselves had been teaching it in their courses on the history of philosophy. . . . They spoke of Thales, Pythagoras, Democrites . . . they had actually explained the development of ideas on atomism, heredity, cosmic evolution, etc. . . . What more did I want?—Well, I wanted so much more and I felt that they were so deeply ignorant of the most elementary facts of science, so unaware of their real significance, so innocent of the true spirit of science, that I often gave up explaining anything. But I became more and more convinced of the necessity of insisting above everything else on the scientific foundation of the history of science. The chief requisite for the making of a good chicken pie is chicken; nay, no amount of culinary legerdemain can make up for the lack of chicken. In the same way, the chief requisite for the history of science is intimate scientific knowledge; no amount of philosophic legerdemain can make up for its absence.

The Teaching Must be Experimental and Concrete

> The purpose of the history of science is to establish the genesis and the development of scientific facts and ideas, taking into account all intellectual exchanges and all influences brought into play by the very progress of civilization. It is indeed a history of civilization considered from its highest point of view. The center of interest is the evolution of science, but general history remains always in the background.[1]

Of course, it is the natural, chronological development that we must especially consider, not the deductive and artificial. One of the petty ideas of philosophers is to elaborate a classification, a hierarchy of sciences. They all try it, and they are generally so fond of their favorite scheme that they are prone to attach an absurd importance to it. We must not let ourselves be misled by this. Classifications are always artificial; none more than this, however. There is nothing of value to get out of a classification of science; it dissembles more beauty and order than it can possibly reveal.

As a matter of fact, the most fascinating part of science is the intimate and intricate relations it possesses, not with fanciful doctrines, but with life itself. We can safely say that each new scientific development is due to the pressure of some social need. Of course, we include amongst these needs the insatiable curiosity of certain men, because even this curiosity, disinterested and inopportune as it may seem, is still nothing but a response either to an old problem of nature, or to one arising from new social circumstances. Even the development of mathematics is largely a natural, not a purely logical one: mathematicians are continually answering questions suggested by astronomers or physicists; many essential mathematical theories are but the reflex outgrowth from physical puzzles.

[1] G. Sarton in *The Monist*, XXVI., p. 333, 1916.

Further, the development of science is to a great extent impersonal. It is not the man of genius who leads it—he is only the "star" of the play—the real causes of this development are far deeper and as much beyond our ken as the sources of organic evolution. The different phyla of animals and plants did not successively appear according to a beautiful scheme of gradually increasing complexity; they are all evolving together because they all depend one upon another in many ways. At any stage of development there are all kinds of organisms—some very simple, some very complex—but it can not be said that the latter are more perfect because they all are the solutions of intrinsically different problems. The simplest are apparently as well adapted to their own conditions as the most complex. In the same way all sciences grow together, helping and stimulating one another, with little if any regard for logic and hierarchy; their growth is simply a function of their inner vitality and of the various needs of life.

The development of science is an organic development. We must study and teach it as such and not otherwise. Our teaching must be as unphilosophical and as unscholastic as possible. The few serious courses that have been thus far devoted to these studies, here and abroad, have been, with the possible exception of Mach's lectures, far too philosophical, I mean—far too prone to premature generalizations. In the case of France, this is due to the influence of Auguste Comte and more generally to the French love of system. In the English-speaking world, the influence of the positivist school has been working in the same direction. More recently the very learned and massive publications of John Theodore Merz have accentuated this ratiocinating tendency in the most disastrous way. His "History of European Thought in the Nineteenth Century," enjoying as it does a kind of monopoly, is unanimously praised, especially by those who would make us believe that they have read it. This book certainly conceals a considerable amount of material, but it is so prolix and discursive that its rich substance has to be almost entirely redigested to be of any great service.

Abstract as it is, science is but an outgrowth of life. That is what the teacher must continually keep in mind. If he seeks his inspiration in any philosophical system instead of letting himself be guided by the plain realities of scientific development, he may produce books that will interest philosophers, but he is lost as a historian. On the contrary, let him follow the lead that I am giving. Let him explain the development of science, as of something living and growing like an animal or a plant, answering to the stimuli of its environment; let him show that each problem of life releases a new train of scientific problems, and that all these trains interfere one with another and continually give birth to new discoveries and arrangements —and he will soon give to the student the feeling that science is not a dead system—the excretion of a monstrous pedantism —but really one of the most vigorous and exuberant phases of human life. Science has always been growing and changing as it does even now. The teacher must continually strive to increase the intimacy of his disciples with this rich inner life of science. Of course, this will only be possible if he be himself on intimate terms with it. But if he succeed in doing this, his teaching will certainly prove interesting and stimulating.

These are the two alternatives: either the course on the history of science will sooner or later degenerate into a new course of philosophy, and its generality and simplicity will give the student a false sense of knowledge, or it will be, as I say, experimental, concrete, matter of fact.

I do not say that generalizations must be avoided, but simply that they must be reduced to a safe minimum and only offered to the student when all the facts of the case are well understood by him.

These facts are of two different kinds: historical and scientific. The teaching of the history of science must be essentially the interpretation of these two sets of facts. Let us now consider how better to explain each of them and how to harmonize the simultaneous teaching of both.

The Teaching of Historical Facts

It is in the historical part of the teaching that the connections between science and all other human activities are made manifest. Hence this part is the most important from the pure humanistic point of view. The basis of any historical interpretation, of course, is the arrangement of all interesting facts in a chronological sequence. This implies painstaking and monotonous research work, a drudgery from which most scientists would fain escape. But this work being fundamental can not be too accurately done, even in those cases where historical details may seem of trivial importance. Accuracy is to the scholar what discipline is to the soldier: it must be implicit or it is not worth anything.

I have already shown elsewhere that the development of science is intimately connected with every other human development; there are continuous interactions, for example, between science and art, science and religion, science and industry, science and law, . . . not to speak of the influences revealed by general or political history. It is the historian's business to disclose these various and continuous interactions, and so to bring into greater relief the organic development of science. He will show that this development is really the culmination of human achievement. He will lay particular stress on the relations of this greatest of human tasks with two others which are almost as important; the creation of beauty and the development of social institutions.[2] Indeed, it should be obvious to all that it is these developments, but chiefly the development of knowledge, upon which the history of human progress should be focused. To make this clear, the teacher will lose no opportunity of showing the cumulative and progressive, also the international character which is specific to science.

The center of gravity of historical studies must be displaced. As a matter of fact it has been moving all along in the direction which I indicate: at first it was dynastic, then military, national, political, institutional, social . . . it is now high time that it become really scientific. Human achievement in the realms of knowledge, beauty and justice is the real thing; the rest is merely anecdotic. Of course, most historians can not be expected to subscribe to this, and many will imperturbably follow their own lines without even trying to know something of the evolution of science. There is no objection to that, any more than there can be any to the simultaneous existence and to the collaboration of organisms having reached different stages of development. Protozoa, insects, birds and men . . . each is doing his little bit. The only thing which will have to be stopped is the old historian's belief that his medieval point of view is really the most catholic; also his absurd pretense to control historical studies.

It is well to give due importance to the biographical side. There is no better way of stimulating the student's interest than to narrate with sufficient detail the lives of those heroes to whose efforts and sacrifices we owe the best of our civilization. And if they really had to suffer because they were so much ahead of their time, and too little concerned with the requisites of every-day life, if they were not understood and died unrewarded, it becomes the historian's sacred duty to redress

[2] However important and impressive these two developments may be, they are not just as important as the development of science because they are less specifically human. Some animal societies have reached a high stage of perfection; it may be that it is less the lack of solidarity than the lack of positive knowledge, of tools, that has prevented them from going even higher. As to beauty, there is an infinite amount of it outside of man.

this injustice by explaining in full the greatness of their work, and making them live again, forever.

The Teaching of Scientific Facts

Important as it is, the historical side of our studies must evidently be subordinated to the scientific side. There would be little sense in explaining the history of something which would not in itself be clearly understood.

And yet this is perhaps the weakest point of most courses on the history of science, and one can not help shivering at the thought of what would happen if such courses fell into the hands of scientifically untrained philosophers. It is a well-known fact that people having no direct knowledge of science are almost bound to make fatal mistakes on essential points, often on those which appear to be extremely simple.

Now, if a course on the history of science were to become the vehicle of false or inaccurate scientific ideas, it would be more detrimental than useful. Hence the professor of general history should forbear from dealing with scientific facts of which he is not able to give an accurate and circumstantial account. As to the instructor on the history of science, he should not undertake to tell the history of any scientific idea, without making sure of his ability to explain the full signification not only of this idea, but also of each step which led to its discovery. He must be able to do this in the most concrete and specific way.

It follows from this that he should be given all the paraphernalia necessary for the explanation of the scientific facts involved, such as maps, charts, pictures, models and various apparatus. How can it be possible to interpret—say—Galen's or Vesalius's anatomical discoveries (also their mistakes) or the discovery of the circulation of the blood or of the nervous function, without having at least some good anatomical models or drawings upon which to point out the various details alluded to? With the proper models the teaching is easy, clear, convincing, interesting; it becomes hopelessly dry, confusing and tiresome without them. It is noteworthy that these models and charts are necessary both for introductory and for the most special courses. In the case of elementary courses, however, they are especially useful in the avoidance of too many technical terms. I have borrowed my examples from the field of biology, but the same thing is true of any other department of science. How shall I properly explain the development as well of primitive tools, as of the steam engine or the dynamo—without models or pictures? of geographical discoveries, without maps? In the latter case, maps are not even sufficient. When I narrate the discovery of America, I should like to be able to explain exactly how Columbus navigated. Therefore I should need a cross-staff, an astrolabe, a primitive compass, a portolano and some early printed astronomical table. It would not be necessary, of course, to have original instruments and copies could be easily obtained at a relatively low cost. Does not any one see that such teaching of the geographical discoveries would have infinitely more sense and import than the usual vague and literary description?—I know that the literary people will insinuate that I would destroy all the romance of these adventures. I do not believe in the romanticism of ignorance. What is truly heroic, pathetic, grand, would certainly be put in stronger relief by such explanations. If the early navigators had been blind fools, we could not call them heroes; they were conscious of their purpose and of the dangers to be encountered and they had to pool all their knowledge and energy to fight against nature. The literary people have told but a small part of their story.

Models and instruments would not be less needed for the teaching of more abstract sciences, even of mathematics. To elucidate the development of the latter, its cultural value and its relation to other sciences, it is well to be able to show ancient instruments—for example, abaci, arithmetical machines, slide rules—not to speak of geometrical models and of more complex mathematical machines which become almost indispensable. Will not a lecture on the work of Fourier, for example—either in a course on the history of mathematics or in one on the history of physics—gain considerably in interest if it be possible to demonstrate its further applications by means of some kind of harmonic analyzer?

It is not less necessary, whenever the subject lends itself to it, to make some fundamental experiments. It would be the more necessary if the students have less scientific training. It should not be permissible to speak of Galileo without making some very simple experiments on gravity, nor to speak of Huygens, without illustrating in a similar way the laws of centrifugal force. No amount of verbal explanation can ever replace such experiments. In a general course on the history of science, all the fundamental facts of physics, chemistry, biology, should be demonstrated experimentally whenever it is possible to do so without too much trouble. I may add that if it became a common practice to illustrate historical courses by experiments, a greater accuracy in the statement of scientific facts would be automatically secured.

The scientists teaching the history of their own science in their own lecture hall, if they are often handicapped by a serious lack of historical training, at least have the enormous advantage of being able to make the necessary experiments with greater ease and effectiveness. What such courses often lose in historical accuracy they gain in scientific precision and experimental pointedness.

I do not hesitate to say that without experiments the very best of these courses on the history of science is lost. The experiment is not simply necessary, as in a regular scientific course, to prove the fact to the student's senses. It is of even greater importance in our case, to introduce him to the handicraft part, the most living part, of science. This can hardly be explained with words. The student must be made to understand that science is not simply a product of the brain, but also of the whole of our muscular and sensual experience. To know a science does not mean simply to remember a certain number of facts and principles duly classified; it implies far more an intimate acquaintance with various methods and apparatus into which a great deal of scientific thought is so to say crystallized. Even in mathematics, there is room for a certain amount of handicraft of a subtler kind—the almost automatic handling of certain formulæ and symbols.

It is essential for the student to understand this to the best of his ability, because it is only on this condition that he will be able to watch the inner growth of science, and to see it, so to say, in the making. Great discoveries have been made chiefly by men whose entire attention was concentrated upon limited problems and specific experiments, then upon certain material details of these experiments. That is the real heart of science; the spring of its eternal youth.

Any philosophical or literary history of science necessarily fails, and will ever fail, to show that. As a matter of fact, no history of science has ever been written from this point of view—none that I know of, not even Ernst Mach's admirable history of mechanics, although he has come considerably nearer to this ideal than any other author.

Equipment

Lectures on the history of science illustrated by experiments and various demonstrations can not possibly be given in an ordinary lecture hall. There are three methods of solving this practical difficulty.

The first is to have the lectures delivered in the various scientific halls where the needed implements would be at hand.

Lectures pertaining to anatomy might be given in the medical school; lectures on Galileo, Newton or Helmholtz in the physics building, and so forth. This method would be the source of so many conflicts and misunderstandings, even if the different halls were sufficiently near to each other, that we may just as well dismiss it as impracticable.

There remain the two other solutions: the ideal one is to provide for this teaching a special lecture room, completely equipped for the making of simple physical, chemical and biological experiments. If this was found to be too expensive, the historical courses could be given in any other scientific hall. The instructor would then deliver most of his lectures in this hall, but would have to take his flock to other halls whenever necessary. It must be noted that even if a well-equipped hall were placed at the lecturer's disposal, he might still find it necessary to give once in a while a lecture in another building, in the observatory, for instance, or in one of the university museums.

It is not necessary here to describe the ideal lecture hall which I have in mind; it would simply combine the main features of ordinary physical, chemical and biological amphitheaters. The chief difference between my lecture hall and these amphitheaters would lie less in the hall itself than in the series of instruments and models collected either around it or in neighboring rooms. There should be sets of geographical and historical maps; also anatomical, zoological, botanical, geological . . . charts and models. In short, the instructor should be enabled to fully interpret each scientific fact to which he would refer. A collection of portraits of the great scientists would also be desirable, but this is less essential. It would be necessary to have a good set of copies of primitive and ancient instruments: early types of armillary and celestial spheres, microscopes, telescopes, celestial machines, alembics, surgical and obstetrical instruments. . . . Most of these early instruments being rather simple, the making of copies would not be very expensive; it would certainly be far less expensive than most of the models or specimens used in the teaching of biology and natural history. Many antiquated instruments might likely be found in the collection rooms (if not in the attics!) of the scientific buildings of the oldest universities, and, I surmise, would gladly be given or lent to the new department for further and better use.

I must limit myself here to these general indications, but I propose to publish subsequently a more detailed description of the lecture hall with a tentative list of the maps, charts, models and instruments which would be most urgently needed.

Previous Work in the Same Direction

I do not know of any general course on the history of science, anywhere, which is conducted along the lines which I have indicated. Most of the courses of which I know are to a large extent philosophical courses and lack both historical and scientific concreteness and accuracy.

But something nearer to what I have in mind *may* have been done in the teaching of the history of special branches of science, especially medicine. Courses on the history of medicine have been delivered in many European and American universities, generally by one of the professors of the medical school speaking in his own auditorium with plenty of illustrative material close at hand. In this case, however, there is little opportunity for experiments, except on the occasion of some physiological digression. I must also refer to the little mathematical museum which Dr. D. E. Smith has organized in Teachers College, Columbia University, close to his lecture room. Almost all the objects exhibited are original implements wherewith to illustrate the development of mathematics, not simply in Europe, but also in India, China and Japan. Dr. Smith uses extensively his treasures in his lectures on the history of mathematics, and it was my own privilege, thanks to his courtesy, to be able to use them too when I lectured at Columbia in the summer of 1917. This strengthened my belief that there is no better way of impressing upon the student's mind the relations of abstract mathematics to reality.

As to the physical and biological sciences, for the historical interpretation of which so much illustrative material and so many experiments would be needed, I do not know of any course in which such demonstrations have been actually carried out. The reader will surely think of Ernst Mach, who was professor of inductive philosophy at the University of Vienna from 1895 to 1901. I have no definite information about his method of teaching; I do not know to what extent his courses were experimental. But as Mach had become more and more interested in psychological rather than historical research, it is likely that his teaching was very different from the one of which I am thinking.

General Science

The development of science has become so multitudinous and luxuriant in the nineteenth century, still more in the twentieth;

its complexity, the wealth of facts garnered all over the world, is increasing at such a terrific rate that it is no longer possible to contribute much to its progress unless one concentrates one's efforts and intelligence upon the exploration of a particular field. Every day the field which the average scientist may hope to till fructuously is becoming smaller, and thousands of men are doomed to spend their lives within a very restricted intellectual horizon. However necessary these human sacrifices may be for the advancement of science, they are nevertheless befraught with perils; nay, if they be not compensated in some way or another, they may endanger the whole fabric of civilization.

The only remedy is that which has already been applied in other departments of human activity, in the industrial realm for instance. There also have an increasing specialization and standardization become conditions of success. But business men, who never run the risk of losing touch with reality, have quickly grasped that if no corrective were brought to this extreme specialism, the loss due to disintegration would soon offset the gain in efficiency. Hence, they will no longer allow the creation of new departments or specialties without providing at the same time for some kind of coordinating agency. In the same way, the more most scientists become intensely specialized, the more urgent it is that at least a few devote themselves exclusively to the coordination and synthesis of the whole work. This new specialty, that is the study of general science, is the only means of avoiding the disintegration of the whole and the impoverishment of the scientific spirit.

This study, which many scientists would hardly dare approach, is not necessarily more difficult than any other special study; it is different; it requires a different training, that is all. The men devoting themselves to it would be able to stand in stead of the specialists, to guide them outside of their own garden, to prepare comprehensive surveys, but what is even more important, they would be able to teach the young before they specialize and to give them a broad and solid scientific basis, which would later enable them to keep in touch with the rest of the creative work of the world, and to escape from their prison whenever they would wish to. This teaching would remain an inspiration to them throughout their life.

How should we organize this synthetic teaching? The most natural method is certainly the historical one. However specialized and distant the various ramifications of science may now be, they have all originated from the same trunk. All sciences have grown together, the progress of each promoting the others and releasing, so to say, new series of thought and inventions all around. To disentangle the apparently overwhelming intricacy of modern science, it is enough to study its heredity.

A concrete, experimental course on the history of science is the best imaginable course of general science, the best introduction to more advanced and special scientific research.

This seems clear enough, but I can not leave the subject of general science without dispelling a grave misunderstanding which obtains in many parts of this country. It is due to the fact that the words "general science" are frequently used with a different connotation from the one which I give to them. What I mean by them is the general fabric of science, the cardinal facts and ideas of each science, and chiefly their interrelations, their points of contact, their relative degree of perfection, the light they throw upon each other, also the view of the universe which is the result of their combined advance. Now I have here before me a very remarkable text-book edited by Frederic D. Barber.[3] It contains an extraordinary amount of information, clearly and simply presented, about most scientific problems which his environment might suggest to any intelligent youngster. The authors have a perfect right to call this book "a first course in general science," inasmuch as it is not dealing simply with physics, chemistry or biology, but with all these branches of science. Yet it is clear that "general science" is here given a very different meaning from my own. It is general science to be sure, but *everyday* science, not *fundamental* science.

The two points of view are radically distinct: the former is practical, utilitarian; the other is theoretical, esthetical, idealistic. From the point of view of everyday science, for instance, it is very important to have sufficient knowledge of the mechanism of an internal combustion engine to be able to handle it without danger or waste, but one may be very familiar with such an engine and yet not know the principles of thermodynamics. On the contrary, from a historical and philosophical point of view it is the knowledge of these principles which is supreme. So also, for him whose material needs must be satisfied as quickly as possible, it is essential to obtain from the beginning some rudimentary knowledge of the functions of his own body; but for one who has time to make his survey of nature in a more leisurely way, it is wiser to grasp first the fundamental principles of physiology and of course it will be easier

[3] "First Course in General Science," by F. D. Barber, M. L. Fuller, J. L. Pricer and H. W. Adams. New York, Henry Holt, 1917.

to lay them bare in the simplest organisms than in such a highly differentiated structure as the human body.

I do not mean to disparage the utilitarian conception of "general science." I am entirely in sympathy with the idea of diffusing clear information on the scientific substrata of everyday life. But neither can it be validly objected to me that courses in general science, such as I propose to establish, already exist, because the courses so-called answer a purpose altogether different from mine. It would be regrettable that such confusion were allowed to persist, and hence I would suggest to call the courses which I have in mind courses on the history of science—a well-grounded designation inasmuch as the method of approach would be essentially historical.

The teaching of the history of science is exposed to two chief dangers each equally to be avoided. The philosophic danger, that is, premature abstraction and generalization, and the utilitarian danger, that is, premature application. Both imply in different ways a serious lack of accuracy; but besides, the former entails a lack of contact with reality, a lack of life. The latter implies a misconception of the essentials of science, a lack of appreciation of its disinterested spirit and of its serene beauty. If the former evil were not sufficiently eschewed, the teaching would be of very little use; on the contrary, if it were too utilitarian, it would have no real educational value.

Typical Program

How then should these courses on the history of science be organized in a large university? I consider that it would be in general sufficient to offer three courses each year. First an introductory course on the history of science throughout the ages. The outline of this course could not vary considerably from one year to another. Secondly, two special courses of which one would be devoted to the history of a special science: physics, chemistry, astronomy, biology . . . and the other to the history of science and civilization at a special period. The latter course would simply be an anticipation of what all courses on general history will be when the literary supremacy passes, a history of civilization focused upon the development of knowledge and social institutions. These special courses should be changed every year, so that students especially interested in them could achieve complete studies in a cycle of three or four years.[4]

[4] The nearest approach to this was made in Harvard. Dr. L. J. Henderson has given there since 1911 a most stimulating course on the history of science. To this general course, I myself added from 1916 to 1918, four

To deliver these three series of lectures, and possibly to direct the activities of a seminary and the research work of advanced students, at least two instructors would be needed. Of both, at least the one in charge of the two special courses should be a specialist, having no other duty than to know and teach his subject as well as possible. His task would still be considerable, as there remains a considerable amount of pioneer work to be done. The writing of a text-book on the history of most sciences is still very much of a venture. There are not yet pedigreed text-books, embodying the accumulated labor of many generations of scholars.

One might ask how far down the history of each science should be carried on. It is not possible to give a general answer to this question. For one thing, neither have the different sciences progressed at the same rate, nor are they equally esoteric; whereas it is out of the question to teach the history of mathematics in the nineteenth century except to advanced mathematical students, the most recent geographical discoveries can be explained almost to any educated person, and nineteenth-century physics or chemistry, to any student having taken only one elaborate encyclopedic course on these branches. The special training of the instructor should also be considered. I assume that he has had a serious scientific training (both theoretical and experimental), but this training may have been chiefly physical, or chemical, or biological. He should be expected to teach the nineteenth-century history of the sciences which he best knows, not of the others.

It is noteworthy that the teaching of the history of modern science is anyhow of a nature very different from the teaching of ancient science. For the latter the main difficulties are historical; for the former, especially when it comes to nineteenth- and twentieth-century science, they rather lie in the statement of the scientific facts themselves. The original documents of nineteenth-century science are generally well known and easily accessible; most scientists have the greater part of them in the sets of periodicals of their laboratory. Hence, the teaching of the history of a branch of science in recent times could often be safely entrusted to a scientist cultivating this particular branch and having a sufficiently acute historical and philosophical sense. This will be even more true when good text-books on the development of nineteenth-century science will be available.

It would be expedient, however, to expect the regular professor of the history of science to devote once in a while a course

special courses. But facilities lacking, none of these five courses was experimental nor as concrete as it should have been.

of lectures to nineteenth-century science, in order to oblige him to keep in touch with living problems. This is essential to ensure the soundness of his teaching.

Local conditions also should be considered. For instance, a university in which the physical department is especially strong and draws a great number of students from all over the country should organize regular courses on the history of physics and induce the advanced students to attend them. In Belgium no one can obtain a doctor's degree in any science without having passed an examination on the history of this science. There is much wisdom in this, although I do not generally believe in examinations.

At least the student should be made to understand the necessity of attending such a course, not because he needs it from a purely material point of view, but because this would form an essential part of his educational background and would help him to appreciate the signification of his own work and its relations to the work of his fellowmen. It is not enough for him to become a clever physicist; he must become, to the limit of his propensities, a generous and broad-minded man. There are only two ways of shaking one's innate narrow-mindedness and provincialism: to move in space or to move in time. One is travel, the other history; both should be periodically resorted to.

Conclusions and Various Remarks

The history of science, to be of any service, must be constantly based on the safest and most complete historical and scientific knowledge. It then provides the most natural and most illuminating interpretation of general science. There is no better way of revealing its disinterested spirit and its supreme beauty; therefore no better way of giving to any scientific teaching its full educational value. A course on the history of science given by the right teacher at the right moment to the right student would constitute his supreme humanistic initiation.

It can not be too often repeated that the value of this teaching will largely depend upon the soundness of its scientific foundation. If it became too philosophic or literary, if it fell into the hands of people knowing science only in a superficial way, the result would inevitably be a falsification of science, with its logical sequences of misunderstandings and verbal quarrels. The course would then be really dangerous, as it would give the students a false illusion of knowledge. I insist that non-committal accuracy is not sufficient; the teaching must be precise and concrete; if not, the result would be neither science, nor literature, but a mongrel thing,—althogether bad. The chief purpose is to interpret the scientific spirit and methods: this can only be done by one having intimate acquaintance with the subject. Literary people and most philosophers are constitutionally unable to understand scientific methods and values. To entrust such courses to them would be to betray our ideal.

Neither should these courses be open without discrimination to any student. It must be kept in mind that the history of science can not be in itself a complete introduction to science. There is no short cut to scientific knowledge. The only way of attaining it is to study it systematically, with brain and hands. No student should be admitted before having successfully taken at least one laboratory course.

The more science they already know, the more would the students enjoy these lectures. They would supply to them the best recapitulation of the scientific facts and principles with which they would already be acquainted, from a novel and higher point of view.

Such historical courses should be considered, indeed, as a reward: the reward of the traveller who, having reached a stage of his long journey, looks down behind him along the slopes of the mountain upon which he has been climbing. The sun sets; his legs, his whole body, are tired but he thoroughly enjoys the well-deserved rest and the broad prospect which he has won. This is exceedingly sweet and cheering; truly, a great reward. . . .

The ultimate aim is to humanize science, and so to give to it its due part of the educational influence which has remained thus far by sheer inertia the monopoly of the so-called "humanities." Hence, the establishment of courses on the history of science, such as I understand them, will sooner or later entail an educational revolution. I have explained elsewhere, for instance, that it will oblige history to move its center of gravity. The history of civilization will be focused on what is most permanent, progressive and specifically human in the development of the race.

It will also procure the means of solving the old controversy "science *vs.* the humanities"—the modern visage of the ever-recurring contest between scholasticism and original and creative thought, the endless struggle between ever-rampant superstition and positive knowledge. The only cure of endemic scholasticism is experimental science.

We are not intolerant of the endeavors of the literary people, however; we love beauty, even the special form of beauty which they worship, as much as they do. Indeed, we have to thank art and literature for some of the greatest benedictions of life. But to value their treasures, it certainly can not be necessary to be ignorant of the laws of nature. It is impossible to see why a man should be less inspired or generous because he knows more. On the contrary, the better a man knows nature, the better will his heart vibrate at the touch of any true beauty. All other things remaining the same, his generosity, his inspiration will directly depend upon the amount and the quality of his knowledge.

The whole contest has been constantly obscured by the fact that it has been generally discussed and settled by literary people, impervious to scientific thought. How could they judge the relative merits of chemistry and Greek? What did they know of it? Yet they were the final judges. It is well known that most university presidents (and trustees) are literary people or lawyers. A generation or two ago they were chiefly theologians. But are literary people not just as unfit for intellectual leadership as theologians? They see only with one eye. The publications of the members of their scientific departments are just as unintelligible to them as if they were written in Chinese. How could these university presidents coordinate activities which they fail to understand? Their function becomes more and more a mere administrative one; they can not possibly be—what they should be—the inspirers, the spiritual guides of the faculty.

The whole thing becomes tragic when we realize that one of the most urgent tasks of our time, namely, to reconcile knowledge and idealism, is chiefly entrusted to them. We need both equally. I do not know which is worst, knowledge without idealism or idealism without knowledge, and yet our whole system of education is leading to their growing estrangement. It is clear that university presidents and trustees could do more than any other people towards the accomplishment of this task, if they were equal to it. In truth, a literary president is as hopeless as a blind admiral.

How long will it take to accomplish this educational revolution? I do not know. The struggle promises to last a considerable time. Think of the immense inertia incorporated in the present alliance of literary people, historians, philosophers; of the enormous weight added to it by the ignorance of the rulers, legislators, publicists, newswriters and of the great bulk of the teachers—all these men continually playing upon the religious and moral feelings of the people. Think of the united strength of tradition, superstition and ignorance. Moreover literary studies will always appeal more than any other to the mass, because they require less intellectual effort. Most people are very reluctant to use their brains; strange as it may seem, not a few find it easier to die than to think.

On the other hand, most scientists are so busy, so absorbed by their own research work, and—it grieves me to add—many have become so dull by dint of premature and extreme specialization that they do not try to get control of educational matters. They do not care any more; they are generally quite happy when a bone is thrown to them in the form of a new laboratory. Of course, business people now begin to understand that to equip a laboratory for physical or chemical, not to speak of medical, research is a sound investment. But how long will it last before they understand not simply the practical, the material value of science, but also its beauty, its greatness? Millionaires and city councils begin to appreciate art museums; but when will they see that there is also an infinite amount of unexplored beauty and fresh inspiration in the realm of science—and that it is high time to dig it out and to let more people, including the scientists themselves, partake of it?

No essential progress in the management of human affairs can be expected so long as the scientific methods and the scientific spirit are not more systematically applied to them. My own efforts are passionately bent on explaining that the brute knowledge of uneducated experts, precious as it may be from a purely material standpoint, would, notwithstanding, be a source of danger to our civilization. What is the use of being efficient, if we are to lose thereby all the joy, happiness and freedom which we need even more than bread? Yet, if we wish to survive, we must be efficient.

Idealism alone is blind and powerless; knowledge without compensation is brutal. We need the golden combination of both. To reconcile efficiency and happiness it is necessary and sufficient that science remain closely allied with beauty and charity. The establishment of this alliance is the whole program of the New Humanism.

Short Bibliography

Two elementary text-books on the history of science have been published in America last year: Walter Libby's "Introduction to the History of Science" (Boston, Houghton Mifflin) and Sedgwick and Tyler's "Short History of Science" (New York, Macmillan). A more elaborate text-book —the best that we have thus far, however imperfect it may be—is Friedrich Dannemann's "Die Naturwissenschaften in ihrer Entwicklung und

in ihrem Zusammenhange," 4 vols., Leipzig, 1910.3. Aldo Mieli has begun the elaboration of a much vaster work, "Storia del pensiero scientifico dalle origini a tutto il secolo XVIII." One volume only has been published: "Le scuole ionica, pythagorica ed eleata," Firenze, 1916 (the author proposes to study the earlier periods later). Two other volumes are ready, but their publication is suspended on account of the war. Mieli is the most active representative of the New Humanism in Italy.

A splendid movement has been launched in Oxford by Dr. and Mrs. Charles Singer, Sir William Osler and others. They have just published the first volume of their "Studies in the History and Method of Science," Clarendon Press, 1917. This offensive is gallantly supported by F. S. Marvin, the author of "The Living Past" (Oxford, 1913), a little masterpiece of historical interpretation. Marvin has edited two other books: "The Unity of Western Civilization" and "Progress and History" (Oxford, 1915–6). See also his article on "Science and History" in *The Contemporary Review*, April, 1918.

Since I have quoted Marvin's work, I should also quote James Harvey Robinson's comprehensive and generous "Outline of the History of the Intellectual Class in Western Europe," New York, 1915, containing copious bibliographical information on the history of thought.

Ph. E. B. Jourdain has contributed many papers on the history and philosophy of science (chiefly mathematical) to *The Monist* (Chicago), of which he is one of the editors, and to the other reviews quoted below. Eugenio Rignano, editor of *Scientia*, international review of scientific synthesis (Bologna), and Sir Ronald Ross have done much also to promote these studies. It is invigorating to read Sir Ronald's caustic and spirited editorials in *Science Progress*, a quarterly review of scientific thought, work and affairs (London). A collection of Rignano's papers has just been translated into English: Essays in scientific synthesis, London, 1918. George Sarton, editor of *Isis*, revue internationale consacre â l'histoire de la science (Wondelgem, Belgium), has published many papers in his own review (1913–4), also in the *Revue générale des Sciences pures et appliquées*, Paris, 1912; in *The Monist*, July, 1915; in *Scientia*, 1918, and in *Science*, 1917 (An institute for the history of science and civilization, Vol. 45, p. 284.6; Vol. 46, p. 399–402). It is not a mere coincidence that each of the four last-named writers is, or was, the editor of a review devoted to scientific synthesis. Many other papers on the humanization of science have also been published in *Science*, New York, and still more in *Nature*, London.

For further bibliography, see Aksel G. Josephson, "Books on the History of Science," The John Crerar Library, Chicago, 1911; Supplement to December, 1916, *ibidem*, 1917.—Aldo Mieli, "La storia della scienza in Italia. Saggio di bibliografia di storia della scienza," Firenze, 1916.

Concerning teaching in the U. S., see Fred E. Brasch, "The Teaching of the History of Science. Its Present Status in Our Universities, Colleges and Technical Schools," *Science*, Vol. 42, p. 746–60, 1915. I would suggest that any new initiative in this field be communicated to F. E. Brasch, The John Crerar Library, Chicago, to enable him to keep the information up to date for the benefit of all concerned.

G. S.

BAKER ON THE MICROSCOPE AND THE POLYPE

By Professor LORANDE LOSS WOODRUFF

YALE UNIVERSITY

THE transactions of learned societies during the eighteenth century are replete with microscopical observations instigated directly or indirectly by the pioneer work of Hooke and Grew in England, Leeuwenhoek and Swammerdam in Holland, and Malpighi in Italy. In particular, Leeuwenhoek's long series of letters, published year after year chiefly in the *Philosophical Transactions* of the Royal Society of London, revealed an undreamed-of microcosm beyond the ken of unaided vision and turned the attention of the "Ingenious and Curious," the philosopher and dilettante, to the slowly developing microscope as a source of pleasure or fame. Among the English disciples of Leeuwenhoek, it was Henry Baker, of London, on whom seems to have fallen the Dutch microscopist's mantle—though, it is true, considerably reduced.

Baker was born in London on May 8, 1698, and began his career at an early age as a bookseller's apprentice. In 1720 he undertook to tutor a deaf and dumb child and with such success that he established a private school in London for deaf mutes. His course of instruction comprised speech and lip reading, writing and drawing, but the essential point of his system, which unfortunately he felt constrained to keep a secret, was that, after the preliminary training, he took his pupils on rambles about London and instructed them by conversation on the events of everyday life with which they came in contact. Baker realized a considerable fortune from his school, and the success of his method brought him to the attention of Daniel Defoe, who in 1728 became associated with him in founding the *Universal Spectator and Weekly Journal.* The following year Baker married Defoe's youngest daughter, Sophia, who bore him two sons. He survived both his wife and children, his sole heir being a grandson. After Baker's death on November 25, 1774, the Royal Society established the Bakerian Lecture with a fund given by him for discourses on "anatomical or chymical" subjects.

Baker's first essay as an author was "The Invocation of

Health," which was published without his sanction in 1723. The same year appeared a pamphlet of "Original Poems: Serious and Humorous," printed for the author, and was followed in three years by the "Second Part of Original Poems: Serious and Humorous." In 1727 was published his philosophical verses entitled "The Universe. A Poem intended to restrain the Pride of Man." This was printed for T. Worrall at Judge Coke's Head, against St. Dunstan's Church, in Fleetstreet, and sold for one shilling. "The Universe," as its subtitle indicates, is an attempt to impress the reader with the vastness and grandeur of nature and the folly of insignificant man believing that it was created for his especial edification. This poem, which attained considerable popularity and was frequently quoted, reminds one of the poetical works of Erasmus Darwin. An idea of the whole may be gathered from the following extract, which is one of the most interesting, and apparently one which Baker especially approved since he quoted it before the Royal Society—the first instance of original versification appearing in the *Philosophical Transactions*—and again nearly twenty years later in "The Microscope Made Easy":

> Each Seed includes a Plant: that Plant, again,
> Has other Seeds, which other Plants contain:
> Those other Plants have all their Seeds; and Those,
> More Plants, again, successively inclose.
>
> Thus, ev'ry single Berry that we find,
> Has, really, in itself whole Forests of its Kind,
> Empire and Wealth one Acorn may dispense,
> By Fleets to sail a thousand Ages hence:
> Each Myrtle-Seed includes a thousand Groves,
> Where future Bards may warble forth their Loves.
> So ADAM'S Loins contain'd his large Posterity,
> All People that have been, and all that e'er shall be.
>
> Amazing Thought! what Mortal can conceive
> Such wond'rous Smallness!—Yet we must believe
> What Reason tells: for Reason's piercing Eye
> Discerns those Truths our Senses can't descry.

During the next decade Baker published two volumes entitled "Medulla Poetarum Romanorum" and also a translation of Molière; but his name has been preserved from oblivion almost solely by his two volumes, "The Microscope Made Easy" and "Employment for the Microscope," which exploited the compound microscope.

For Many have been frightened from the Use of it, by imagining it required great Skill in Optics, and Abundance of other Learning to comprehend it to any Purpose: whereas nothing is really needful but good Glasses, good Eyes, a little Practice, and a common Understanding, to distinguish what is seen; and a Love of Truth, to give a faithful Account thereof. Others have considered it as a meer Play-thing, a Matter of Amusement and Fancy only, that raises our Wonder for a Moment, but is of no farther Service: which Mistake they have fallen into, from being unacquainted with any Principles whereby to form a right Judgment of what they see. Many, again, have laid the Microscope aside, after a little Use, for want of knowing what Objects to examine, where to find, how to prepare, and in what Manner to apply them. The trouble of managing it has also frighted some. . . .

The likeliest Method of discovering Truth, is, by the Experiments of Many upon the same Subject; and the most probable Way of engaging People in Such Experiments, is, by rendering them easy, intelligible, and pleasant. To effect this, is my Endeavor in the following Treatise. . . .[1]

"The Microscope Made Easy" was dedicated to the Royal Society and, receiving its imprimatur in 1742, was published by the famous London bookseller, Robert Dodsley.

Where Tully's bust and honour'd name
Point out the venal page,
There Dodsley consecrates to fame
The classics of his age.[2]

The book's popularity is attested by the fact that a second edition, with some additions, appeared the following year, and later editions, unchanged, in 1744, 1754, 1769, 1785, etc., not to mention the translations into foreign languages. The scope of the work is given *in extenso* on the title page (*cf.* Fig. 1).

The spirit of the eighteenth century which called forth Baker's volumes is well expressed in the Introduction:

In this inquisitive Age, when the Desire of Knowledge has spread itself far and wide, and we sit not down contented, as heretofore, with the Opinions of ancient Times, but resolve to examine for Ourselves, and judge from our own Experience; it may not, perhaps, prove unacceptable to point out some proper Subjects of Enquiry.

The Works of Nature are the only Source of true Knowledge, and the Study of them the most noble Employment of the Mind of Man. Every Part of the Creation demands his Attention, and proclaims the Power and Wisdom of its Almighty Author. The smallest Seed, the minutest Insect, shews the Skill of Providence in the Aptness of its Contrivance for the Purposes it is to serve, and displays an Elegance of Beauty beyond the utmost Stretch of Art.

The Wise in all Ages have been sensible of this Truth; and, as far as they were able, have studied and enquired into the Recesses of Nature; but for Want of proper Helps have frequently been mistaken. As certain Principles must first be learned ere we can become Masters of any Science, so in the School of Nature, we must begin with the *Minutiæ*, the smallest and most uncompounded Parts, ere we can understand the larger and more considerable. . . .

[1] "The Microscope Made Easy," Dedication.

[2] *London newspaper*, 1756.

That Man is certainly the happiest, who is able to find out the greatest Number of reasonable and useful Amusements, easily attainable and within his Power: and, if so, he that is delighted with the Works of Nature, and makes them his Study, must undoubtedly be happy; since every Animal, Flower, Fruit, or Insect, nay, almost every Particle of Matter, affords him an Entertainment. Such a Man never can feel his Time hang heavy on his Hands, or be weary of himself, for want of knowing how to employ his Thoughts: each Garden or Field is to him a Cabinet of Curiosities, every one of which he longs to examine fully; and he considers the whole Universe as a Magazine of Wonders, which infinite Ages are scarce sufficient to contemplate and admire enough. . . .

All these, and numberless Wonders more, the MICROSCOPE can exhibit to us. I shall therefore proceed to describe this noble Invention, shew how far it is improved at present, give a brief Account of what Discoveries have been made, and point out some Objects for the Curious to examine by it. In doing this, I shall avoid as much as possible all Affectation of Learning, or Expressions that are not in common Speech, being desirous that every body may understand me.

The author, then, in Part I. of the book, first describes and illustrates in succession the Single Microscope and a new invention for "giving Light to it by a Speculum," the Double Reflecting Microscope, the Solar or Camera Obscura Microscope and the Microscope for Opake Objects, and then devotes the remaining chapters to general microscopical technique, concluding with some sound advice:

Beware of determining and declaring your Opinion suddenly on any Object; for Imagination often gets the Start of Judgement, and makes People believe they see Things, which better Observations will convince them could not possibly be seen: therefore assert nothing till after repeated Experiments and Examinations, in all Lights, and in all Positions.

When you employ the Microscope, shake off all Prejudice, nor harbour any favourite Opinions; for, if you do, it is not unlikely Fancy will betray you into Error, and make you think you see what you would wish to see.

Remember, that Truth alone is the Matter you are in Search after; and if you have been mistaken, let no Vanity seduce you to persist in your Mistake.

Part II. of the work (*cf.* Fig. 1) is devoted to an account of microscopical discoveries and to "Pointing out many uncommon Subjects to the Enquiry of the Curious." The material presented is largely gleaned from the works of others, chiefly Leeuwenhoek, Swammerdam, Hooke, Power and Derham—to whose works he gives page references in every instance—but in addition he inserts many observations of his own, some new and some from his papers before the Royal Society, and also intersperses the whole with pertinent remarks in regard to the subject under immediate consideration. For example, in his account of blood:

I believe it will be allowed, that where one Person dies from a Dis-

THE

MICROSCOPE Made Eaſy:

OR,

I. The *Nature*, *Uſes*, and *Magnifying Powers* of the beſt Kinds of MICROSCOPES *Deſcribed*, *Calculated*, and *Explained*:

FOR THE

Inſtruction of ſuch, particularly, as deſire to ſearch into the WONDERS of the *Minute Creation*, tho' they are not acquainted with *Optics*.

Together with

Full Directions how to *prepare*, *apply*, *examine*, and *preſerve* all Sorts of OBJECTS, and proper Cautions to be obſerved in viewing them.

II. An Account of what ſurprizing *Diſcoveries* have been already made by the MICROSCOPE: With uſeful Reflections on them.

AND ALSO

A great Variety of new *Experiments* and *Obſervations*, pointing out many uncommon Subjects for the Examination of the CURIOUS.

By *HENRY BAKER*, Fellow of the *Royal Society*, and Member of the Society of *Antiquaries*, in *London*.

Illuſtrated with COPPER PLATES.

The SECOND EDITION: With an additional *Pllate* of the *Solar Microſcope*, and ſome farther Accounts of the POLYPE.

Rerum Naturæ nuſquam magis quàm in Minimis tota eſt.
PLIN. Nat. Hiſt. Lib. xi. c. 2.

LONDON:

Prnted for R. DODSLEY, at *Tully's Head* in *Pall-Mall*, and ſold by M. COOPER in *Pater-noſter-Row*, and J. CUFF, Optician, in *Fleetſtreet*. 1743.

FIG. 1.

EMPLOYMENT
FOR THE
MICROSCOPE.
In TWO PARTS.

I. An Examination of *Salts* and *Saline Subſtances*, their amazing *Configurations* and *Cryſtals*, as formed under the Eye of the *Obſerver*:

WITH

Plain Directions how to prepare ſuch Subſtances, and preſerve them in conſtant Readineſs for Inſpection; whereby the *Curious* may always be furniſhed with numberleſs Objects hitherto little known.

ALSO

Occaſional Conſiderations on *Gems*, *Poiſons*, the *Vegetation of Metals*, the *Reſuſcitation of Plants*, the *Formation of Amber*, *Corals*, and many other Subjects.

II. An Account of various ANIMALCULES never before deſcribed, and of many other *Microſcopical* DISCOVERIES:

With OBSERVATIONS and REMARKS.

LIKEWISE

A Deſcription of the MICROSCOPE uſed in theſe Experiments, and of a new *Micrometer* ſerving to ſhew the Size of magnified Objects.

Together with

Inſtructions for printing off any *Medal* or *Coin*.

Illuſtrated with Seventeen COPPER PLATES.

By *HENRY BAKER*, Fellow of the *Royal Society*, and Member of the Society of *Antiquaries* of *London*.

Rerum Natura nuſquam magis quàm in Minimis tota eſt.
PLIN. Hiſt. Nat. Lib. XI. cap. 2.

LONDON:

Printed for R. DODSLEY, at *Tully's-Head* in *Pall-mall*: and ſold by M. COOPER in *Pater noſter-Row*; and J. CUFF, Optician in *Fleet-ſtreet*. 1753.

FIG. 2.

order in the containing Vessels, twenty miscarry by some unnatural Alteration in the Fluids that pass through them: and therefore, if we can find what their natural State is, the Means whereby it may be preserved in such State, by what Accidents it may be prejudiced, and how it may be restored, our Pains will be well employed.

In order to obtain this useful Knowledge, it will be necessary to examine the human Blood and other Juices, frequently, with the *Microscope,* in every Condition, and under every Distemper, as well as in a State of Health: by which we shall have ocular Demonstration of its different Appearances in each State, and of the Changes it undergoes; and by Experiments of various Mixtures with it, may possibly discover by what Means it can be altered from one Condition to another. . . .

Would our learned Physicians, who are best able to judge of such Matter, be induced to take this Method into their Practice, it is reasonable to believe, that in a few Years the Causes of Diseases would be better known, and the Art of Healing brought to a much greater Certainty, than it is at present. . . .

Many Distempers might perhaps be cured by an immediate Admission of some Medicine into the Veins, which elude the Power of all that can be taken by the Mouth. For the Stomach, by its Heat, its Action, and a Mixture of its Juices, works such an Alteration in Things before they can be admitted into the Blood, that they are unable to produce the same Effects as if they were received into it simply and unchanged.

In the chapter on the generation of organisms he says that

Nothing seems now more contrary to Reason, than that *Chance* and *Nastiness* should give a Being to Uniformity, Regularity, and Beauty: that two such unlikely Principles should produce, in different Places, Millions of Vegetables of the same Kinds, and alike exactly, even in the most minute Particularities: or, what is yet more amazing, that dead *corrupting Matter,* and blind *uncertain Chance,* should create living Animals. . . . This, however, was the Opinion, not only of the Ignorant and Illiterate, but of the most learned grave Philosophers of preceding Ages; and would probably still have been taught and believed, had not *Microscopes* discovered the Manner how all these Things are generated. . . .

And, again, that

The Growth of Animals and Vegetables seems to be nothing else but a gradual Unfolding and Expansion of their Vessels, by a slow and progressive Insinuation of Fluids adapted to their Diameters; until, being stretched to the utmost Bounds appointed them by Providence at their Formation, they attain their State of Perfection, or, in other Words, arrive at their full Growth

—a view which called forth the verses from *The Universe* which were quoted on an earlier page.

The numerous illustrations which are grouped on 15 copper plates include, for example, good reproductions of Leeuwenhoek's original figure of *Hydra* from the *Philosophical Transactions,* and what is probably the first figure of a *Paramecium,* from an anonymous communication in the same publication.

Concordant with the custom of the time:

Before this Treatise is concluded, it will not perhaps be thought unprofitable to examine some of the finest and most exquisite Performances of human Art, and compare them with the Productions of Nature; as such a Comparison must tend towards humbling the Self-conceit and Pride of Man, by giving him a more reasonable and modest Opinion of himself; and at the same time may in some Degree conduce towards improving his imperfect Conceptions of the SUPREME CREATOR. . . .

The Use of the *Microscope* will naturally lead a thinking Mind to a Consideration of *Matter*, as fashioned into different Figures and Sizes, whether Animate or Inanimate: it will raise our Reflections from a Mite to a Whale, from a Grain of Sand to the Globe whereon we live; thence to the Sun and Planets; and, perhaps, onwards still to the fixt Stars and the revolving Orbs they enlighten, where we shall be lost amongst Suns and Worlds in the Immensity and Magnificence of Nature.

Although the proportion of Baker's own observations is relatively very small, the work is far from being merely an excellent compilation, as it is permeated throughout with the spirit of a man who is a constant, enthusiastic devotee of microscopic study and who is acquainted first hand with a large part of the material he is presenting.

The success of "The Microscope Made Easy" led Baker to publish ten years later his "Employment for the Microscope," which is practically a supplement to the second part of his first book—and after 1753 the two works were usually sold together under the title "Baker on the Microscope." This second volume is largely a compilation of Baker's own studies of animalcules from various sources and here we find a Suctorian figured for the first time, apparently *Podophrya quadripartita,* as well as a number of other hitherto undescribed organisms. Baker, like Joblot, makes an attempt to give more or less appropriate names to the various organisms which he describes but he does not apply a binomial nomenclature or classify them—Dr. John Hill, during the previous year, being the first to give animalcules definite Latin names (*e. g., Paramecium*) and to arrange them in groups, under the influence of the rapid advances in taxonomy at the time.

Although Baker's studies on microscopic organisms have been emphasized above, apparently he himself and the Royal Society were more pleased with his studies, presented at length in this volume, which he had been making

for above ten Years past, on a great variety of Saline Bodies, Mineral, Vegetable and Animal, as well as many other Substances, both simple and compound, whose Parts can be dissolved in Fluids, after a Method which has never hitherto been described by any Author, or practised before myself by any body that I have heard of. And tho' I have found their original Particles undiscoverable by any Microscope, the Time I hope has not been wholly misemployed; since I have been enabled, by the help of that

Instrument, to behold the amazing Order and Regularity, wherewith, after being separated by Dissolution, they come together and re-unite under the Eye, when put in Action by certain Degrees of Heat, in Configurations appropriated to each of them respectively, and with a Constancy that is surprising.[3]

The Experiments here described, and which the Reader is instructed to make, must I think generally entertain; but merely to entertain, is, I hope, the least of their Worth. They may possibly lead to the Knowledge of what passes in the Formation of Gems, and the most beautiful mineral Productions: And as every new Discovery is an Encouragement to farther Disquisition, the Hints here given may perhaps set abler Heads at Work to improve Art on the Principles of Nature. Examinations by the Microscope, in the Manner here directed, may likewise be employed to ascertain the Truth and Purity of many simple Substances and Compositions made use of in Medicine, and detect Fraud and Imposition.[4]

For this work Baker received the Copley Medal of the Royal Society for 1774 which was awarded "to whomsoever of the members shall be deemed to have produced the most extraordinary Discovery during the whole year."

The volume concludes with a chapter on "Miscellaneous Observations" which includes a section on the microscopes of Leeuwenhoek.

Though Mr. Leeuwenhoek's Microscopes are much talked of, very few People are acquainted with their Structure and Apparatus, no Figure of them that I remember having ever been made publick: 'tis therefore hoped the Curious will be pleased to see a Drawing of them, taken with great Exactness from those in the Repository of the *Royal Society*. . . .

Baker was apparently a congenial spirit and "Societarian," being for nearly thirty years one of the most active Fellows and frequent members of the Council of the Royal Society, a Fellow of the Antiquarian Society of London, and a founder and secretary of the Society for the Encouragement of Arts, Manufactures and Commerce. Martin Folkes, during his eleven-year presidency of the Royal Society, was on terms of considerable intimacy with Baker, being one of a small group of the Fellows who met now and then at Baker's home to consider matters philosophical. Folkes apparently had great confidence in Baker's skill with the microscope and frequently asked him to verify observations communicated to the Royal Society through the president.

It was in this capacity, for example, that Baker made his observations on the origin of "Eels in blighted wheat" (which Needham had communicated in his "New Microscopical Discoveries," London, 1745, and later advanced as support of the

[3] "Employment for the Microscope," Chapter I.

[4] *Ibid.*, Dedication.

An Attempt towards a

NATURAL HISTORY OF THE POLYPE:

In A LETTER To

Martin Folkes, *Esq*;

PRESIDENT of the *Royal Society*.

DESCRIBING

Their different Species; the Places where to seek and how to find them; their wonderful Production and Increase; the Form, Structure and Use of their several Parts; and the Manner they catch their Prey:

With an Account of their DISEASES and CURES; of their amazing REPRODUCTION after being cut in Pieces, (as first discovered by Mr. TREMBLEY, at the *Hague*;) of the best Methods to perform that Operation, and of the Time requisite to perfect the several Parts after being divided: And

Also full DIRECTIONS how to feed, clean, manage and preserve them at all Seasons of the Year.

Likewise a COURSE of real EXPERIMENTS, performed by cutting these Creatures in every Way that can be easily contrived: shewing the daily Progress of each Part towards becoming a perfect POLYPE.

The Whole explained every where by great Numbers of proper Figures, and intermixt throughout with Variety of OBSERVATIONS and EXPERIMENTS.

By *HENRY BAKER*, Fellow of the *Royal Society*, and Member of the Society of *Antiquaries*, in *London*.

Rerum Naturæ nusquam magis quàm in Minimis tota est.
PLIN. Nat. Hist. Lib. xi. c. 2.

LONDON:

Printed for R. DODSLEY, at *Tully's Head* in *Pall-Mall*, and sold by M. COOPER in *Pater-noster-Row*, and J. CUFF, Optician, in *Fleetstreet*. 1743.

(Price bound Four Shillings.

FIG. 3.

well-known "Buffon-Needham Theory") as well as his study of *Hydra* which he published in a volume of 222 pages under the title of "An Attempt towards a Natural History of the Polype: In a Letter to Martin Folkes, Esq; President of the Royal Society," London, 1743 (*cf.* Fig. 3).

> That curious Observer of Nature, Mr. LEEUWENHOEK, first took notice of this Animal, and the uncommon Way its young ones are produced, in the Year 1703 . . . but its more amazing Properties were reserved for the Inquisitive and happy Genius of Mr. TREMBLEY to discover, in the Year 1739 . . . observing it in some Respects to bear the Resemblance of a Plant, and in others of an Animal, he resolved, by cutting it in pieces, to satisfy himself, whether of the two it really was; and found, by this Trial, that, after a few Days, each Piece became a perfect Body, of the same Form exactly as *That* of which it had been only a Part: which Appearance would have determin'd him to conclude it to be a Vegetable, had he not discovered in it at the same time, a frequent Change of Figure, a Motion from place to place, a greedy and voracious Appetite, and a singular Dexterity in catching, mastering and devouring Insects and Worms. . . .
>
> In consequence of these Discoveries, he, ever since, has been making a Variety of such Experiments as none but his own fertile Invention would, probably, have contrived. These Experiments were performed in Sight of many of the Curious. . . . Some of these Creatures were likewise sent both to Mons. REAUMUR and YOU, lest any Difficulty of finding them, might prevent, discourage, or delay making the same Trials in *France*, or *England*, as himself had done at the *Hague*.[5]
>
> When Accounts of the extraordinary Properties of this Creature were communicated to you . . . it was never expected we should rest contented with their Accounts without making Experiments ourselves: *Nullius in Verba* being the wise Motto and establish'd Maxim of the ROYAL SOCIETY. But in respect to the Reputation of the ROYAL SOCIETY as well as to the Gentlemen who communicated these Discoveries, it became incumbent on us, as soon as they had sent the Insects over hither, to put them to a severe but speedy Trial, and from the Issue of our own Experience, either convince the World that these Gentlemen had been mistaken, or give our Testimony that what they affirm is true. This, SIR, was your opinion. . . .[6]
>
> YOU was, likewise, so obliging to favour me with three of your *Polypes*, very soon after their Arrival, with Intent that I should put them to the severest Test; and, to encourage and assist me in so doing, have frequently honoured me with your Company, and been yourself a Witness of my Proceedings.
>
> With these three *Polypes* I began my Experiments. . . . And I have gone on till this very Day repeating most of them several Times over, without finding any considerable Difference, but that of a much quicker Growth and Separation of the Parts cut to Pieces as the Weather became warmer. . . . Though it may not be improper to remark, that what by Divisions, Subdivisions, and the Creature's natural Increase, several hundreds have been produced by my first three, between *March* the twenty fifth, and the present fourth Day of *August*.

[5] "Natural History of the Polype," pp. 4–5.

[6] *Ibid.*, p. 201.

These, however, were not all the Polype I have had under my daily Care and Inspection: for . . . Mr. ELLICOTT, F.R.S. gave me six *English* Ones, and . . . seven or eight green Ones, . . . which have also increased considerably. And, in *July* last, you favoured me farther with some of the longarm'd Sort, just then arirved from Mons. TREMBLEY.

You, SIR, who know my Way of thinking, will not I am persuaded so far mistake me, as to imagine I am attempting, by this Essay, to vie either with yourself, or Mr. TREMBLEY; but it may not be improper to assure that Gentleman and the World, who are not so well acquainted with me, that I am as far from, as unequal to, such a Design; and that my real and only Motive to the many Experiments I have made, to the Care I have taken in propagating these Creatures, to the Readiness wherewith I have sent Numbers of them to *Oxford* and *Cambridge,* and dispersed them, as much as I have been able, amongst the Curious, and to this present Undertaking, has been to vindicate the Truth: which suffers sometimes for want of proper Means to prove it: and to display before Mankind, a new Instance of the amazing Power of the Creator.[7]

Thus the first book devoted to regeneration in animals appeared in England in 1743 and in a French translation in Paris in 1744, the same year that Trembley's famous "Mémoires pour servir à l'histoire d'un genre de Polypes d'eau douce" was issued at Leyden.

In view of the fact that Baker's work is not discussed in any, and the title of his book appears in the bibliography of only one of the recent volumes on regeneration, as a matter of record it seems worth while to give his list of experiments:

Experiment I. Cutting off a Polype's Head; II. Cutting a Polype in two Pieces, transversly; III. A Polype cut in three Pieces transversly; IV. Cutting the Head of a Polype in four Pieces; V. Cutting a Polype in two Parts, lengthways; VI. Cutting a young Polype in two Pieces whilst still hanging to its Parent; VII. Cutting a Polype lengthways through the Body, without dividing the Head; VIII. A Repetition of the foregoing Experiment, with different Success; IX. Cutting a Polype in two Places through the Head and Body, without dividing the Tail; X. Cutting off half a Polype's Tail; XI. Cutting a Polype transversely, not quite through; XII. Cutting a Polype obliquely not quite through; XIII. Slitting a Polype open, and cutting off the End of its Tail; XIV. Cutting a Polype with four young Ones hanging to it; XV. Quartering a Polype; XVI. Cutting a Polype in three Pieces the long way; XVII. An Attempt to turn a Polype, and the Event; XVIII. Turning a Polype inside out; XIX. An Attempt to make the divided Parts of different Polypes unite; XX. A speedy Reproduction of a new Head; XXI. A young Polype becoming its Parent's Head; XXII. A cut Polype producing a young One, but not repairing itself.

In regard to Experiment XVIII., a repetition of Trembley's famous one in which he believed that he had permanently turned a Polype inside out, Baker says:

Though I made several Trials before and since, I could never succeed

[7] *Ibid.*, pp. 6–10.

in turning *Polypes*, so well as in the above Experiment: which I impute to my Want of the Means Mr. TREMBLEY uses, as well as the Dexterity whereof he is Master: whose Account of his having turned many, and their living, thriving, and producing young Ones in that inverted State, I don't in the least doubt the Truth of. And when that Gentleman pleases to publish his own Method, which I should think myself unworthy of knowing if I endeavoured to take any of the Honour of it from him, most reasonable People, I believe, will be convinced.

The following extracts are from Baker's concluding remarks:

Having now, SIR, laid before you the most remarkable of my Experiments, in relation to the cutting *Polypes* asunder, and the Re-production of new Parts to make each Piece a perfect *Polype*; I shall entreat your Patience a little longer, whilst I add a few occasional Reflections. . . .

Though real Facts are incontestable Arguments, and no Reasoning seems necessary after so many repeated Experiments, there are certain Prepossessions, Prejudices and Humours among Mankind (arising from early imbibed Theories or Systems, according to which they have accustomed themselves to judge of Things) that make People sometimes disbelieve even what they see, are stronger than Reason, and will hardly be conquer'd even by the plainest Facts.

Hence it is that some have objected to the Reality of the *Polype's* being a living Creature, notwithstanding its moving from Place to Place, seizing its Prey, eating, digesting, and other Animal Functions: because its other Properties happen to be unsuitable to their Hypothesis of Life in general.

If the Animal Soul or Life, say they, be one indivisible Essence, all in all, and all in every Part, how comes it, in this Creature, to endure being divided forty or fifty Times, and still continue to exist and flourish?

Again: If animal Identity, say they, consists in Consciousness; and if every living Creature is sensible of Pleasure and Pain, or in other Words has a Consciousness, which most think a reasonable Supposition; when the *Polype* is divided into several Parts, all soon becoming perfect *Polypes*, where shall we find the Identity of the original *Polype*?

These Queries, I must acknowledge, I am wholly uncapable of resolving: but let those who tye themselves down to such Theories seriously consider, whether they believe themselves so perfectly acquainted with every living Creature God has made, and with all the Modes and Circumstances of the Life of each, as to be certain their Theories comprehend them all. 'Tis, methinks, a little presuming to restrain the Operations of Nature, or imagine that God has done nothing but according to certain Rules well known to us.

It is one great Part of Wisdom to know what we have Abilities for, and what Things are beyond our Power; that we may apply to the former, and avoid perplexing ourselves about the latter. How much valueable Time has been thrown away in framing whimsical unsatisfactory Schemes to account for the Operations of Nature, which might have furnished a great deal of profitable Knowledge, if spent in real Experiments on those self-same natural Operations?

When a Twig is cut off, and by planting in the Earth becomes a Tree of the Kind whereof it was a Part, can we account for its becoming so, any thing better than we can for the like Effect in a *Polype*? . . . The whole Difference is, we have known the One a long while, and the other is a late Discovery, which has not yet been noticed in our System of Animal Life. . . .

'Tis no great Wonder that Discoveries contrary to old and established Opinions should not at first be credited; but then, neither should they be absolutely rejected till Experiment has been made whether they are true or false.

Those that know the most, are most sensible how little they know in comparison of what is yet unknown, and therefore consider Things with Modesty and Candour: but Ignorance cries out at once, it cannot be:—inconsiderately measuring the Powers of Nature by the scanty Compass of its own Experience, and more ready to reject the Truth than take the Pains to find it out.—A truly wise Man is so fully sensible how little he knows, and what Things he once was ignorant of, which he is now acquainted with, that he is far enough from supposing his own Judgment a Standard of the Reality of Things.

Trembley's and Baker's demonstrations of the potentialities of the polype, reflected by Linnæus naming it *Hydra,* and Hill, *Biota,* on account of the "strong principle of life with which every part is endued," created considerable excitement in scientific, philosophical and literary circles. They apparently had forgotten that Aristotle observed that there are animals as well as plants which propagate themselves by shoots; and on cutting one of these animals, the pieces which before comprised altogether but one animal become suddenly so many distinct individuals. And further that the soul in animals is in effect but one, though "multiplied in its powers as in plants." Or that St. Augustine relates in his "De Quantitate Animæ" that a friend in his presence cut a 'polype' in two, and immediately the two parts betook themselves to flight in opposite directions![8]

Henry Baker's original observations undoubtedly do not entitle him to a place among the leading pioneers with the microscope—for most of his observations were made apparently at random without any particular purpose in view and none of his discoveries is of great significance—while some of them are not discoveries at all, as Hill,[9] in his animadversions on the Royal Society, takes especial pleasure in pointing out. But Baker's books, appearing at a time when the effects of the first glimpses into the "world of the infinitely little" were slowly permeating into general culture, had a considerable influence on the popularization of microscopic work and the general recognition of its practical value, as well as in stimulating microscopic research.

[8] Adams, "Essays on the Microscope," 2d edition, London, 1798.

[9] *Review of the Royal Society,* London, 1751.

"Baker on the Microscope" was something new—a product of the time—though, in a way, a descendant, with modifications, of Joblot's work on animalcules and microscopes[10] first published during the Leeuwenhoek period, and later reprinted with but slight change in 1754, when Baker's works were among the "best sellers." "Baker" was the humble forerunner within the limits of less than 800 octavo pages of our present-day manuals on bacteriology, protozoology and microbiology in general as well as of manuals on the microscope. Its success soon brought many competitors into the field, both in England and on the Continent—competitors such as the works by Adams which increased in bulk with each edition—but none of them approached it in originality of treatment, quaintness of expression, philosophical insight or the contagious enthusiasm of its author for things that are small.

"Baker on the Polype," the first volume ever devoted to regeneration in animals, gradually sank into oblivion on account of Trembley's classic memoir, but not without having exerted a considerable influence in England in stimulating experiments and speculations on life phenomena as "exhibited by that wonderful fresh-water insect the Polype."

> It has been said of Mr. Baker, that he was a Philosopher in little things. If it was intended by this language to lessen his reputation, there is no propriety in the stricture. . . . He was an intelligent, upright, benevolent man much respected by those who knew him best. His friends were the friends of Science and Virtue: and it will always be remembered by his contemporaries, that no one was more ready than himself to assist those with whom he was conversant, in their various researches and endeavors for the advancement of knowledge, and the benefit of Society.[11]

[10] "Descriptions et usages de plusieurs nouveaux microscopes, tant simples que composez; avec de nouvelles observations faites sur une multitude innombrable d'insectes, & d'autres animaux de diverses especes, qui naissent dans des liqueurs préparées, & dans celles que ne le sont point." Paris, 1718.

[11] Biographia Britanica, 2d edition, London, 1778.

ON THE HISTORY OF THE PROBLEM OF SEPARATING A NUMBER INTO ITS PRIME FACTORS

By Professor D. N. LEHMER

DEPARTMENT OF MATHEMATICS, UNIVERSITY OF CALIFORNIA

PERHAPS no other branch of mathematics offers to the non-mathematician so many inviting problems as the theory of numbers. The tools it employs are the simplest, and the methods of operation are familiar to every school-boy. It abounds in problems apparently of the greatest simplicity and really of such subtle make-up that they have baffled the efforts of the greatest mathematicians for centuries. There are many properties of numbers which we use daily, and which most of us are willing to take on experimental evidence, which would puzzle the untrained man to account for. What clerk has not used the method of "casting out the nines" to prove his computations—and how many clerks could give a valid reason for the check, and tell what are its limitations, or state the general law of which this is a special case?

Every carpenter has made use of the right triangle whose sides are 3, 4 and 5 with which to lay off a right angle. No doubt this was the practical method of constructing a right angle in the days of the pyramid builders. He would be a stupid carpenter who would never inquire if other triangles of that sort were not obtainable. He might easily find that others were to be had by multiplying the sides of this triangle by any number, but the question would still confront him as to the existence of other such triangles with sides having no common divisor. By experiment, which enters more into the investigation of problems of this sort than many imagine, he would perhaps hit upon the triangle 5, 12, 13, and then upon the triangle 8, 15, 17. He might then, for his own amusement, undertake to make a list of these triangles, arranging them in order according to the magnitude of the largest side. He would be rewarded first of all by the interesting discovery that sometimes two different triangles may have the same hypothenuse! such as 39, 52, 65 and 25, 60, 65. If he were of a statistical turn of mind he might discover that the number of triangles in his list increased with remarkable regularity with the magnitude of the largest side. The number of triangles with largest side less than N is roughly proportioned to N. At this point in his career he may apply for help to some well-equipped specialist in the theory of numbers, and the result may be that a good carpenter is spoiled to make a trifling mathematician. One such experimenter, to my knowledge, pushed the investigation through till he found that the number of triangles with sides not greater than N is approximately $N/2\pi$ where π is the number 3.1415926 . . . which represents the ratio of the circumference of a circle to its diameter.

But of all the problems that lure the man of the street into the halls of useless but fascinating research none seems to appeal with more potent call than the problem of separating a given number into its prime factors. It is so easy to multiply two numbers together, and so hard to find them again when they have been welded into one! A multiplying machine will furnish the product of two eight-digit numbers in a few minutes. With all the resources of the theory of numbers at my disposal, I have spent I am ashamed to say how many hours in trying to determine whether the number 403,978,495,031 is a prime or not, and the question is still open. Why should I be interested, you ask, in such a problem? The answer to that question is that experimental work in another field is stopped till this vexing matter is settled. The problem of finding the factors of a given number is not only interesting in itself, but is vital for the investigator in many other researches, particularly in the theory of groups.

Perhaps some notion of the immense antiquity of this problem may be gained by observing that it is a problem that freguently suggests itself to children of ten or twelve years of age. When the progress of civilization in any tribe was such that the most thoughtful members were capable of the intellectual effort of a modern boy of fifteen the problem might likely arise. It might easily have attracted the attention of the cave man that six pebbles could be arranged in two ways; ...... and :::, while only one such arrangement could be found for five or seven pebbles. The discovery of the three ways of grouping twelve pebbles must have been as exciting and mystifying to the original researcher as the discovery of the first magic square. No doubt the number twelve gained considerable respect from this mystic property. The number six later enjoyed great prestige, because it was found that the sum of its divisors 1, 2 and 3 is equal to six! Pythagoras is said to have venerated the number 6 on account of the "integrity of its parts and the agreement existing in it," calling it marriage and health and beauty! According to the early Christians, God created the earth in six days rather than in one because of the perfection of the number six. The entire human race sprang from the eight souls in Noah's Ark, and, as 8 is not so perfect as 6, we have been living under a disadvantage ever since!

Little is known of the assaults of the ancients on our problem. Their clumsy notation would have lent them little aid in their fight. It was a learned man that could perform a simple division even as late as the thirteenth century. Men like Archimedes were needed to get an approximation to a square root. Practical computation was done on the fingers or on the abacus, and perhaps the notation was of little more use than as a means of recording results. Nevertheless, it would be wrong to assume that previous to the invention of the modern method of denoting numbers mankind was not in possession of some of the most beautiful theorems concerning the properties of numbers. Thus Euclid gives a proof of the infinite number of primes, a proof which is found in almost every treatise on numbers to this day; and his process of finding the greatest common divisor, and his formula for perfect numbers are familiar to every student of this subject.

The first practical contribution to the problem of finding the factors of a number comes from another Greek, Eratosthenes, who lived some time in the second or third century B.C. He seems to have been a man of the greatest versatility, and has left his imprint on many different pages of science. He was librarian at the university of Alexandria, and was noted for his athletic achievements as well as for his literary interests. He devised the calendar in which every fourth year is 366 days long. He measured the length of a degree on the earth's surface and got a good approximation for the radius of the earth. In connection with our problem he invented the so-called "sieve" method which is the basis of construction of all the great factor-tables constructed since his day.

The sieve of Eratosthenes is constructed on the following observation: Every other number after 2 is divisible by 2; every third after 3 is divisible by 3; every fifth after 5 is divisible by 5 and so on. If then we write down the successive numbers in a row and erase every other number beginning with 4, and every third number beginning with 9, and every fifth number beginning with 25; and every seventh number beginning with 49, and so on, we shall have in the remaining numbers a list of successive primes. If instead of erasing the numbers we write over every other number beginning with 4 the factor 2, over every third number beginning with 9 the factor 3 we shall have for each number its decomposition into prime factors. The process requires no computation, and may be carried out by measurement alone.

Now the writing of a million numbers in a row turns out to be a somewhat tedious undertaking. Moreover, we are not much interested in finding the factors of the even numbers nor of the multiples of 5. If now we group the numbers in lines of ten thus

1,	2,	3,	4,	5,	6,	7,	8,	9,	10
11,	12,	13,	14,	15,	16,	17,	18,	19,	20
21,	22,	23,	24,	25,	26,	27,	28,	29,	30

we see that all the even numbers lie in the same columns and that the same is true of the multiples of 5. We then omit these columns altogether, thus cutting out sixty per cent. of the numbers in our list. This method of shortening the table of factors seems not to have been used till about the middle of the seventeenth century, when Rahn,[1] or Rhonius, gave such a table extending to 24,000, shortly afterwards extended to 100,000 by Thomas Brancker.[2] The tables preceding Rahn's tables were of a very insignificant sort. Thus Leonardo Pisano[3] in 1202 gave a list of the primes from 11 to 97, and the factors of the composite numbers from 12 to 100. Cataldi[4] in 1603 gave a table extending to 800 and Van Schooten[5] (1657) gave a list of primes to 9979.

It was later discovered that the multiples of 3 could be omitted from the table without very great complication. If we group our list of numbers in lines of thirty we see that the multiples of 2, 3 and 5 all appear in certain columns. Omitting those columns, our list of numbers appears thus:

1,	7,	11,	13,	17,	19,	23,	29
31,	37,	41,	43,	47,	49,	53,	59
61,	67,	71,	73,	77,	79,	83,	89

With the table arranged in this way it is easy to show that if a factor p appears in any place it will also appear in that same column p lines farther down. Eratosthenes's sieve method may then be applied to each column, or better by means of a

[1] Rahn, "Algebra," Zurich, 1659.

[2] Brancker, "An Introduction to Algebra," translated out of the High-Dutch [of Rahn's "Algebra"] into English by Thomas Brancker, 1668.

[3] Pisano, "Il Liber Abici di L. Pisano," 1202, revised 1228.

[4] Cataldi, "Trattato de' numeri perfetti," Bologna, 1603.

[5] van Schooten, "Exercitat. Math.," Leiden, 1657.

stencil to all the columns at once, to find the multiples of p. A table in which the multiples of 2, 3 and 5 were omitted was first published in 1728 by Poetius.[6] The invention of the stencil method is to be credited to C. F. Hindenburg,[7] 1776. That same year was published Felkel's[8] table in which the multiples of 2, 3 and 5 were omitted, the extent of the table being 408,000. Felkel made use of the device of designating the numbers by means of letters for the sake of saving space. The manuscript extended to two millions, but the sale was so meager that the entire edition was made into cartridges to use against the Turk. Only a few copies were saved.

In the early nineteenth century, responding to the urgent appeals of men like Gauss and others who were interested in verifying certain curious laws just discovered relating to the distribution of primes, there appeared the great table of Chernac[9] (1811) giving all the prime factors of all numbers not divisible by 2, 3 or 5 up to 1,020,000 containing 1,020 pages. The bulk of a factor table becomes a serious matter when a limit of several million is contemplated. It occurred to Burckhardt[10] that it is sufficient to know the smallest divisor, as the others may be obtained from the quotient. Burckhardt published such a table of the first three millions. Tables modeled after Burckhardt's were afterward published for the 4th, 5th and 6th million by Glaisher,[11] and for the 7th, 8th and 9th, by Dase.[12] The factor tables computed by myself[13] and published by the Carnegie Institution of Washington omit the multiples of 2, 3, 5 and 7 and carry the work up to the limit 10,000,000 (1909). A list of primes based on this factor table was published in 1914.

It should be stated that manuscript tables of factors were computed by a Bohemian named Kulik[14] up to the extraordinary

[6] Poetius, "Anleitung zu der Arith. Wissenschaft vermittelst einer parallel Algebra," 1728.

[7] Hindenberg, "Beschreibung einer ganz neuen Art," Leipzig, 1776.

[8] Felkel, "Tabula omnium factorum simplicium numerorum," 1776.

[9] Chernac, "Cribrum Arithmeticum," 1811.

[10] Burckhardt, "Tables des diviseurs," Paris, 1817, 1814, 1818 (for the respective three millions).

[11] Glaisher, "Factor Tables for the Fourth, Fifth and Sixth Millions," London, 1879, 1880, 1883.

[12] Dase, "Factoren-Tafeln für alle Zahlen der siebenten (1862) der achten (1863) der neunten (1865) Million," Hamburg.

[13] Lehmer, "Factor Table for the First Ten Millions," Carnegie Institution of Washington, 1909.

[14] Kulik. An account of Kulik's table will be found in the introduction to my list of primes. Carnegie Institution of Washington, 1914.

limit of 100 million! They were never published, and are at present, with the exception of one volume which has disappeared, in the library of the Royal Academy at Vienna. The tenth million of this colossal work I examined with great care in comparing it with my own computations and found some 226 errors in this one million. The great work is not accurate enough to warrant publication, but is of the greatest value for purposes of checking. He also represents the prime factors by means of letters, which makes it a little difficult to compare his table with others.

So much for factor-tables and lists of primes. We are still fairly helpless in the presence of a number that exceeds the limit of our tables, but there are certain schemes which avail to shorten the labor of decomposing a number into its factors which are of considerable service, particularly for numbers of certain kinds.

In 1643 Fermat[15] wrote to his friend Mersenne concerning the number 100,895,598,169: "You ask me whether this number is prime or not, and for a method for finding in one day's time whether it is prime or composite. I reply that it is composite and is the product of 898,423 and 112,303." Now this number happens to be associated with certain numbers of the form $2^n - 1$, the factors of which belong, as Fermat was the first to discover, to certain particular arithmetical progressions. If n is prime the factors of $2^n - 1$ are all equal to one plus a multiple of n. Naturally this wonderful theorem relieves one of the necessity of trying as divisors the greater part of the primes less than the square root of the number. Thus the number $2^{11} - 1 = 2047$ can have factors of the form $22n + 1$, so that the only factors we need try are 23 and 45, and the last being composite is also ruled out. By trial 23 is found to be a factor and $2047 = 23 \times 89$. This discovery of Fermat's has delivered into our hands our largest known primes. The largest one known at the present time is, I believe, $2^{127} - 1$, a number of 39 digits examined by Lucas in 1877.

The great Fermat[16] also invented a method of finding factors when nothing is known of the form of the factors which is very effective when the two factors do not differ very greatly from each other. If a square number can be found which when added to the given number produces a square then the given number is at once reduced to the difference of two squares and is the product of the sum and difference of two numbers. Fer-

[15] Fermat, "Œuvres," Tome 2, p. 255.

[16] Fermat, "Œuvres," Tome 2, p. 257.

mat gives the example 2,027,651,281, which he finds by a few trials to be the difference of the two squares 45041^2 and 1020^2. But the difference of these two squares is equal to the product of their sum 46061 by their difference 44021. Fermat was in possession of devices for shortening the labor of finding the two squares, but even with every such device and the help of computing machines, which adapt themselves very well to this method, the process may lead one an interminable chase in finding the factors of some numbers.

A more effective method depends on the theory of quadratic residues, the underlying principles of which may be made clear in a few words. If a number x can be found such that $x^2 - D$ is divisible by a number m then D is said to be a *quadratic residue* of m. D and m are supposed prime to each other. Such a number x is not always obtainable, and if none is to be found D is said to be a *quadratic non-residue* of m. From the definition it follows that if D is a quadratic residue of m it is a quadratic residue of every factor of m, for surely if an x exists such that $x^2 - 1$ is divisible by m then for that same value of x we shall have $x^2 - D$ divisible by every factor of m. The importance of this simple remark arises when we find that the numbers m which have a given D for quadratic residue all fall into certain arithmetical progressions. Thus those numbers which have 2 for a quadratic residue are all multiples of eight plus or minus unity. Those which have 3 for a quadratic residue are all multiples of twelve plus or minus unity, etc. If then it is known by any means that 2 and 3 are residues of a number we know that not only the number itself, but every odd factor of it, belongs to both of these series of numbers, and consequently belongs to the series 1, 25, 49, 73, 97, . . . or to the series 23, 47, 71, 95, . . . or, as we say, is of the form $24n + 1$. This knowledge enables us then to omit from our list of trial divisors all primes which do not fall in these series and the process of searching for factors is notably shortened.

It will at once be observed that the difficulty has only been shifted from one corner to another, and we are still confronted with the serious problem how to obtain quadratic residues small enough to be of service in this connection, for it should be observed that for larger quadratic residues the number of series is increased. Various devices have been invented for finding directly suitable quadratic residues, the best of which seems to be a by-product of the theory of continued fractions. Another is based on the theory of binary quadratic forms. All of these methods have been in use for over a century, and are to be found in the works of Euler[17] and Legendre.[18] Where nothing is known of the form of the factors of the number these methods are perhaps the most powerful in our possession.

As the matter stands, then, we are complete masters of the situation for numbers up to ten millions, having reliable tables extending so far. There are photographic copies in this country of Kulik's table for the eleventh million, of which I have one. His second volume running from 12,642,600 to 22,852,800 is lost. The remaining volumes carry the table up to a limit of 100,330,201. In spite of their inaccuracy they are of the greatest value for comparison. For numbers beyond the limits of the available tables modern methods can be applied with fair hopes of success up to a limit, perhaps, of a billion. Beyond that limit, except for numbers of special form, the task of finding factors may well daunt the most intrepid of computers. The problem will always confront the human race. The invention of new methods may push off the limits of the unknown a little farther, just as the invention of a new astronomical instrument may push off a little the boundaries of the physical universe; but the unknown regions are infinite, and if we could come back a thousand years from now we should no doubt find workers in the theory of numbers announcing in the journals new schemes and new processes for the resolution of a given number into its factors.[19]

[17] Euler, "Nova Acta Petrop," 13, 1795–6.

[18] Legendre, "Theorie Des Nombres," 1798, pp. 313–320. A more complete bibliography will be found in the forthcoming "History of the Theory of Numbers," by L. E. Dickson, from which many of the above references are obtained.

[19] Since writing the above I have found the number 403,978,495,031 is equal to 6,151 × 65,676,881, both factors being primes. By expanding the square root of the number in a continued fraction it was found that the following numbers were quadratic residues: 2, 5, 7, —13, —17, 23, —29, 31, 43. This knowledge enabled me to reduce the number of trials to fifty-five. If the number had been a prime I should have had some seventy-five trials to make instead of over fifty-one thousand to determine the fact. The number is the denominator of the twenty-ninth convergent to the base of Naperian logarithms when that base is expanded in a regular continued fraction.

PLANT PATHOLOGY TO-DAY

C. L. SHEAR and NEIL E. STEVENS

BUREAU OF PLANT INDUSTRY

THAT plant pathology in America has passed through its pioneer period and is now entering on a period of increased activity, broader scope, and greater usefulness is evident to all who have followed its recent development. In the words of Galloway,[1] who was one of the early workers and who has been closely associated with the growth of phytopathology in this country for the past thirty years, "For nearly a quarter of a century the study of plant pathology in this country was without very broad or definite aim or object." The condition described was due largely to the fact that the development of the subject in this country has been largely determined by economic and political conditions and demands rather than by any well-conceived and directed plans of the plant pathologists.

Plant pathology as a special subject of study and investigation in this country was taken up chiefly by the United States Department of Agriculture and the state experiment stations. At that time the work was necessarily restricted, the available knowledge of the subject small, the demands for immediate practical results large and the workers few. Notwithstanding these restrictions and the imperative demands for immediate results, many important discoveries of fundamental value were made, for example, the discovery that bacteria[2] caused plant disease and that the bacteria may be carried by insects.[3]

This was distinctively the utilitarian period in the development of the subject. During this economic or utilitarian period much time was necessarily devoted to spraying experiments, describing and cataloging pathogens and other fungi, and laying the foundation for more thorough and fundamental re-

[1] Galloway, Beverly T., "Some of the Broader Phytopathological Problems in their Relation to Foreign Seed and Plant Introduction," *Phytopathology*, 8: 87–97, 1918.

[2] Burrill, T. J., "Report on Botany and Vegetable Physiology—Pear-blight," *Trans. Ill. State Hort. Soc.*, N. S., 11: 114, 1877, and 12: 80, 1878; Arthur, J. C., "Proof that Bacteria are the Direct Cause of the Disease known as Pear Blight," *Bot. Gaz.*, 10: 343–345, 1885.

[3] Waite, M. B., "Results from Recent Investigations in Pear Blight," *Bot. Gaz.*, 16: 259, 1891.

searches. The demands for immediate practical results and the application of pathological knowledge have continually tended to exceed the output of the necessary fundamental research and exact knowledge and have tended to encourage superficial work and the drawing of conclusions from too little evidence. The great demand for men and for practical applications of the science has also tended to encourage hasty preparation and insufficient training. The notable achievements in the field during the period have been due to the importance of the problems attacked, and to the skill of the individual investigators rather than to definite and coordinated plans of work. So striking indeed were the discoveries of the earlier pathological investigators in this country, and so important their results in the control of plant diseases that recent workers have tended too generally to follow the lines laid down by their predecessors, lines which had proven profitable in the past and give promise of results of more or less importance in the future.

In part then as a result of notable successes in certain directions and in part for economic and political reasons, the plant pathologist has had a rather restricted field of activity, not only as to the area in which he worked and as to the host plants investigated, but in particular as to methods of work and as to the aim and subject-matter of his studies.

The geographic limitations of the work were particularly unfortunate in that they were not the natural limitations of crop or climate, but the artificial ones of state and national boundaries. There was also a lack of cooperation and coordination of work. Pathologists in adjacent states investigated related problems with too little interchange of views. Foreign visits and studies have been too few and too short and have not been followed by sufficient work at home, as is indicated by the fact that there has been but little publication on the work of American pathologists in foreign countries. In this hemisphere tropical pathology has been, when the agricultural importance of the regions is considered, all but neglected.

It is natural and desirable that the study of plant pathology should be centered on plants of great economic importance. Scientifically and in the long run economically it would be of great value if the diseases of wild plants could be thoroughly investigated, especially those closely related to important cultivated plants.

Equally restricted have been the lines of attack followed when a new disease was to be studied or a familiar one attacked in a new area. To find a plant or plant part with evident abnormalities, to describe the condition, to isolate an organism from the affected parts, to grow this organism in pure culture and describe it, to produce an abnormal condition by inoculation with this organism and to prevent or reduce the abundance of the disease by spraying, these things were usually considered sufficient.

The field of the plant pathologist has been largely limited to the production phases of the important crops he has chosen for his work. By seed treatment and by spraying, by crop rotation and soil treatment, he has assisted the farmer in producing a crop and there he has stopped. The student of apple diseases, for instance, has taken his results and ceased his work when the crop was harvested, leaving the study of the important and far-reaching changes between field and consumer largely to the pomologist, the commercial cold-storage man, the retail grocer and the board of health. Forest pathology fortunately has never been thus limited in its outlook; following the able example of Hartig,[4] the study of the diseases of structural timber and the methods of its preservation have been considered as truly a part of forest pathology as the study of leaf spots and other parasitic diseases.

In addition to these self-imposed restrictions there have also been in some cases the additional restrictions of administrative organization. Phytopathological problems were first attacked from the standpoint of the parasites producing diseases. This led to devoting the greater part of the time and effort of the investigator to the parasite, with a resulting neglect of the host and its very important relations. It also led in many cases to the idea that plant pathology included only troubles caused by "germs" or parasites instead of all abnormal physiological conditions by whatever cause induced.

Recognizing that this method of handling the subject was not an entirely satisfactory one, work was organized and divided largely on the basis of the economic host plants involved. This division of the subject has many disadvantages from a strictly scientific standpoint. In the case of parasites attacking several hosts it is necessary to study them in their relations to all their hosts in order to fully understand them and determine their relationships and pathogenic characteristics and to most effectively devise methods of control.

The most recent attempt at the classification of the subject

[4] Hartig, R., "Die Zersetzungserscheinungen des Holzes der Nadelholzbaume und der Eiche," Berlin, 1878.

is according to the physiological effects upon the host. This has much to be said for it, but it also has its limitations.

The ideal method of attacking a pathological problem depends upon the nature of the specific case and should be interfered with as little as possible by system of classification or administrative arrangement. If it be a disease caused by a fungus the life history, relationship and physiological characteristics of the parasite must be studied, also the host reactions and relations under various environments. If the causal organism is found to attack other hosts it should be studied in its relation to these hosts also, whether they happen to be fruits, or vegetables or forest trees.

As a result of these limitations of the field, largely self-imposed by the pathologist, some of the most striking and valuable recent contributions to the science have been made by investigators who were not professionally, at least, plant pathologists. The work of Morse[5] on the cause and nature of the deterioration of asparagus after cutting, the researches of Allard[6] on the mosaic diseases of tobacco, the control of blue mold on oranges by Powell,[7] and of lettuce drop by Ramsey and Markell,[8] and the discovery by Meyer[9] that the chestnut bark disease was native in China and Japan are cases in point.[10]

During the past decade, marked by the establishment of departments of plant pathology in some of our universities and the organization of the American Phytopathological Society, with its journal, "Phytopathology," there has been a marked change in the attitude of plant pathologists toward their work. Recent epidemics of diseases introduced from foreign countries have emphasized and attracted attention to the very important

[5] Morse, F. W., "Experiments in Keeping Asparagus after Cutting," Mass. Agricultural Experiment Station Bull. 172, March, 1917.

[6] Allard, H. A., "Some Properties of the Virus of the Mosaic Disease of Tobacco," *Jour. Agri. Res.*, 6: 649–674, July, 1916. (And other papers in the same journal.)

[7] Powell, G. H., "The Decay of Oranges while in Transit from California," Bu. Plant Ind. Bull. 123: 1–75, 1908.

[8] Ramsey, H. J., and Markell, E. L., "The Handling and Precooling of Florida Lettuce and Celery," Bu. Plant Ind. Bull. 601, 1917.

[9] Fairchild, D. G., "The Discovery of the Chestnut Bark Disease in China," *Science*, N. S., 38: 297–299, 1913.

Shear, C. L., and Stevens, Neil E., "The Discovery of the Chestnut-blight Parasite (*Endothia parasitica*) and Other Chestnut Fungi in Japan," *Science*, N. S., 43: 173–176, 1916.

[10] Throughout this paper no attempt is made at full citations of literature. The papers mentioned are merely by way of illustration. Further examples will occur to any one familiar with the subjects and would be useless to others.

international and cosmopolitan aspects of the subject and the need of a greater knowledge and better provisions to prevent the introduction of new parasites and diseases into this country. A greater breadth of view and to some extent a new spirit are apparent. There is evidence on the one hand that plant pathologists are realizing the obligation laid upon them to extend their studies to wider fields of activity and service and on the other hand there is a new spirit of cooperation among pathologists and students in closely related fields of research.

A Wider Field

In the present awakening of phytopathologists to the real importance and extent of their field most of the self-imposed restrictions are disappearing. Investigators supported by state and federal funds still confine their attention chiefly to single areas, but cooperative effort has widened until we find the pathologists of Massachusetts joining with those of California in the study of a disease of cauliflower[11] and Faucett[12] is able to publish a comparative study of the citrus diseases found in California, Florida and the West Indies. A genuine international Phytopathology[13] was well under way when interrupted by the present war and we find Galloway (I, p. 90) stating as the first of the fundamentals of a new phase of plant pathology, "The work is international."

While pathological research is still confined largely to cultivated plants of economic importance, attention is being given at least to the diseases of newly introduced plants (I), especially to plants of potential economic importance. Work of this type is Harter's[14] study of the storage rot of the dasheen. Scientific data of the greatest future importance will be accumulated if accurate records are preserved of the changing pathological relations of a plant during the period it is being brought under cultivation and its area of cultivation is being extended. No better present opportunity offers than a study of the diseases

[11] Further illustrations of this type of cooperation may be found in Allen, E. W., Wilcox, E. V., Schulte, J. I., "Work and Expenditures of the Agricultural Experiment Stations," 1916, Part I., pp. 18 and 19, Washington, 1918.

[12] Fawcett, H. S., "Citrus Diseases of Florida and Cuba compared with those of California," University of California Publications, Bull. 262, 1915.

[13] Shear, C. L., "Some Observations on Phytopathological Problems in Europe and America," *Phytopathology*, 3: 77–87, 1913.

[14] Harter, L. L., "Storage-rots of Economic Aroids," *Jour. Agri. Res.*, 6: 549–571, 1916.

of the blueberry, now chiefly a wild plant, but already under cultivation and bidding fair to be of considerable economic importance.[15]

As the range of host plants investigated is being widened, so also are the phases of pathology which are being studied. The varied lines of attack on plant-disease problems evidenced in recent publications indicate that plant pathology now includes a wider range of interest than ever before. The chemical changes produced in the host by fungus parasites,[16] oxidation in healthy as compared with diseased plant tissue,[17] the relations between climate and disease,[18] the importance of birds[19] and insects as disseminators of fungus spores,[20] and even the relation between the diseases of plants and those of man,[21] are being investigated.

In particular there is evidence that pathologists are no longer restricting their investigations to production problems. Brooks and Cooley[22] are studying the diseases of apples in storage. The importance of plant pathology in its relation to the loss of perishable fruits and vegetables in transit has been recognized.[23] The somewhat artificial and arbitrary boundaries

[15] Coville, F. V., "Directions for Blueberry Culture," U. S. D. A. Bull. 334 (Professional Paper), 1915.

[16] Hawkins, Lon. A., "Effect of Certain Species of *Fusarium* on the Composition of the Potato Tuber," *Jour. Agri. Res.*, 6: 183–196, 1916. (And earlier papers cited therein.)

[17] Rose, D. H., "Oxidation in Healthy and Diseased Apple Bark," *Bot. Gaz.*, 60: 55–65, 1915.

[18] Stevens, Neil E., "Temperature of the Cranberry Regions of the United States in Relation to the Growth of Certain Fungi," *Jour. Agri. Res.*, 11: 521–529, 1917. (And earlier papers cited.)

[19] Heald, F. D., and Studhalter, R. A., "Preliminary Note on Birds as Carriers of the Chestnut Blight Fungus," *Science*, N. S., 38: 278–280, 1913.

[20] Gloyer, W. O., and Fulton, B. B., "Tree Crickets as Carriers of *Leptosphæria coniothyrium* (Fckl.) Sacc. and Other Fungi," New York (Geneva) Agri. Exp. Sta. Technical Bull. No. 50, 1916.

Gravatt, G. F., and Posey, G. B., "Gipsy-moth Larvæ as Agents in the Dissemination of the White-pine Blister-rust," *Jour. Agri. Res.*, 12: 459–462, 1918.

[21] Smith, Erwin F., "Studies on the Crown Gall of Plants; its Relation to Human Cancer," *Jour. Cancer Research*, 1: 231–258, pls. 1–25, 1916.

[22] Brooks, Charles, and Cooley, J. S., "Temperature Relations of Apple-rot Fungi," *Jour. Agri. Res.*, 8: 139–164, 1917 (and subsequent papers in the same journal).

[23] Coons, G. H., and Nelson, Ray, "The Plant Diseases of Importance in the Transportation of Fruits and Vegetables," Circular 473-A American Railway Perishable Freight Association. Chicago, February, 1918.

Shear, C. L., "Pathological Problems in the Distribution of Perishable Plant Products." Memoirs Brooklyn Bot. Gard., 1: 415–422, pls. ix–xi, 1918.

of the pathologist's work have hindered their entering this important field. Credit is due the pomologists for first attacking the problem of the losses occurring in handling and transportation. Many pathological questions, however, are involved in this work, and a thorough knowledge of the fungi concerned, as well as of the abnormal physiology of the plant products under different conditions, must be obtained. A significant incident in this connection was the appointment in 1917 of a plant pathologist by the Illinois Central Railway. Almost simultaneous and of equal significance in a quite different field was the appointment of a plant pathologist by the American Smelting and Refining Company.

On the establishment of the Food Products Inspection Service by the Bureau of Markets,[24] the chief of that bureau, Mr. Charles J. Brand, requested the detail of plant pathologists to assist in the work. Pathologists were quick to realize their opportunity and have been active in assisting in the work since its establishment.[25] Partly as a result of this, and partly as a result of the world food shortage which called attention sharply to the fact that, at a conservative estimate, thirty million dollars worth of fruits and vegetables are annually lost between field and consumer in this country, the study of diseases of fruits and vegetables in the market is already assuming importance. The phytopathology of the future will not stop when the crops have been harvested, but will extend until the food products are eaten.

There is another source of encouragement for pathologists in the fact that there is a rapidly growing appreciation of the scope and value of their work on the part of the general public and the agencies which provide the financial support for their work. In this connection there is need of greater publicity among city residents and consumers. They should know something of the scope, purpose and practical utility of plant pathology and its intimate connection with their food problems. Millions of dollars, worth of perishable plant foods are destroyed each year in city homes because of lack of appreciation of some of the simplest principles of plant pathology.

[24] Service and regulatory announcements No. 28. Bureau of Markets, U. S. Department of Agriculture. Issued October 31, 1917.

[25] Shear, C. L., "Pathological Aspects of the Federal Fruit and Vegetable Inspection Service," *Phytopathology*, 8: 155–160, 1918.

Team Work

There is no single characteristic by which the new plant pathology is and will be better distinguished than that of team work among investigators. The magnitude of the problems and the angles from which they must be attacked place them out of the reach of a single investigator. We may confidently expect organized "teams" to attack pathological problems in the future; not a group of assistants around a single leader but investigators of training and recognized ability in different lines, each of whom will attack the problem from his own point of view, finally coordinating and combining the results. Such an organization was temporarily formed in the study of the chestnut bark disease.[26] In this case foresters, mycologists, plant physiologists, entomologists and geologists united in attacking a single problem.

A striking example of what may be accomplished by team work is furnished by the workers in Blackman's laboratory who,[27] attacking a problem of great scientific interest from several angles, have contributed notably to our knowledge of the physiology of parasites. In the future we may expect to find mycologists, plant physiologists, and ecologists uniting with chemists, plant breeders, refrigeration experts, entomologists, horticulturists and meteorologists in the solution of problems of plant pathology. With this will go the freest and frankest interchange of ideas among plant pathologists themselves.

Pathologists are coming to realize that cooperation and coordination must be the watchwords of plant pathology as they are coming to be the watchwords in every line of human activity and endeavor. Any one familiar with pathological problems as they present themselves to-day can not fail to realize that no individual however broad his training, or whatever the time and facilities at his disposal, can hope to solve unaided the larger problems now needing attention.

The old idea which has been too prevalent in the past, that the individual investigator may by discovery, preemption or any other means acquire property rights in a scientific problem which will prevent any one else from attacking it, is being abandoned. The advancement of science and the benefit of mankind should be the primary aim and purpose of the pathologist. We are coming to realize that the end is more important

[26] The Publications of the Pennsylvania Chestnut Tree Blight Commission, Harrisburg, Pa., 1915.

[27] Brown, William, "On the Physiology of Parasitism," *New Phytologist*, 16: 109–127, 1917.

than any individual credit, honor or distinction. The all-important question is, how can the problems be solved in the quickest and most effective manner and the results be made most readily available.

Perhaps the most typical manifestation of the new spirit of cooperation is the creation by the American Phytopathological Society of the War Emergency Board of American Pathologists.[28] This board, made up of representative pathologists from different parts of the United States, is effectively engaged in uniting the efforts of plant pathologists on the phases of the great problems of food production and preservation which plant pathologists are peculiarly fitted to solve.

The work of this board may be more properly discussed at a later date, when its activities have produced the important tangible results which are in prospect. It is mentioned here as a recognition on the part of American phytopathologists that their science is, and should be, of great and general usefulness. It is not a science for special interests or special industries. Mankind is absolutely dependent on plant food, and reducing the loss of this plant food both on the farm and on its way to and in the hands of the consumer is the duty of the plant pathologist; a duty which in such a crisis as the present becomes imperative and vital.

[28] "News Items," *Torreya*, 18: 40, 1918.

THE SEASONAL DISTRIBUTION OF SWINE BREEDING

By Dr. RAYMOND PEARL

U. S. FOOD ADMINISTRATION

1. In any analysis of the food resources of a nation the stock and production of swine constitutes a highly important factor. The hog is the primary source of nutrient fat in this country. Considering human food alone, or in other words disregarding fodders and feeds, fat for human nutritive use is derived in about the proportions shown in the following table from all sources.

TABLE I

SOURCES OF FAT, IN CHEMICAL SENSE, PRODUCED FOR HUMAN FOOD IN 1913–1914 IN THE UNITED STATES

Sources	Tons of Nutrient Fat Produced in 1913–14	Percentage Distribution
Pork	2,413,763	41.3
Dairy products	1,721,748	29.5
All vegetable foods[1] (excluding fodders and feeds)	982,964	16.8
Beef	486,373	8.3
Eggs	131,250	2.2
Mutton and lamb	90,405	1.5
Veal	14,679	.3
Total	5,841,182	99.9

From this table the paramount position of pork in our national fat supply is evident. It is clear that any one having the task of safeguarding our food resources must give large attention to the pork supply.

The hog is an animal which reproduces itself relatively rapidly. The duration of gestation is about sixteen weeks, and the sow can be bred any time in the year. Consequently, it is theoretically possible to keep an even flow of additions to the swine population throughout the year. In dealing with the problem of our future pork supply, however, the question arose as to whether, in fact, hogs were bred in this country in such a way as to result in an even birth-rate throughout the year, or whether the breeders' practise was such as to lead to more

[1] Including, of course, cottonseed and corn oils.

births in certain seasons than in others. A special investigation of the point was made, with the results here set forth.

2. To arrive at reliable and representative data as to the birth dates of the swine population recourse was had to the registry records of pure-bred swine of two breeds, the Poland China and the Duroc Jersey. These breeds were chosen because of their popularity and wide geographical distribution in the United States. Frequency distributions of date of birth of litters, by month, were made by extracting at random litter records from the American Poland China Record (Vols. 17 and 18) and the Duroc Jersey Record (Vol. 40). Equal numbers of male and female records were taken. For the purpose of this inquiry the country was divided in four zones on the basis of latitude as follows:

Zone I., Northern Zone—includes Maine, New Hampshire, Vermont, Massachusetts, New York, Michigan, Wisconsin, Minnesota, North Dakota, South Dakota, Washington.

Zone II., North Central Zone—includes Rhode Island, Connecticut, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Iowa, Nebraska, Wyoming, Idaho, Oregon.

Zone III., South Central Zone—includes Delaware, Maryland, Virginia, West Virginia, Kentucky, Missouri, Kansas, Colorado, Utah, Nevada, California.

Zone IV., Southern Zone—includes North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Louisiana, Arkansas, Oklahoma, Texas, New Mexico, Arizona.

For each zone and breed 500 records were taken at random from the herd books, giving 2,000 records for each breed in total. I am indebted to my assistant, Mr. John Rice Miner, for extracting these records.

TABLE II

FREQUENCY DISTRIBUTIONS, BY ZONES AND MONTHS OF BIRTH, OF 2,000 LITTERS OF POLAND CHINA SWINE

Month of Birth	Births in Zone I	Births in Zone II	Births in Zone III	Births in Zone IV	All Zones
January	1	3	7	41	52
February	13	24	37	34	108
March	103	166	77	48	394
April	239	134	110	84	567
May	86	60	64	58	268
June	17	16	42	37	112
July	8	2	36	33	79
August	7	25	29	26	87
September	10	32	36	32	110
October	11	28	42	46	127
November	3	6	8	39	56
December	2	4	12	22	40
Totals	500	500	500	500	2,000

3. The frequency distributions are given in Tables II. and III.

TABLE III

FREQUENCY DISTRIBUTIONS, BY ZONES AND MONTHS OF BIRTH, OF 2,000 LITTERS OF DUROC JERSEY SWINE

Month of Birth	Births in Zone I	Births in Zone II	Births in Zone III	Births in Zone IV	All Zones
January	5	9	14	29	57
February	13	41	26	10	90
March	189	230	168	90	677
April	170	87	87	114	458
May	53	13	34	61	161
June	13	8	24	56	101
July	5	5	13	28	51
August	6	20	25	12	63
September	21	46	51	19	137
October	13	22	39	29	103
November	4	11	15	24	54
December	8	8	4	28	48
Totals	500	500	500	500	2,000

These frequency distributions are shown graphically in Fig. 1.

Tables IV. and V. give the necessary frequency constants for the distributions.

TABLE IV

FREQUENCY CONSTANTS FOR BIRTH DATES OF POLAND CHINA SWINE

Zone	Mean Date of Birth	Standard Deviation in Date of Birth
I	April 26 ± 1.46 days	48.50 ± 1.03 days
II	May 7 ± 2.17 days	71.79 ± 1.53 days
III	June 1 ± 2.43 days	80.60 ± 1.72 days
IV	June 12 ± 2.95 days	97.88 ± 2.09 days

TABLE V

FREQUENCY CONSTANTS FOR BIRTH DATES OF DUROC JERSEY SWINE

Zone	Mean Date of Birth	Standard Deviation in Date of Birth
I	April 24 ± 1.87 days	61.04 ± 1.32 days
II	May 2 ± 2.45 days	81.28 ± 1.73 days
III	May 20 ± 2.56 days	84.74 ± 1.81 days
IV	May 31 ± 2.69 days	89.24 ± 1.90 days

4. From these tables and diagrams certain conclusions are at once evident.

(*a*) There is clearly considerable difference in breeding practise in different latitudes in this country. In the northernmost zone (I.) the majority of sows are bred to farrow in the spring months March and April, but there is a slight indication of bimodality of the seasonal distribution curve, with the sec-

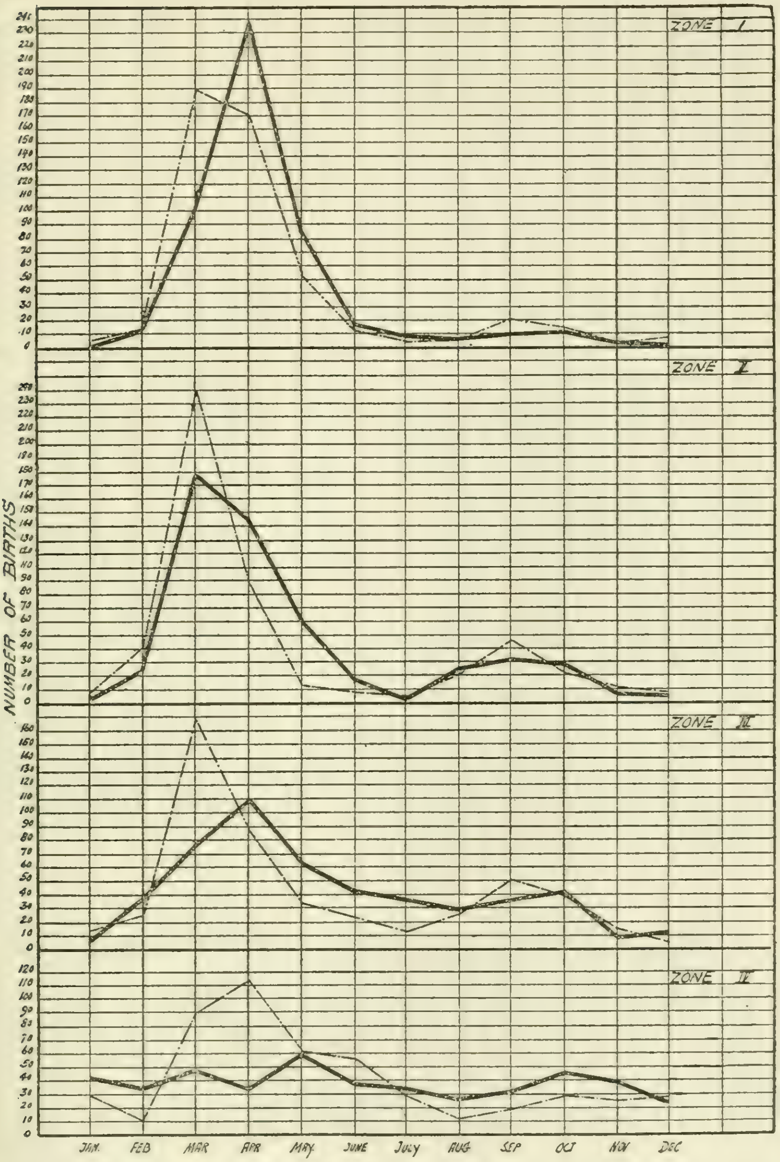


FIG. 1. Frequency polygons showing the seasonal distribution of birth dates in Poland China (solid line) and Duroc Jersey (dash line) swine.

ond peak in the autumn months September and October. In the North Central Zone (II.) this tendency to bimodality becomes much more pronounced and there is a distinct second peak produced by the farrowing in the autumn. As we proceed to the South Central (III.) and Southern (IV.) Zones the curve becomes more and more flat topped, indicating less and less tendency to segregate the breeding period to any one particular season of the year. The spring mode, however, is not entirely lost, even in the southernmost zone.

(*b*) The effect of this tendency to a secondary autumn farrowing season is to advance the average birth date of swine as we proceed from north to south. In the case of the Poland China records this difference in mean birth dates between the north and south amounts, in the extreme, to about a month and a half, and in the Duroc Jerseys to about a month. Another result of the same tendency is, of course, to make the variations in birth dates, as indicated by the standard deviation, larger as we proceed southward.

(*c*) While there are minor differences in the distribution for the two breeds, it is clear that the breeding follows substantially the same rule in both. The maximum difference is in Zone IV., where there is a difference of 12 ± 3.99 days between the means, an amount almost exactly 3 times the probable error, and of doubtful significance.

(*d*) To get a rough but sufficiently accurate general index of hog breeding conditions we may combine the figures for the two breeds. This process gives the distributions exhibited in Table VI.

TABLE VI

MONTHLY DISTRIBUTION OF BIRTHS BOTH BREEDS COMBINED

Month	Frequency				
	Zone I	Zone II	Zone III	Zone IV	All Zones
January	6	12	21	70	109
February	26	65	63	44	198
March	292	396	245	138	1,071
April	409	221	197	198	1,025
May	139	73	98	119	429
June	30	24	66	93	213
July	13	7	49	61	130
August	13	45	54	38	150
September	31	78	87	51	247
October	24	50	81	75	230
November	7	17	23	63	110
December	10	12	16	50	88
Totals	1,000	1,000	1,000	1,000	4,000

(*e*) The essentially bimodal character of the swine breeding curve appears clearly from Table VI. There is a distinct autumn mode but it is only from 20 to 25 per cent. as high as the spring mode. Broadly speaking about three fourths of all the pigs are born in the first half of the year.

According to the official statistics of the Department of Agriculture nearly one half of the country's total hog population is included in our Zone II.[2] Probably this zone contributes two thirds to three quarters of the commercially slaughtered hogs. In Zone II. the following relations hold:

47.3 per cent. of all pigs are born between January 1 and April 1.
69.4 per cent. of all pigs are born between January 1 and May 1.
76.7 per cent. of all pigs are born between January 1 and June 1.

Or, in other words, in the chief swine growing region of the country nearly one half of the pigs are born in the first quarter of the year, and over three quarters of the whole number of pigs are born in the first five months of the year. This assumes of course that we may take the samples of the two breeds here dealt with as indicative of the whole population, which I think we can to a sufficient degree of accuracy.

5. It is of interest now to consider the marketing or slaughter curve for hogs. The Bureau of Animal Industry of the Department of Agriculture maintains some nine hundred stations throughout the country for the inspection of all meat animals received for slaughter. These stations do not cover all the slaughter in the country, but only that of the larger centers slaughtering for interstate shipments; however, they represent in the case of hogs 58.9 per cent. and in the case of cattle 56.4 per cent. of the total slaughter of the country, as determined from the 1910 census.

The following table presents the average percentage that each month's inspection bears to the total for the calendar year, computed from the reported inspections for the six years ending December 31, 1916.

The percentages of Table VII. are shown graphically in Fig. 2, on which is also given for comparison the birth curve in terms of percentage.

From the table and the diagram it is evident that the slaughter follows a very different curve than the births. The most essential point of difference is that the slaughter is much more evenly distributed over the year than the births. The

[2] Cf. Finch, V. C., and Baker, O. E., "Geography of the World's Agriculture," U. S. Dept. Agr., 1917, pp. 130–132.

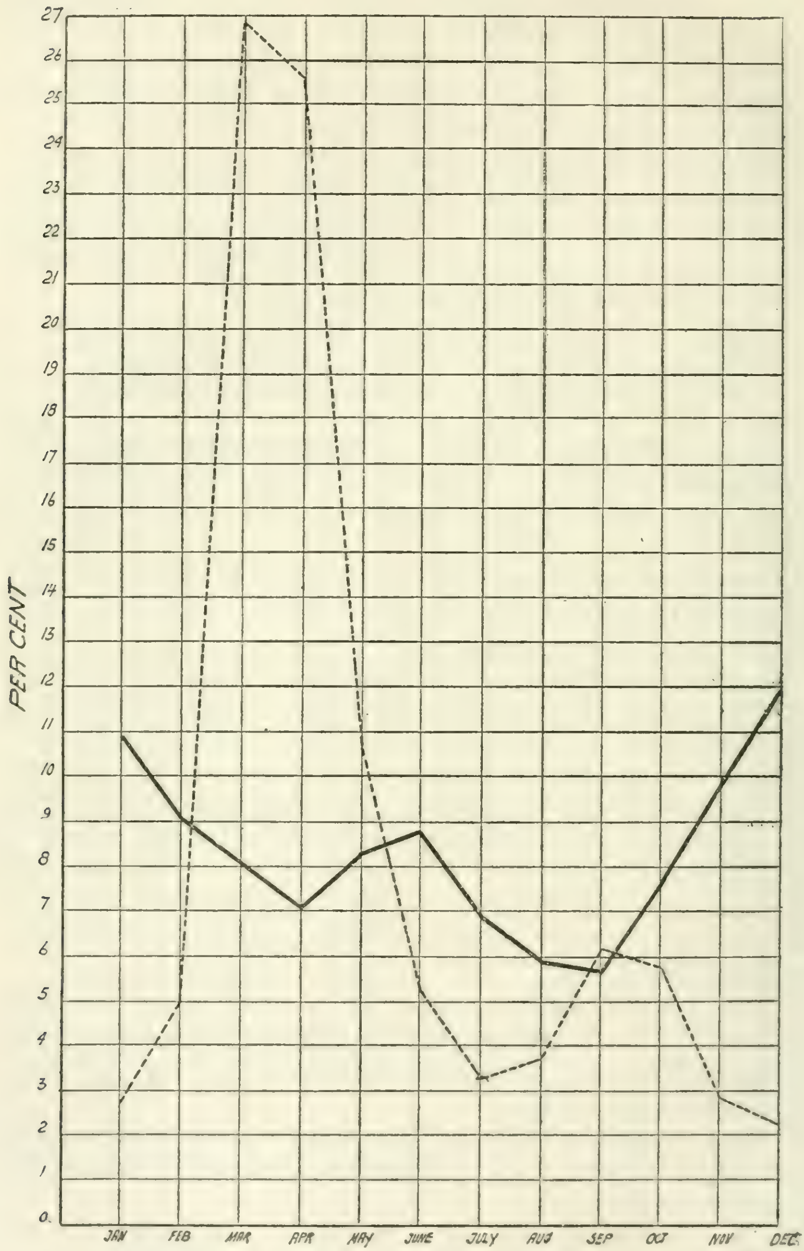


FIG. 2. Diagram showing the monthly slaughter under inspection (solid line) of hogs, expressed as percentage of total slaughter for the year, in comparison with the monthly birth rate (dash line), again expressed as percentage of the year's total.

TABLE VII

INSPECTION FOR SLAUGHTER

Per Cent. that each Month bears to Total for the Calendar Year

Month	Hogs
January	10.97
February	9.07
March	8.08
April	7.10
May	8.22
June	8.74
July	6.89
August	5.82
September	5.64
October	7.13
November	9.88
December	11.98

former curve shows no such violent fluctuations as the latter. During the hot months of the year, July, August and September, the shipments are only about one half those of the winter months, because properly conditioned hogs will not stand shipment and losses are heavy. As the cooler weather comes on, the heavier movement begins and reaches its maximum in December and January, with a decline in each of the succeeding months until May and June, when there is another increase. The two high points of the year in December and June reflect the marketing of the two crops of pigs, spring and autumn, that are produced each year, but in a much reduced degree.

6. What the above facts mean is that there is much more variability on the part of the farmer in the finishing of his pigs than in the breeding of them. To a very considerable extent this removes the potential danger to the nation's food supply which inheres in having 41 per cent. of the nutrient fat supply produced from a source of which 75 per cent. comes into existence in less than one half of the year. The data in this paper show that for all practical purposes the danger point which wants watching is the absolute number of pigs born, not their distribution in different seasons of the year.

THE MARRIAGE OF MUSEUMS

By LEWIS MUMFORD

NEW YORK CITY

I

THERE is something symbolic in the proposal, possibly soon to be effected, to join by a direct path the museums of art and natural history in Manhattan; for it points to a new kinship between these two instiutions that lies much deeper than their supposedly common purpose in fostering learning and spreading culture. Were the tie of education the only one that bound them together there would be no greater fitness in the plan for a connecting walk through Central Park than there would be in one for cutting a driveway between New York University and the American Geographical Society. It is not the aims of the two museums being alike, but their becoming complementary, that gives the proposal a significance. The physical connection will serve to emphasize a cultural borrowing which has at once introduced the presentments of graphic art into the nature museum, and the organic conception of life into the art museum: with the result in certain galleries that the absent-minded visitor will be at loss to recall which museum he is making an inspection of.

The transformation which is taking place in our museums may be roughly described as that from storehouse to power-house. The healthy disorder one finds in these institutions to-day gives evidence of a conflict of traditions which marks this change from a passive "showing off" to an active education, from the uninformed miserly tradition of an earlier day to the directed socialized spirit of the opening age. On the one hand the museum bears all too plainly the stamp of its primitive origin. It is either the robber's cave, the receptacle for princely loot, or the hunter's cache, the repository for animal skins and bleached bones. In both of these capacities it is the function of the museum to acquire as much loot as possible, or as many bones, and to display as great an amount of these in its halls, hit or miss, as space and time will allow. In general, this subordinates esthetic values to those of cash, and scientific values to those of sportsmanlike interest: and to follow this tradition is not so much to promote science and art as to add renown to the hunter and the warrior, as they existed in their past nakedness or in the various thin disguises of to-day: commercialist and art collector, country gentleman and explorer.

Nominally instituted to further science and art, the museums have been at the mercy of every rich ignoramus who has cared to perpetuate his name to posterity through a respectable interest in cultural activities; and while this handicap has not worked grievously in the domain of natural science, it has spelt disaster in the arts, where such bequests as the Stewart Gallery in the Public Library and the biblical supplement gallery in the Brooklyn Institute swamp those of our Altmans and Morgans in the ratio of about three to one. We may laugh at the savage for burying the trophies of chase alongside the deceased hunter; but on closer inspection the savage has the advantage over us. He at least buries the trophies. We can only remove the dead, whilst, through the operation of legal processes, we allow the trophies an ascendancy over us we would never permit the living to enjoy.

Now the museums can not slough off the trophy-collecting convention by overtly refusing gifts, especially when these are accompanied by funds, and when the slightest hint of aversion would withdraw the support of some pillar of society; but they can nullify the effects of indiscriminate collection by reconstituting the very ends, and therewith the methods, of museum exhibition, so that no object need be kept on view for purely honorific reasons. *It is possible to avoid invidious selection by creating a certain environment within the museum and then trusting to the processes of* natural *selection to weed out objects which are exotic to the environment.* I do not say that this is what the museum authorities are at present consciously attempting; but I do say that their efforts come practically to this conclusion. And it is the tendency to abandon the traditions of the warehouse and the treasure vault, and to make the museum a concrete theater of history, as one follows life from region to region and from period to period, which has given it a new social orientation, and which promises that in pursuing the same goal the two museums will tend to approach within hailing distance of each other. Given a common social basis, collection and presentation will have a common social end: for it is chiefly owing to the absence of any serious purposes that the art and nature museums have seemed to be at cross purposes. Once it is granted that both seek to enrich the meaning of contemporary life by showing men, in colloquial phrase, where they are at, in relation to ages past and present, and lands far and near, and ancestors, living and dead: once this is granted, the museum is equipped with a criterion of selection to supplement (and in many cases reinforce) the criterion of beauty which prevails in one place, or that of truth-furtherance which holds in the other.

II

While the natural history museum has always nominally kept in mind the conception of a *habitat*, the idea of art's being presented in its social background was for long quite foreign to museum authorities. Art was something apart; by its nature divorced from this world of shadows and at home only in the heaven of platonic ideals; and the museum existed solely to conserve and consecrate objects of art so that men might commune with them within its walls as their fathers in an earlier age communed with God. There was no notion here of the arts being as closely bound to life as the shell to the snail: not to be severed without causing death to the creature or making futile the thing it had erected for its comfort and delight. Rather, it was felt that snails could not only live without shells, but that roundworms could by careful imitation create shells like those snails had once deposited. This attitude toward art, baldly put in metaphor, was the outcome, not of any real break between art and life (for they are joined even in dissolution) but of a divorce between life and those who patronized art; and until a very late date, when the old teachings of Ruskin and Morris began to take effect, the idea of art's being irrelevant to its environment was reflected in the museums. The showcase or the gallery was the exhibition unit; the aim was to admire art as a thing in itself; the subsidiary instruments for satisfying historical curiosity were the guidebook and the professional treatise.

Unfortunately this detached view of art defeated the very aim it thought to serve. There is indeed something to be said for not hedging the esthetic mood with all sorts of secondary intellectual interests, and on the surface the introduction of the social background might seem to provoke a discordance; but this no more holds in reality than (as I shall show) the contrary practise in the museum of natural history. Putting objects of art into what is approximately the environment out of which they have been plucked actually heightens the savor of the art itself, the esthetic note being only fully sounded when every object in the vicinity takes up the note and vibrates in sympathy with it. This is what is done in the Swiss, the Georgian, and the Queen Anne rooms in the Metropolitan Museum. Were the gallery tradition followed each bed, picture, mirror, or table in these rooms would have been presented, so to say, in severalty: and had the museum been able to put seven fourposters side by side, or a dozen consoles, the supposition would be that the museum was so much the richer. And this would be true from a mercenary and miserly point of view; but it would be a banal distortion from the standpoint of art. Three double beds by Robert Adam in the same room would give the impression that the Walpole ministry had a housing problem in Portland Square; a dozen mantels in one dining room would give currency to the notion that every one used to "eat off the mantelpiece." A plethora of discrete objects, especially when they are the same or similar objects, prevents one from seeing a single object: when the eye is overwhelmed with a horde of creditors crying for attention, it despairs of meeting any demand at all and goes bankrupt. Hence the wisdom of putting art in its proper setting, which means putting it in its place. It is the scientific, environmental presentation that meets all the demands of art. For only when the proper surroundings have been established to provoke the esthetic mood will the esthetic mood lift the observer out of his surroundings.

Plainly this naturalist treatment of the arts, at once historic and esthetic, is but yet in its infancy; and the museum has still many a dusty corner to sweep away before every art collection will have its environment. Certain periods, it goes without saying, can never be done minutely in the grand style, with rooms to illustrate amply phase after phase of significant social life: this would be the true pinnacle of attainment, and a "consummation devoutly to be wished"; but to accomplish so collossal a work of reconstruction at present staggers the imagination, and as a compromise the miniature period stage, as indicated in the models that the Metropolitan is acquiring, enters with an air of importance.

Models have long played no little part in museum exhibition. Those of the Parthenon and of Notre Dame at the Metropolitan are especially well known; and because of their solidity and four-squareness they have a place in the study of architecture that could never be completely usurped by pictures and working drawings. But the new use of models is theatric; it aims at embodying a whole period in a scene. The model-maker takes the scattered materials that have survived the ages, here a chair and there a table and yon a wall, and he reconstructs in little the details of the society whose relics have been gathered, bringing together on his stage elements that have been widely scattered and showing in concrete, relations which would otherwise have only been dimly perceived. This art, or rather its fresh bias, is not yet sufficiently familiar to permit a final word to be pronounced upon its possibilities: its present status is due to the fine craftsmanship of a single man, Mr. Dwight Franklin. But one can not study the already attained successes with lighting and vividly depicted action without coming to the conclusion that the mimetic representation of past epochs will annex for itself a wide territory in the reconstituted museum, and that the time may come when people, plain and sophisticated, will have opportunity for a glimpse of ancient art and manners (and therewith of social history) through the direct medium of the vision, without being forced to rely solely upon the attenuated descriptions of the printed word. Not as substitutes for the "real thing," but as a method of making real things less strange will models like those foreshadowed in the English Hall or the entrance to St. Sophia's finally be made for every period of significance. Their appearance in the Museum of Art is surely a token of that nascent social interest to which reference has been made. They introduce the notion of the arts as a natural flowering of healthy societies, rather than as a mysterious irruption that somehow, despite a popular love for the false, the vile, and the hideous, intrudes itself upon a society. To see the arts in their proper setting is to restore the organic conceptions of the arts, and the organic conception is that of natural history.

III

But if the art museum is espousing the methods of science with its emphasis upon the continuity of living things, and the relation of organism to environment, and craftsman to period, it is no less true that the science museum is taking advantage of the synthetic vision of the artist. So far from being occupied with the purely cognitive aspects of the natural sciences, the American Museum has been increasingly eager to develop their emotional aspects and to further their application to the arts. This has been done in three ways. In the first place, art workers have been encouraged to make use of the primitive patterns created by the indigenous American craftsmen of the loom and the potter's wheel. The result of this has been to lengthen our historical perspective and to detach the workers from a perhaps too close apprenticeship to European models. These borrowings from a more primitive culture break down the ancient Greek antithesis between nature and art by means of the arts created by the so-called nature-peoples; and by bridging the gap between the two separate fields it has brought the museums that represent these fields into a closer working community.

The second phase of the museum's artistic activity has been in the reconstruction, first in drawings and then in single cases and now in whole galleries, of the natural habitat of the wild creatures whose lives are to be portrayed. No mention of this return to nature in the study of nature could be made without reference to the work of Mr. Charles Knight. Combining scientific penetration and artistic insight in a remarkable degree he has in his drawings, from the first water-color sketches of our saurian ancestors, divined from the meager evidence of a rag, a bone, and a hank of hair, to the last sweeping mural of the hairy mammoth, effaced by the synthesis of his own personality the ill-conceived antagonism between science and art that was handed down from an earlier age. That without the love and the beauty of nature there can be no geography or no nature study worthy of the name has already been urged by the eminent botanist, and art critic likewise, Patrick Geddes. But conventional practise sterilized this love and made abortive this beauty by isolating art in a peculiar building, as though it were a contagious disease, at the same time that it reduced nature study to a mere grind of names. From this paralyzing practise the artist-scientist is cutting loose. He places his art at the service of science, and he uses his science as a frame for his art: and he has thus to no little extent given back to the artist the opportunity for public service which disappeared with the decline of the middle ages and the usurpation by the leisure classes of the artist's talent for the gratification of idiotic whimsies.

The decoration of nature backgrounds for animal groups is but the recovery for the new cosmogony of those religious interpretations which have a hallowed place in medieval churches. And the fact that the interest in nature *per se* is contemporary with the development of landscape painting (due in both cases to the arousal of a new, non-invidious curiosity in things) is perhaps an indication of the essential reasonableness in calling in the landscape painter as an aid to the naturalist. This is a new field of the artist of realist tendencies: it opens the way for an escape from "gallery art," while it gives the *photographer* of contemporary esthetic derision a fresh raison d'être and a refurbished purpose in life. Here is also at last a place for those academics and scholiasts who in the teaching of art insist upon truth values, those of anatomical perfection and fidelity to exterior form, as the salvation from slackness, laziness, meretriciousness and the like. Losing their foothold inch by inch in the art galleries, they may at least find refuge without compromise in our museums of natural history. I do not point out this possibility in irony. The classicists in art have still a place left for them in society, as the creators of decorations that aim to establish a moral, a civic, or a scientific truth through the medium of art. And it is only within the very narrow sanctuary of pure esthetic being that the incense they offer on the altar of truth pours upward in a heavy fume that conceals all the delicate beauties of the little temple. In the museum of natural history their craft is not to be despised; for the technique of naturalism is largely an objective technique; and its logic is the single one that will accommodate itself to values extraneous to those demanded by an absolute esthetic response. Despite the difficulties offered by walls whose surface is marred with useless windows and by galleries which were never meant to serve the ends of esthetic contemplation, the artist has much in the nature museum to spur as well as hinder his technique. And beyond doubt the new additions to the Natural History Museum will be planned in full recognition of the artist's coeval interest with the scientist in the most effective display of a collection in its manifold aspects.

The third manner in which the museum has utilized the artist is by employing him to render models in plaster and wax of animals, man for one, that defy the most adept efforts of the taxidermist. Here is a province that the sculptor of highest rank need not disdain to tread. Consider the opportunities offered by one of the life-sized or slightly reduced groups of peoples engaged in their native occupations; such a group as that of the Pueblo dwellers, for example. In many ways the ethnic casts made by the museum workers are beyond approach: they are faithful in all the minutiæ which patience and manual skill can take care of, and they appear against such ably conceived backgrounds that it is not easy to detect wherein they fall short of the highest. Examining with more critical eye the figures themselves, however, one gets the sense of a lost opportunity, and one feels that in order to measure up to the scientific accuracy of the setting as a whole the figures should have been done by as skilled a hand as knows how to use modeling tools—that here is a subject which might tempt the genius of Phidias or Praxiteles or which might in our own day have enlisted the hand of such a many-faceted master as Rodin himself. Is it too much to expect that the museum of the future will include along with its numerous and capable artists of the brush an array of naturalist sculptors whose quality will be little, if any, below the finest offerings of their contemporaries?

The interest of the age is above all scientific: why then should it not use art creatively for its purposes? The great statues of Greece and Rome were found in the baths and gymnasia and theaters; for there the cultured life of the time was centered, and the artist was called upon to enrich the meaning of that life by transfiguring its quality in marble. To-day we have not lost these interests, but we have added to them the impassioned curiosities of science; and the Milesian Venuses and Indian Bacchuses of another day have a niche awaiting them in our museums of natural history. Who but the sculptor with undisputed mastery should perpetuate for us the subtly molded human figure, differing as it does from race to race and climate to climate. The present figure groups in the museum are but a beginning. They do no more than represent the grosser divisions of the human race, as between Bushman and Kaffir, between Chinaman and European. And even here, in lieu of a robuster ideal of art, there is a perpetual baffling of the scientific interest by differentiating not between men as animals, but between men as the lay figures of civilization, a Chinese farmer being placed alongside a Norwegian matron, each in the regalia of daily life, as though the sculptor had been dismayed by his deficiencies and had thought to conceal them under the obvious camouflage of clothes. Further than this naïve revelation of types the museum must soon go; but it can obviously not travel far until the highest range of artistry is incorporated in its staff. This is not to disparage present achievements: it is rather to acknowledge their worth by showing to what heights they draw the imagination. Once let the scientific impulse get hold of the sculptor (who is an anatomist by current practise anyway) and a new horizon of possibility will open up for both science and art.

In the statuary exhibited last year by Mr. Charles Knight there is a hint of how deep the communion of purpose may be when once it is realized that knowing and feeling are not warring "faculties" of the mind, but diverse attitudes which men assume at appropriate times in their endeavor to have commerce with the things that lie about them. Any emphasis of antagonism is more than banal: it is ignorant. Both science and art are means of opening that oyster, which is the world; and if the one seeks chiefly to dissect the bivalve while the other loses itself in contemplation of the pearl, this should not obscure the fact that they must open the same oyster, and that they may well, for the attainment of this mutual end, take hold of the same instrument and use their forces jointly. It is this truth that is coming to be recognized in our museums as they abandon their primitive reasons for existence and seek to justify their further extension by activities which harmonize with the democratic sympathies of the present order. Hence the environmental treatment of the arts in the art museum; hence the artistic presentation of nature in the nature museum; hence the shift in accent, but not in aim, as one passes from one museum to the other. This perception of a common and complementary purpose indicates, I believe, something like a marriage between the two kinds of museum; a union which might well be sanctified by civic authority in a connecting pathway.

WHAT IS SOCIOLOGY?

By Dr. F. STUART CHAPIN

ASSOCIATE PROFESSOR OF ECONOMICS AND SOCIOLOGY IN SMITH COLLEGE

IN the public library you find grouped under "Sociology" such a bewildering variety of books that the name sociolgy seems to be a vague term quite devoid of definite content and without specific limitation. Books on economics, social psychology, penology, anthropology, philanthropy and the like, are promiscuously corralled together. Some writers on sociology have maintained that sociology is the great synthetic social science which, by combining the generalizations of the special social sciences, economics, politics, ethics and philanthropy, arrives at a scientific reality quite different from the particular elements entering into the combination, and by this reason alone, worthy of an independent and dignified place in the hierarchy of sciences. This has prompted the critic to say that then sociology is "a little bit of everything and nothing at all."

On the other hand, sociology may mean to the graduate student at the university such a definite thing as that body of principles which govern the evolution of society from primitive forms to its highly complex modern form. To the social worker, sociology may mean the very definite body of scientific knowledge involved in successful social legislation or case work.

Is it hopeless to unravel the tangled skein? I think not.

Scientific progress in sociological writing, on the one hand, and in concrete practical achievement, on the other, has been so rapid of late years, that there has tended to develop an entirely natural but a very deplorable misunderstanding between the writer-teacher group and the practical social workers. This situation may be readily understood by a moment's consideration of a few relevant, though often neglected facts.

In the first place, it should be recognized that certain over-academic and superficial writers have brought the serious scientific group of writer-teachers into disrepute among many practical workers. But it is equally true that a small element of self-advertising "uplifters" has brought the social worker group into disrepute among many of the writer-teacher group.

Now a careful examination of the best work of the writer-teacher group represented by Franklin H. Giddings, Lester F. Ward, William G. Sumner, Edward A. Ross, Charles H. Cooley and Charles A. Ellwood, to mention a few by name, shows that the common subject-matter of their writings is those massed and correlated psychic elements variously known as social customs, standards, traditions, institutions, fashions, conventions, folkways and mores. All of the profound theoretical, evolutionary and historical studies of these writers, however academic they may seem to the practical-eyed social worker, are but scientific efforts to discover, formulate and define those principles which govern the origin, growth and evolution of our modern social customs, standards and institutions.

Similarly, a careful examination and evaluation of the work of the practical group of social workers, however foreign it may appear to the interests of the others, reveals the fact that the common end of all their efforts is to restore normal standards, to encourage helpful traditions, and to preserve and upbuild normal social institutions. They restore to normal standards the flood-stricken community. They rehabilitate the disorganized family.

Thus it is seen that the two groups, of students and of workers, are really laboring in the same field, upon a common subject-matter. This fact has received tacit recognition in such recent sociological books as Blackmar and Gillin's, "Outlines of Sociology," and in Hayes's "Introduction to the Study of Sociology," and by the establishment at Western Reserve University of a school of applied social science. But it should be given an immediate, more general and cordial recognition on the part of both the writer-teacher group and the social-worker group. In proportion as this is done, the discoveries of the two groups of scientists will become gradually articulated into that body of tested scientific principle which is so much needed to solve the pressing problems of our democratic social order.

But have we answered the question, what is sociology? Having cleared the air of misunderstanding and discovered the common ground of interest, let us proceed to answer the question directly.

Says Professor E. C. Hayes, "The problem phenomena of sociology are of one clear and distinct class, as much so as those of the best established sciences," and he continues, "Sociology must deal with massed and correlated psychic elements, and with environmental factors of every kind by which social customs and institutions are effectively conditioned." Now it will be admitted that the special social sciences of politics and economics, as well as the science of psychology, do not treat the phenomena of social customs, standards and institutions as their chief subject-matter. Indeed, these sciences treat such social phenomena, if at all, only as incidental to the special subject-matter of each. Thus there have been left over the important residual problems of the origin and growth of social customs, standards and institutions, and these problems have become the special field of a legitimate and independent science—sociology.

The science of sociology, like some other sciences, may be divided into two branches: *pure sociology*, that is, theoretical and historical sociology (sometimes styled "scientific sociology," but erroneously so designatd if the term implies that the other branch is not scientific) ; and *applied sociology*, variously called social pathology, or social economy, or social legislation and social work.

Pure sociology is concerned with the laws that govern the origin, growth and evolution of social customs, standards and institutions. It analyzes social phenomena into its elements and seeks to explain the relative importance of such conditioning phenomena as biologic (for example, are the standards of one race low because of native inferiority?), geographic (or, are the standards low because of paucity of natural resources or isolation?), technic (or, are the standards low because of perverted attempts to control nature or to interfere with natural processes?), and social (or, are standards low because it is a young race and lacks length of social experience?). Thus in so far as pure sociology throws new light on old problems by assembling the data of biology, geography, psychology and anthropology, it is synthetic; in so far as it assembles statistical data and discloses new and unsuspected relations, it is inductive.

Applied sociology studies the causes that force human beings individually and collectively to live below those "normal" standards of living which are exemplified in the prevailing customs, traditions and institutions of the time (as analyzed and defined by pure sociology). Thus it studies the causes of poverty and dependence, the causes of crime, and the social causes of sickness and disease. But applied sociology also endeavors to discover the principles (and here it should borrow from pure sociology), and to develop the technique, which, when applied, will either prevent the recurrence of socially pathological conditions, or at least relieve the abnormal situation. For example, the principles of case work applied to family rehabilitation; the individualization of punishment to secure reformation; and the introduction of investigation, follow-up work and ideals of restoration to self-support, into the practise of poor-relief.

Briefly stated, pure sociology traces and defines normal human tendencies and standards; applied sociology endeavors to preserve and re-establish them.

We may therefore define sociology as the science of the origin, growth and evolution of social customs, standards and institutions. It analyzes and defines them, and studies the causes that tend to force people below normal standards, thus showing us how to prevent recurrent lapses from these norms, as well as to relieve abnormal conditions.

PALEONTOLOGICAL EVIDENCES OF THE ANTIQUITY OF DISEASE

By Professor ROY L. MOODIE

DEPARTMENT OF ANATOMY, COLLEGE OF MEDICINE, UNIVERSITY OF ILLINOIS, CHICAGO

PATHOLOGICAL conditions among fossil animals are known as far back in geological time as the Carboniferous, hence it may be proper to state on the basis of our present knowledge that disease began, among both plants and animals, during the great Coal Period. These evidences are found both in the new and the old world, so that there must have been a very fundamental condition underlying the evolution and development of animal and plant races which favored the ingress of disease and the overpowering of the natural immunity which had previously protected the forms of life from the devastations of disease. This statement of affairs implies the absence of disease, or of a tendency toward disease, among the inhabitants of the earth during the geological periods prior to the Mississippian. This may not be correct, but so far as we know at present the animals of the Paleozoic and Proterozoic were free from disease. The factors which have been important in the origin of disease have been discussed by the writer[1] in an essay which had in view an outline of the entire subject of the origin and development of disease as seen in the lesions on fossil bones. A study of senescence in dogs and the relation of old age to disease recently made by Goodpasture[2] supports in an interesting manner a suggestion made by the writer[1] concerning certain factors in the origin of disease among the animals of past ages.

CARBONIFEROUS

Present evidences tend to show that the Coal Measures witnessed the origin of disease. The oldest known evidences of pathological conditions among fossil animals are to be found in the enlarged stems of fossil crinoids, which have been known for many years. They were described by Robert Etheridge, thirty-eight years ago, from the Carboniferous of Scotland. Five years later a correct interpretation of these deformities was given by L. von Graff. He showed, on the basis of similar

[1] "Studies in Paleopathology. I., General Consideration of the Pathological Conditions found among Fossil Animals," Annals of Medical History, Vol. 1, No. 4, 1918.

[2] "An Anatomical Study of Senescence in Dogs, with especial Reference to the Relation of Cellular Changes of Age to Tumors," *Journ. Med. Research*, Vol. XXXVIII., No. 2, pp. 127–190, 1918.

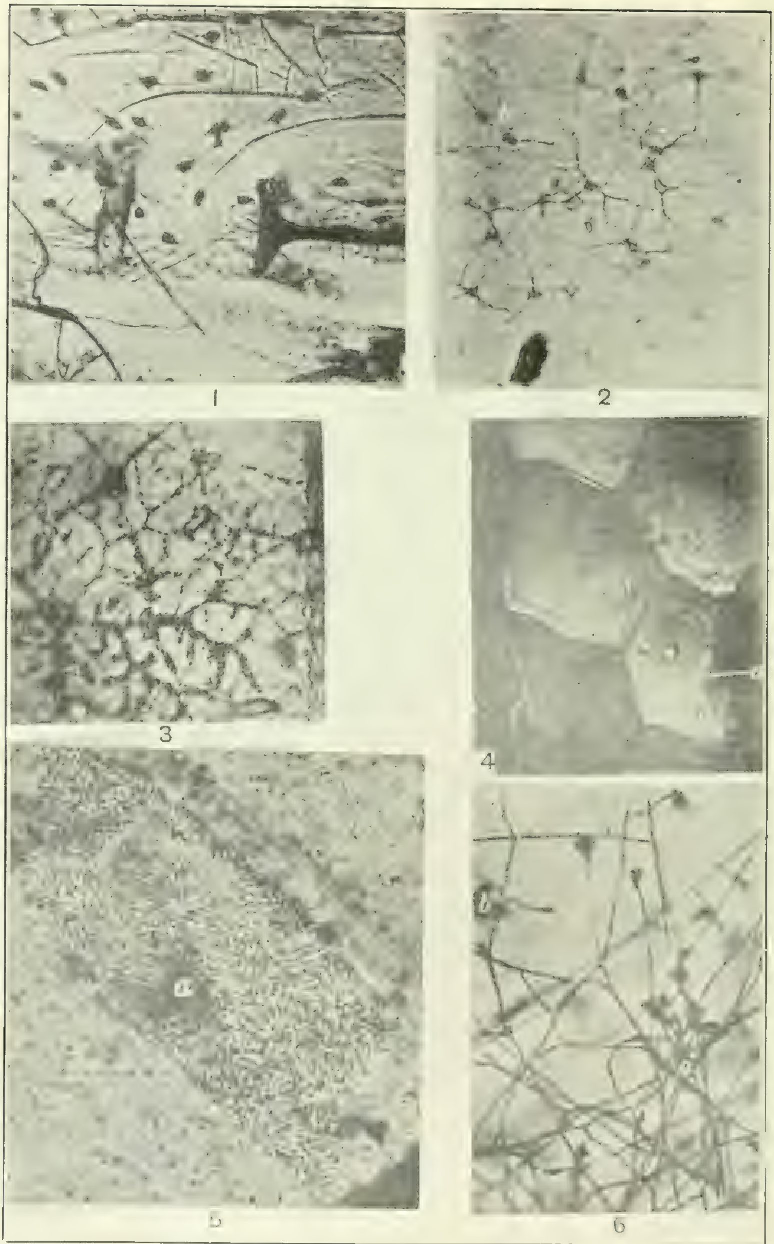


FIG. 1. PHOTOMICROGRAPH OF A FRAGMENT OF FISH BONE FROM THE AUTUN BASIN OF FRANCE, showing the nature of the osseous lacunae, canaliculi and vascular channels.

FIG. 2. PHOTOMICROGRAPH OF ANOTHER PORTION OF THE SAME BONE showing in the enlarged canaliculi and lacunae the ravages of micrococci which have invaded the channels and have begun the destruction of the bone.

FIG. 3. PHOTOMICROGRAPH OF ANOTHER PORTION OF THE SAME BONE showing a further stage of destruction. The form of the lacunae and canaliculi are barely perceptible, since they are packed full of colonies of micrococci.

FIG. 4. SCATTERED BACTERIA IN FOSSILIZED PLANT CELLS, one of them at *a* showing faint indications of a mucoid capsule.

enlargements among recent crinoid stems, as described and figured in the Reports of the Challenger Exploring Expedition, that these enlargements were due to the parasitic action of myzostomids. Graff supported his interpretation by describing the carbonized remains of some worm, supposedly one of the myzostomids, to which the tumor was due, preserved in a channel of one of the fossil lesions. Similar objects are common from the Carboniferous of North America and doubtless they have a very wide distribution.

During the Carboniferous also there was a widespread development of fungi and bacteria which doubtless were influential in the spread of disease. Renault has found these forms abundantly preserved in the fossilized feces of fishes, in ancient wood and in coal. He also discovered in the teeth of certain extinct fishes indications of caries, as shown by the irregular decayed spots within the substance of the teeth. Renault's work covered many geological periods later than the Coal Measures, and his large monograph is the summing up of twenty-four years of activity spent in investigating the nature of the "Microorganismes des combustibles fossiles" in peat, lignite, bituminous schists (in which he found rhizopods, bacteria and fungi), boghead coal, cannel, ancient schists and the silicification of organisms in very ancient rocks. Renault's work is of great importance. A few of his figures are given herewith (Figs. 1–6). The bacteria take the form of coccoids, bacilli, diplococcoids and micrococcoids. Often in sporangia of the early cryptogamous plants Renault found natural cultures (Fig. 5) of bacteria which have been preserved by silicification. These organisms, which have been made so well known by the studies of French scholars, may all of them have been non-pathogenic forms, but the possibility of their being the cause of the disease of succeeding forms of life is very evident, and they should be mentioned as possible sources of disease.

Permian

The great Permian period, with its widespread development of curious reptilian forms, has furnished us with the first evidences of traumatic conditions as they prevailed among the early forms of life. Fractures may have occurred earlier than the Permian, but they have not yet been seen. The oldest known fractures are found among the reptiles from the Permian of Texas. A left radius of *Dimetrodon*, a primitive reptile, pre-

Fig. 5. Silicification of a Natural Culture of Bacteria from the Permian.

Fig. 6. Mycelia and Sporangia of Fossil Fungi as seen under high magnification in a thin section of fossil wood. Favorite places for the growth of bacteria. All figures taken from Renault's monograph "Microorganismes des combustibles fossiles."

FIG. 7. LEFT RADIUS OF *Dimetrodon*, a primitive reptile from the Permian of Texas, showing, in the enlarged portion of the bone above, a simple fracture and considerable callus with some intermediary callus. Specimen the property of the Walker Museum University of Chicago. Loaned for study and description by Dr. S. W. Williston.

FIG. 8. X-RAY PICTURE OF THE BONE. The fracture lines above and below the callus are post-fossilization fractures and have no significance.

sents a well-marked case of fracture (Fig. 7) with subsequent healing, although there is still some intermediary callus. An attempt to study the nature of this fracture by means of the X-ray has not resulted in any new knowledge, but it may be interesting to present the attempt (Fig. 8). The fracture runs directly across the bone, as do all the early cases of fracture among animals with solid limb bones, and the resulting callus has produced a decided enlargement of the bone around the fracture. The fractures seen in the X-ray picture above and below the callus were produced after fossilization and have no significance.

A small fragment of a fractured rib from the same beds, in which there was quite an old callus, has been studied microscopically (Fig. 9). The callus was quite evidently an old one, for the fracture was completely healed. A study of the microscopic section proves this to be true, since evidences of osteosclerosis and osteohypertrophy are clearly evident. The region

Fig. 9. Microscopic Study of the Details of a Fracture in a Rib of a Reptile from the Permian of Texas. The white spicule running vertically in the figure is the ingrowth of bone into a split portion of the rib. On the left of this spicule is to be seen the osteosclerotic portion of the old callus, indicated by a heavy unorganized deposit of calcium carbonate or some similar salt. On the right is seen the hypertrophied area, identified by the heavy deposition of bone with small lacunae and canaliculi. The lacunae have largely disappeared in reproduction but are clearly evident on microscopic examination of the bone.

of the figure to the left of the spicule of bone is regarded as due to osteosclerosis, which is interpreted on the basis of the presence of a heavy deposit of calcium salts and the absence of osseous trabeculae. The white band running vertically may be interpreted as a spicule of bone due to the splitting of the rib. Its bony nature is definitely established by the presence of lacunae, and its presence in this position is due to the ingrowth of new bone along a cleft produced by the splitting of the rib. The hypertrophied area to the right of the osseous band is often seen in old calluses and is interpreted on the basis of the presence of numerous trabeculae of bone. There is no evidence that the fracture was infected, necrotic sinuses being entirely wanting.

Triassic

Except for occasional specimens of fossil fishes and other forms preserved in the pleurothotonos and opisthotonos (Fig. 10A), attitudes suggesting a condition of spastic distress,[3] little is known about the pathology (Fig. 10B) of the animals which

FIG. 10*A*. THE SKELETON OF *Compsognathus longipes*, a small Triassic dinosaur, fossilized in the position of opisthotonos, a position which has been suggested as an evidence of cerebrospinal infection. The head is thrown far back over the pelvis and tail thrown sharply up with the feet and limbs in a spastic attitude.

FIG. 10*B*. THE SKULL OF *Mystriosuchus Plieningeri* H. von Meyer, a parasuchian, from the Triassic of Aixheim, exhibiting a broken snout (above letter *B*) with resulting callus and bone necrosis. After Huene.

lived during the Triassic. There doubtless is much to learn in the future, since many vertebrate species are known from this period.

JURASSIC

The Jurassic of England furnishes us the first evidences of necrosis and a suggestion of metastasis as seen in the pathological nature of the bones of *Metriorhynchus moreli* Desl., a crocodile described by Erwin Auer[4] from the Oxford Clay.

The skeleton of this interesting animal was only partially preserved. There are evidences of pathology in the palate, on the two femora, on a sacral vertebra and on the pelvis. Auer says:

[3] "Studies in Paleopathology. III., Opisthotonos and allied Phenomena among fossil Vertebrates," *American Naturalist*, Vol. LI., No. 617–618, 1918.

[4] *Paleontographica*, Bd. 55, pp. 277, 279–280, figs. 13–14.

On the middle of the inferior side of the palatine is a section that is unusually differentiated by cavities, and consists of fossulae, a condition that is not otherwise encountered in crocodiles, and that doubtless is connected with the pathogenic deformities the bones exhibit.

The right femur is normally formed, but it displays below the caput femoris a peculiar corrosion, and the condylus internus is reduced at the distal end.

The left femur (Fig. 11*a*) departs in form quite considerably from the normal type. The head of the bone has undergone a significant contraction, and the formerly globular articular surface is deformed. Under

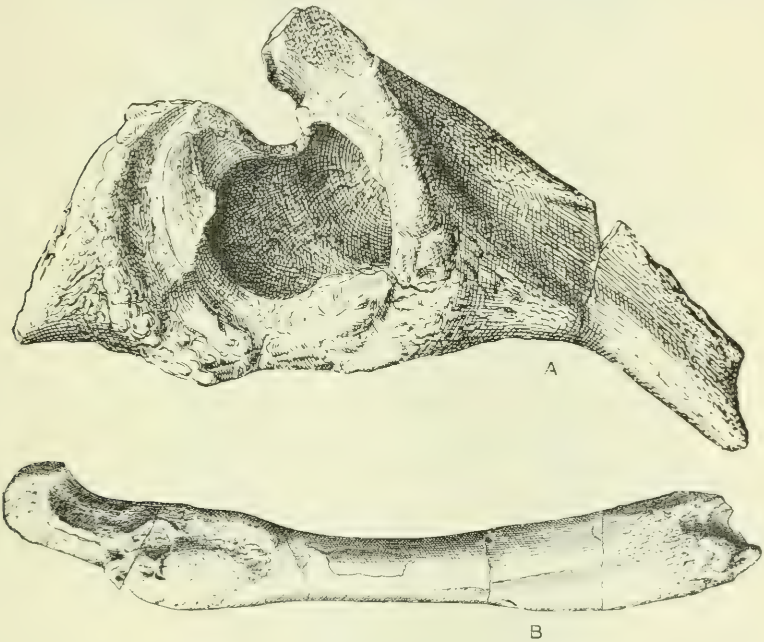


Fig. 11*A*. Sacral Vertebra of *Metriorhynchus moreli* Desl. from the Oxford Clay of England, showing carious roughening and necrosis. After Auer.

Fig. 11*B*. Left Femur of the same, showing pathological roughening at the upper and lower extremities, especially around the trochanetric region. After Auer.

the head of the bone the femur exhibits an abnormally small diameter, and on the external side of the bone a ridge is raised.

The sacral vertebra (Fig. 11*b*) also exhibits significant deformities of a pathogenic nature; the body of the vertebra is noticeably thickened, irregularly jagged on the outer side and set with numerous rather deep holes. The body of the vertebra is completely hollowed out from the end surface.

The description indicates the presence of a tuberculous or similar necrosis of the bones and is the most complete example of a seriously diseased vertebrate which has been seen in the fossil condition.

Comanchian

The gigantic dinosaurs of the Comanchian have long been known to have suffered from disease and injury and the writer

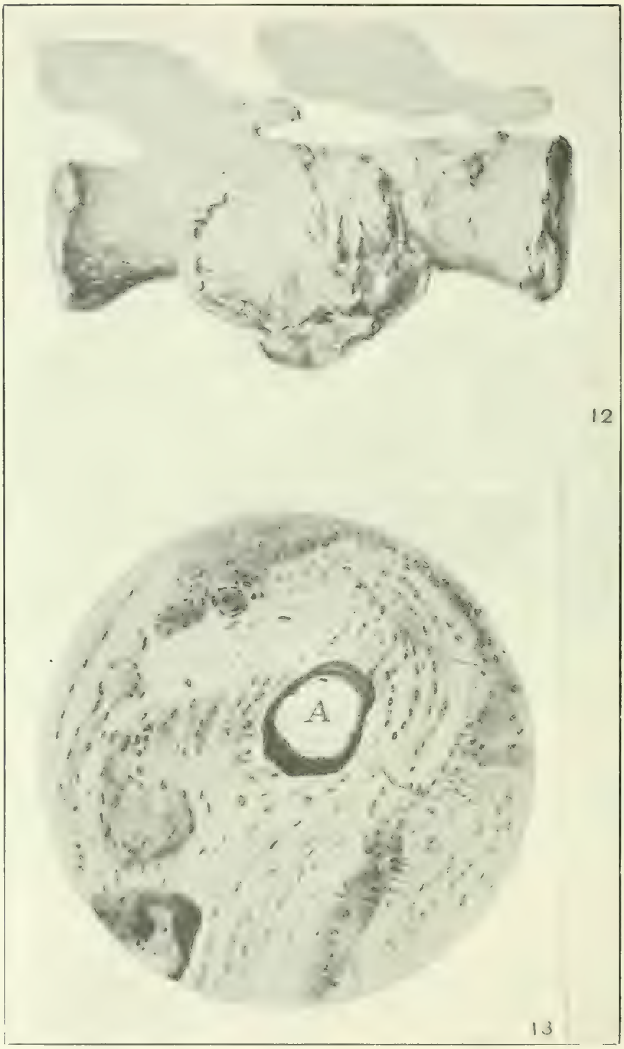


FIG. 12. DEFORMED JOINT BETWEEN TWO CAUDAL VERTEBRAE OF A DINOSAUR (*Apatosaurus*) caused by the growth of a tumor-mass, which on account of its extreme vascularity represents possibly an haemangioma, or some similar pathological growth.

FIG. 13. MICROSCOPIC SECTION OF A PORTION OF THE PERIPHERY OF ABOVE TUMOR, showing arrangement of lacunae, vascular spaces (*a*) and lamellae of bone. How much this differs in arrangement of elements from normal bone remains to be determined.

has described these sufficiently in other places[5] to make their characters well known. The most interesting lesion seen among the dinosaurs has been regarded as resembling a modern hemangioma (Figs. 12–13). Fig. 14 will show the nature of the

[5] "Pathologic Lesions among Extinct Animals: A Study of the Evidences of Disease Millions of Years Ago," *Surgical Clinics of Chicago*, Vol. 2, No. 2, pp. 319–331, Figs. 108–116, 1918.

vascular spaces and the arrangement of the osseous trabeculae as seen in a sagittal section of the tumor mass.

Fig. 14. Photograph, enlarged, of the Cut Surface of the Tumor shown in Fig. 12, to show the arrangement of the trabeculae of bone and the large vascular spaces (areas outlined in ink). The large area at the top of the figure is apparently a portion of the intravertebral space, which has become largely obliterated by the growth of the tumor. The substance of the chevron, seen in Fig. 12 as portion of the tumor, has been incorporated, when seen in section, with the mass of pathological bone.

Cretaceous

The diseases of the mosasaurs may be taken as a sample of the prevalence of disease and injury among the vertebrates of the Cretaceous. These aquatic vertebrates, as well as their congeners, the plesiosaurs and dinosaurs, were afflicted with a variety of diseases and the writer has been able to study the details of the lesions on the fossils from the Cretaceous of Kansas. Twenty years age Doctor Williston called attention to the diseased nature of the arm bones of one of the Cretaceous mosasaurs. Recently I have been able to study these bones (Fig. 15). Their pathological nature and the exostoses of a hyperplastic nature are at once evident (Fig. 15). A tentative diagnosis of osteoperiostitis has been given as the cause of the lesions. Microscopic study of the lesions (Figs. 16 and 17) reveals the bony lamellae laid down in a concentric manner, as if to form Haversian systems. The lacunae are relatively large

FIG. 15. HUMERUS OF A MOSASAUR, *Platecarpus coryphaeus*, from the Niobrara of Kansas showing the details of pathological lesions resembling those seen in modern osteoperiostitis. The microscopic sections (Figs. 16–17) were taken from the lesion at *A*. The disturbance also involved the articular surfaces indicating the presence of an arthritic infection.

and are provided with short canaliculi, and there are areas where osteoid tissue (Fig. 16) is present, comparable in every way with osteoid tissue, seen in modern cases of osteomyelitis. For the first time in the history of paleohistology perforating fibers of Sharpey (Fig. 17) are seen running through the sections.

A dorsal vertebra of *Platecarpus*, a well-known mosasaur from the Cretaceous of Kansas, presents an extremely interesting example of an osteoma (Fig. 18), the only one thus far known in a fossil condition. The specimen has not yet been studied microscopically, but a gross examination of a sawn section (Fig. 19) through the osteoma and vertebra shows in a very interesting manner how the tumor mass grew out of the vertebra. An X-ray examination of the bone reveals nothing of importance.

A radius of another mosasaur shows on the proximal surface an extensive necrosis. Sections of the bone show hyper-

Fig. 16. Photomicrograph of the Portion of the Lesion (A, Fig. 15), showing osteoid tissue. The black lacunae are seen to be without canaliculi and their arrangement in concentric lamellae suggests the presence of an Haversian system. The dark area running obliquely out of the lower left hand corner is a post fossilization fracture filled with calcite. This area of osteoid tissue in the humerus of a mosasaur, 15,000,000 years old, is identical in anatomical structure with osteoid tissue from the human humerus in a case of osteomyelitis.

trophy of the peripheral substance. The nature of the organism producing the necrosis is not determined, but the fossil presents an exact duplicate of modern instances of extensive arthritic necrotic sinuses, which result in hypertrophy and the production of numerous osteophytes.

Dollo has described dental caries in a mosasaur jaw, with a hyperplasia of the bone with accompanying necrosis, as if the creature had suffered from a mouth infection similar to modern alveolar pyorrhea. The results are identical in modern and ancient bones.

The prevalence of disease reached a climax in the mosasaurs, dinosaurs, plesiosaurs and turtles of the Cretaceous, and with the opening of the Tertiary the incidence of disease went sharply down, to rise again with the rise of mammalian life and reach a very high point during the Pleistocene.

FIG. 17. MICROSCOPIC STUDY OF ANOTHER AREA OF THE SAME SECTION AS THAT SHOWN IN FIG. 16, showing the presence of perforating fibers of Sharpey, the long black fibers running obliquely through the figure, and small lacunae with short canaliculi, without any definite arrangement into systems.

FIG. 18. A DORSAL VERTEBRA OF A MOSASAUR, *Platecarpus*, from the Niobrara of Kansas, showing on the posterior (right hand of figure) end of the vertebra an osteoma, the only known fossil representative of this type of tumor.

EOCENE

The extinction of the large groups of reptiles at the close of the Cretaceous doubtless brought about the disappearance also of many forms of disease which attacked these animals. Some forms of disease, as seen in the lesions left on the fossil

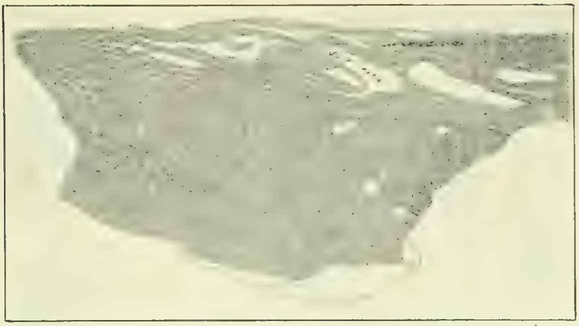


FIG. 19. A DRAWING OF A SAWN SECTION OF THE VERTEBRA, at the region of the occurrence of the osteoma, showing how the pathological structure grew out of the body of the vertebra.

FIG. 20. TIBIA AND FIBULA WITH TARSAL BONES OF *Limnocyon potens*, a carnivore from the Washakie Eocene, showing in the carious roughening and hyperostoses evidences of disease resembling the results of osteomalacia of today. Published through courtesy of Dr. W. D. Matthew.

bones, were persistent as may be seen in cases of caries and alveolar osteitis with the associated forms of necrosis. It is to be expected that the paleontological evidences of disease would be rather scanty during the Eocene and in fact not a great deal is known. One interesting indication of a pathological condition may be seen in the tibia, fibula and associated tarsal bones of *Limnocyon potens*, a creodont carnivore from the

FIG. 21. *a*, metatarsal of a giant wolf, *Canis dirus*, from the Pleistocene, Rancho la Brea beds, of southern California showing a fracture of the middle of the bone with repair and the ensuing callus and exostoses. *b*, metatarsal of a saber-toothed cat, *Smilodon*, from the same deposits, showing on the upper right-hand surface a sharp exostosis, doubtless due to the infection of a tendon sheath, or some similar irritation. *c*, another metatarsal of a saber toothed cat from the same beds, showing on the lower end of the bone considerable carious roughening and hyperostosis. *d*, *e*, *g*, phalanges of a giant wolf showing slight exostoses due to some infection. *f*, phalange of a wolf. In the lower end the erosions of chronic osteomyelitis (?) or some similar long standing necrosis, produced by infection. An end view of this phalange, enlarged, is shown in *h*. *h*, end view of phalange (enlarged) shown in *f*, giving a clear idea of the necrosis produced by the infection. *i*, a pathologic camel phalanx from the Rock Creek beds (Pliocene or early Pleistocene) of Texas. This specimen has been discussed by Troxel (*Amer. Journ. Sci.*, XXXIX., p. 626, 1915) where he says: "Possibly the disease which caused the death of the individual also contributed to the destruction of the species." A supposition which is not supported by the evidence, since the pathological condition as seen in this single phalanx would have caused merely a stiffness and consequent lameness of the foot. Photo published by courtesy of Dr. R. S. Lull. *j*, vertebra of a saber toothed tiger from the Rancho la Brea beds of southern California, showing necrosis in the process seen on

Washakie Eocene. These bones (Fig. 20) show considerable exostoses and hypertrophy indicating an infection of some duration. The appearance of the bones suggests modern conditions of nutritional disturbances resulting in the softening and lightening of the bones as in osteomalacia.

Oligocene

The mammals of the Oligocene suffered from disease and injury, though not so greatly as their successors, nor were any of the diseases prevalent at that time of sufficient importance to produce extinction. It must be remembered, however, that paleontological evidences of the antiquity of disease deal with hard parts exclusively, the soft parts known not being pathologic. The Oligocene dog, *Daphænus felinus,* so carefully and beautifully described and figured by Hatcher[6] presents on the inferior portion of both radii a symmetrical tumor-like mass, the only example of duplicate exostoses in fossil animals. The nature of the exostosis is problematical and I have not been able to find a parallel for this condition among the lesions on human bones. An excellent example of fracture with resulting callus formation and a splendid pseudarthrosis is known in a rib of the right side of *Titanotherium robustum* a perissodactyl from the White River beds of South Dakota, described by Osborn.[7] A careful account of this interesting fracture has been given by the writer,[8] accompanied by a detailed illustration of the callus.

Miocene

As an example of the nature of disease during the Miocene may be mentioned the nature of the lower jaw of the type skeleton of *Merychippus campestris,* a three-toed horse from the Loup Fork beds of South Dakota. One ramus of the jaw has a prominent swelling indicating the presence of a long-standing infection possibly of actinomycosis in its early stages, before the eruption of the bone took place. Alveolar osteitis with the

the upper right hand spine. *k,* end view of vertebra of saber tooth from the same beds, showing on the ventral surface of the body of the vertebra pathologic lesions of *spondylitis deformans.* Doubtless a series of vertebrae were ankylosed by the lesion, since the part shown is broken square across. Lesions of spondylitis deformans are fairly common in the mammalian remains of the Pleistocene.

[6] "Oligocene Canidæ," *Mem. Carnegie Museum,* Vol. 1, no. 2, p. 85, pl. XIX., figs. 9 and 11.

[7] *Bull. Amer. Mus. Natl. Hist.,* Vol. VII., p. 347, 1895.

[8] *Annals of Medical History,* Vol. I, No. 4, 1918.

formation of some osteophytes, resembling the results of pyorrhea are also seen, and one molar tooth is afflicted with caries, a common occurrence among fossil animals.

Pliocene, Pleistocene and Recent

The pathological conditions found among the mammals of the Pliocene, Pleistocene and Recent geological periods were the first known and have been extensively described and studied by a number of writers from Esper (1774) to Virchow (1895). There are about twenty contributions dealing with the diseased nature of bones from these periods. A review of our knowledge, especially of the pathology of fossil man, has been given elsewhere[9] and little need be said here concerning the pathological evidences from these periods. A few examples of diseased and injured bones from the Pleistocene, Rancho la Brea beds of southern California shown in Fig. 21, a–k, will give an idea of the prevalence of disease in the bones from these periods.

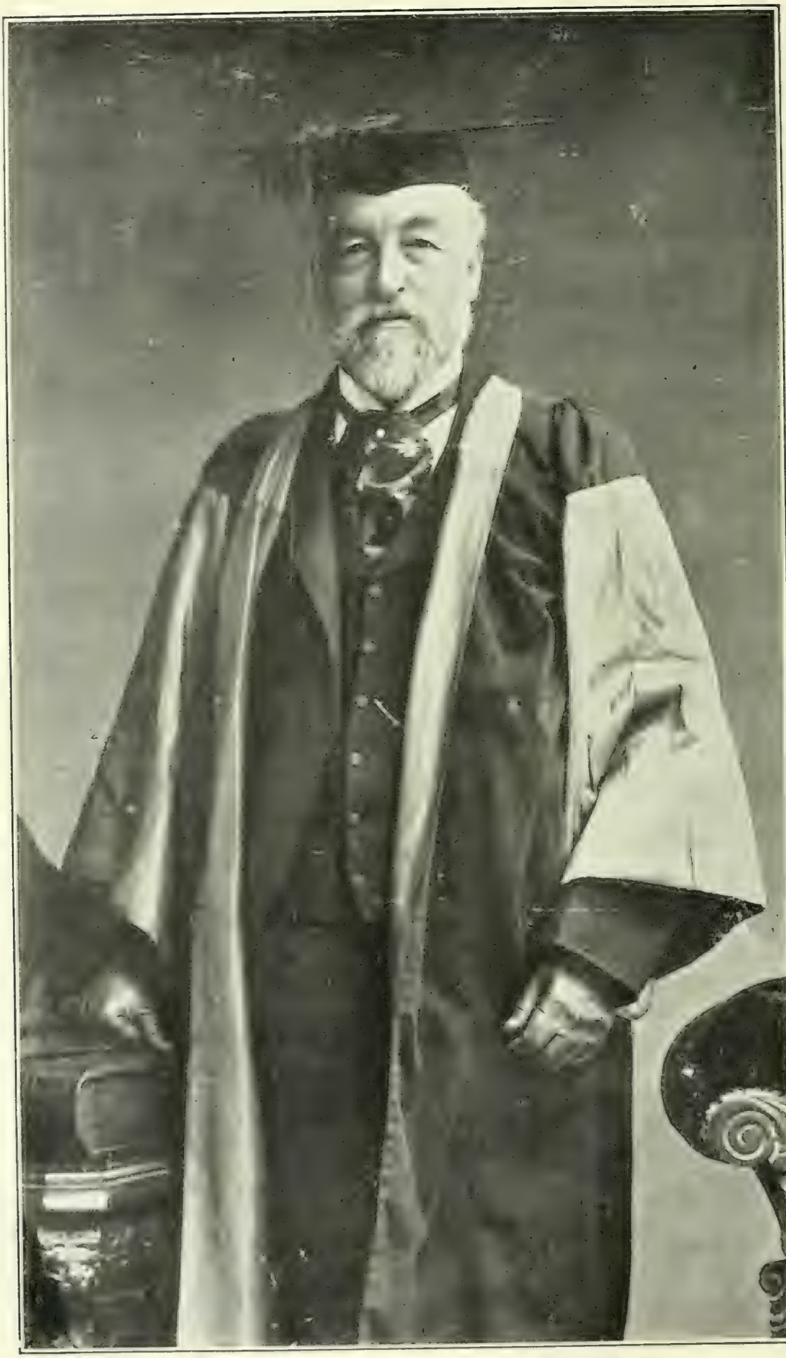
Summary

The above brief summary of paleontological evidences shows that in each geological period there are a few evidences of pathological processes known, although there has been no organized search made for diseased remains. In fact paleontologists as a rule have paid very little attention to evidences of pathology in fossil remains, though the subject is one which yields much that is interesting. The subject increases our vision as to the possibilities of medical history and extends our knowledge of the occurrence of disease back into geological time for many millions of years. No new ideas of pathology have been seen in the study of these ancient lesions—nor were any expected. Since the organization of animal and plant forms of ancient times differ in minute details only from those of recent times there is no reason why we should expect any new ideas. Doubtless many of the lesions described and figured above will on closer examination prove to be lesions of extinct diseases. We know from medieval history that diseases do become extinct and doubtless many of the diseases from which ancient animals suffered are now extinct. Their results, however, as seen in the fossilized bones, closely parallel the pathological anatomy of recent times.

[9] "Studies in Paleopathology. II., Pathological Evidences of Disease among Ancient Races of Man and Extinct Animals," *Surgery, Gynecology and Obstetrics*, 1918, figs. 1–45.

The question of extinction is still an open problem. A study of the paleontological evidences of disease, as seen in the bone lesions, does not help us much yet in an appreciation of what part disease may have played in extinction. The part may have been great, but this is a hypothetical assumption, based purely on analogy.

The subject of paleopathology and the significance of its study were first commented upon and developed by Sir Marc Armand Ruffer, while studying the lesions seen in Egyptian mummies. A study of fossil lesions is merely an extension of the work began by him but it broadens perceptibly the scope and value of paleopathology.



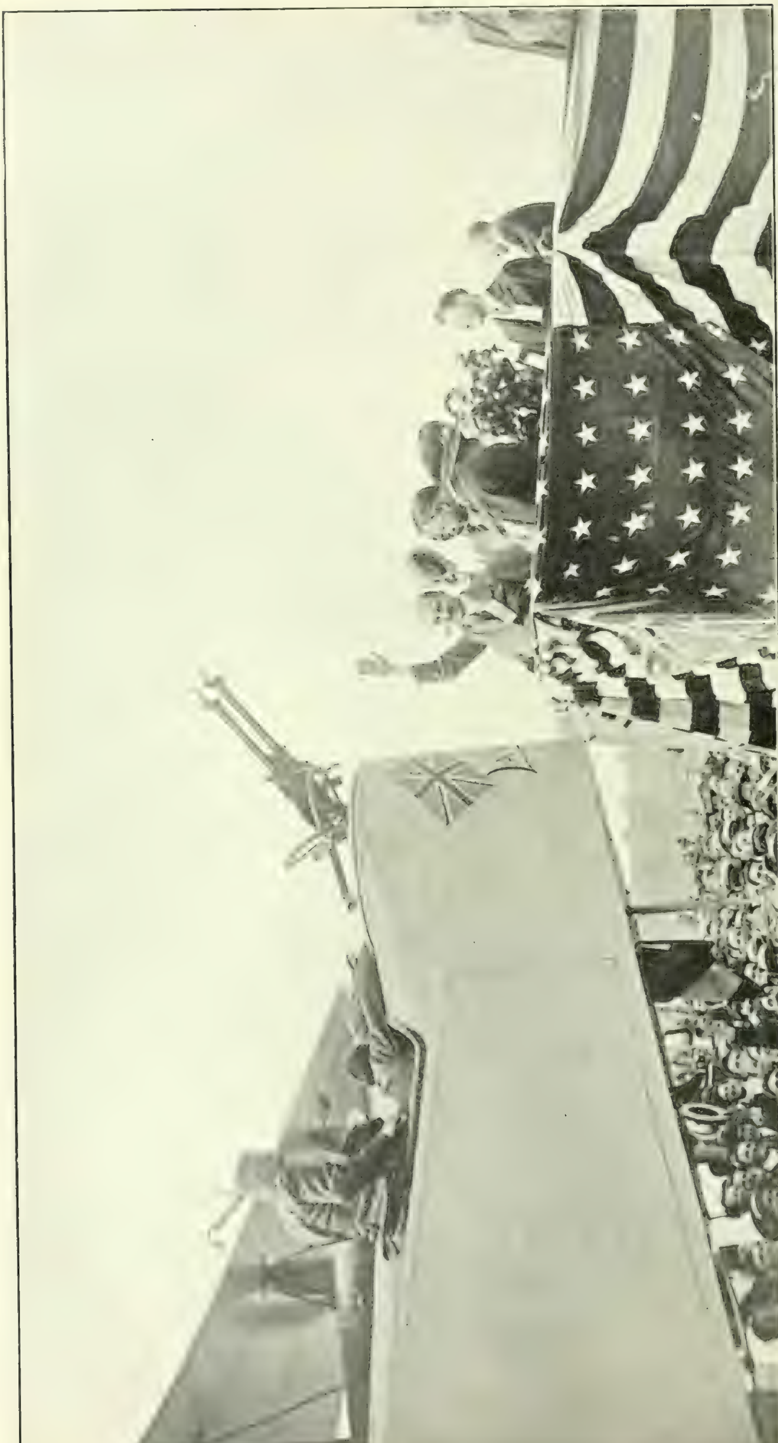
Samuel Pierpont Langley

THE "LANGLEY" IN FLIGHT

THE PROGRESS OF SCIENCE

THE LAUNCHING OF THE "LANGLEY"

For three inventions that have transformed modern warfare, the aeroplane, the submarine and the automobile, this country is in large measure responsible. Like other inventions, they have had a long course of evolution contributed through centuries by many lands, but the critical advances appear to have been made here. In the case of the automobile, including the truck and the tractor, and of the telephone, also of prime importance in warfare, the use has been most extensive in America. The aeroplane and the submarine, at present of use chiefly in warfare, have naturally had their principal development among the nations at war. But what has been accomplished here with the automobile and the telephone will be accomplished with



CHRISTENING OF THE "LANGLEY"

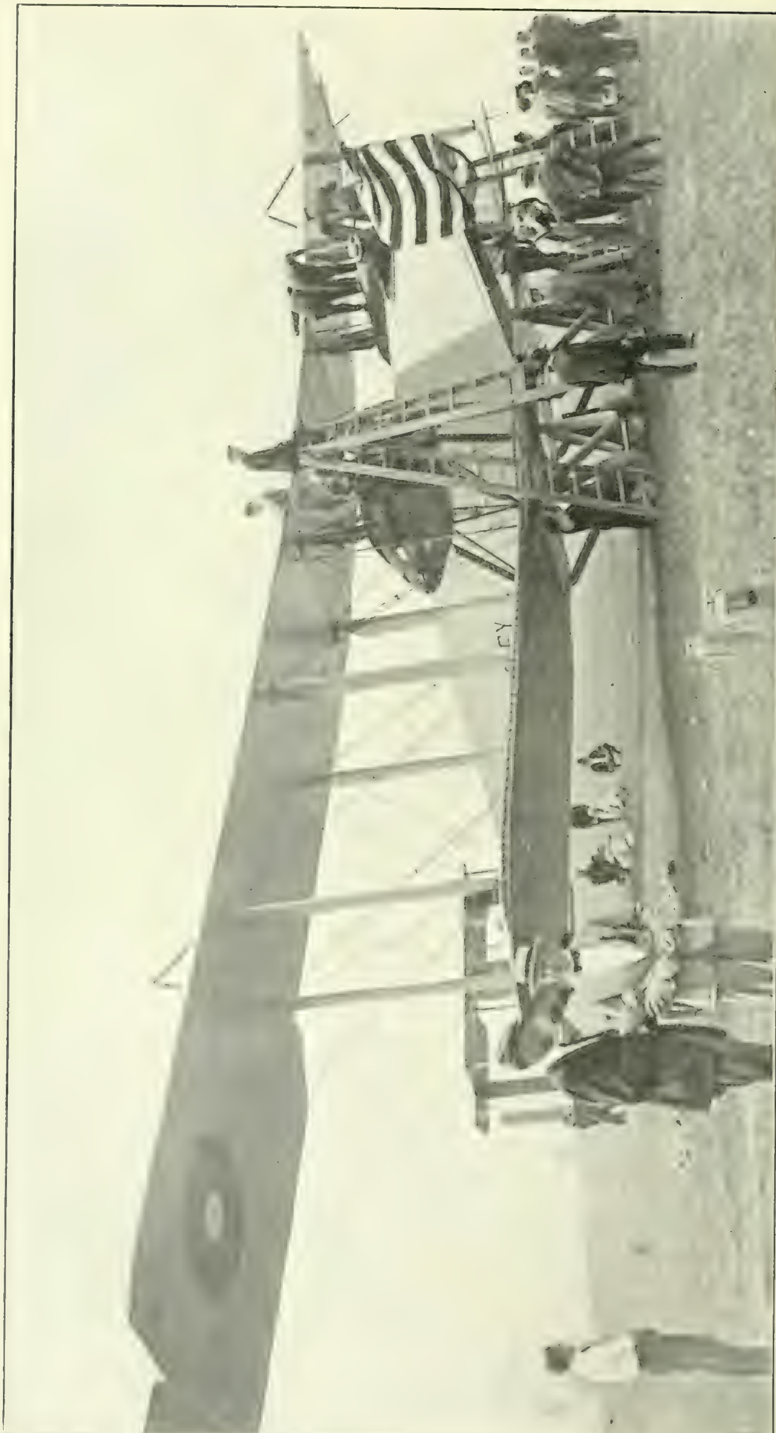
the aeroplane and the submarine, since they have become a necessity to us.

The production of aeroplanes on a large scale and the scientific research which created the aeroplane have been linked together by giving the name "Langley" to the first Handley-Page bombing machine built in America. This huge machine was launched on July 6 from the yards of the Standard Aircraft Corporation at Elizabeth, New Jersey. According to *Flying*, speeches were made by President Mingle, of the company, Assistant Secretary of War Crowell, Mr. John D. Ryan, director of aircraft production, and General William L. Kenly, director of military aeronautics, Sir Henry Fowler, representing the British government, for whom the machine was built, and Mr. Langley, nephew of Samuel Pierpont Langley, who said:

"My uncle, Professor Langley, was not more than fifteen or sixteen years old, while lying under a tree in the field, he gazed up and saw a hawk flying, and he said, 'If a hawk can fly, men can.' Twenty years later he took up that problem and put his whole efforts to investigate the action of plane surfaces, and he said, 'what were the vital facts that we must know,' and it was this first investigation of the air action upon plane surfaces that brought him to the attention of scientists, and they said, 'go ahead.' Since that time the world has been very kind in acknowledging his researches; for the application of his principles by the men of America and every other nation has now produced actual flying machines according to the calculations that he set down."

The Handley Page, with a wing spread of 100 feet and driven by twin Liberty motors of 400 horsepower each, has a range of 600 flying miles with an average speed of 90 miles per hour. The aeroplane

AERODROME IN FLIGHT, 1906



THE HANDLEY-PAGE BOMBING MACHINE, THE "LANGLEY" is of the O-400 type and was put into production in April. Without its cargo of bombs, the machine weighs 9,000 pounds and to drive it requires fuel consumption of approximately sixty gallons an hour. The Liberty motors are in an armored compartment on either side of the fuselage. In addition to its bombs, the machine also mounts two light Browning machine guns, which can be fired from any desired angle.

Samuel Pierpont Langley, secretary of the Smithsonian Institution, died on February 27, 1906, at the beginning of the era of mechanical flight to which his researches had so largely contributed. In 1905 the Wright Brothers remained in the air for half an hour but it was not until 1908 that they fully demonstrated the practicability of sustained flight. Langley began his experiments when he was director of the Allegheny Observatory, and in 1887 carried on experiments with free flight models. He showed as the result of experiment and theory that one-horse power would propel and sustain in horizontal flight at the velocity of about forty miles an hour somewhat more than two hundred pounds. In 1901 Langley began the construction of a light steam-engine as a motor. Daimler had invented the internal combustion engine in 1885, but it was necessary to await for the development of the automobile to demonstrate the remarkable combination of power and lightness in an engine which has made possible the contemporary aeroplane. Mr. Langley was, however, able to construct an aerodrome, as he called it, which weighed about 44 pounds and which flew for half a mile on May 6, 1896. In 1898 the War Department appropriated $50,000 for experiments with a man-carrying aerodrome. After many experiments and after overcoming many difficulties, the attempt was made to launch the aerodrome, with Mr. Manley as aviator, on October 7, 1903. Owing to defects in the launching the trial ended disastrously, and Mr. Manley narrowly escaped drowning. The experiment was repeated on December 8, when again the launching gear was at fault, and the aerodrome had no opportunity to demonstrate its power of flight. Owing mainly to ridicule in the newspapers and the fear of its effect on the Congress, the Army Board was unwilling to continue the work. The Langley aerodrome, however, with a new engine flew over Lake Kenka in June, 1918.

ANCIENT ARMOR ADOPTED TO MODERN WARFARE[1]

The war has brought back into use many discarded weapons and practices of medieval warfare. This is shown in the adoption of steel helmets by all the warring powers; in the use of heavy breastplates by the Germans, and lighter breastplates, for attack, by the English; in the armored waistcoats used by the Italians and in trench shields which all the armies are using. Because of this it has become desirable to review the entire study of ancient armor, to which for centuries some of the greatest artists and scientists gave their best efforts. To such masters of the science of armor design as Leonardo, Guilio Romano, Cellini, Holbein, Duerer, Michael Angelo, and others, are ordnance experts of today turning for guidance and inspiration. In fact, it can be stated that so completely were armored defenses studied in the past that today there is scarcely a technical idea brought forward which was not worked out in elaborate detail by the old-time armor makers.

Fortunately for the Ordnance Department, one of the greatest collec-

[1] Publication authorized by the War Department.

tions of ancient armor in the world, accessible to study by the American armor designers, is in the Metropolitan Museum of Art in New York City. This collection, ranking probably seventh in the world, now includes the famous Riggs Collection, which represents the life work of a wealthy student of the subject, and includes some of the richest and rarest pieces that have been in the market since 1850. It is as an incident to this collection that there was established at the museum an armorer's workshop. So far as is known it is unique. It was established for the purpose of cleaning, repairing, or, in rare cases, restoring pieces that were defective. To this end the museum has studied exhaustively the processes of making armor, and has collected from all parts of the world the tools of the ancient armorer's art.

When the war broke out, learning that the government was in need of skilled makers of models for the preparation of armor, Director Robinson, of the Metropolitan Museum, with the sanction of the trustees, placed the department of armor at the disposition of Secretary of War Baker. Since then numerous designs have been carefully worked out by Major Dean and actually made by Tachaux and his young French assistant, Sergt. Bartel, now of the Ordnance Department.

Major Dean, himself, was brought into the service of the Army in November, 1917. Owing to his lifelong study of the subject he was commissioned as a major and sent abroad at once to report on the status of armor. He returned to the United States late in January and has kept the armor workshop of the museum busy, week days and holidays, turning out models in accordance with the suggestions of General Pershing and the Ordnance Department. No less than 25 different types of armor defenses have been made in various factories in experimental lots, including in number from a few score to many thousand pieces, some of which have found favorable comment at American headquarters. These armor defenses include even arm and leg guards, the use of which was suggested by the study of hospital statistics in France and England. It appeared that more than 40 per cent. of the hospital casualties suffered were leg wounds, and no less than 33 per cent. arm wounds.

In connection with this work every effort has been made to improve the character of metal used in the armor making. A committee of the National Council of Defense, including the names of such armor experts as Alexander McMillan Welch, Edward Hubbard Litchfield, Ambrose Monnell, Dr. G. O. Brewster, and Clarence H. Mackay, has dealt especially with the problem of personal armor. And some of the most eminent metallurgists of the country, including those on the committee, have devoted almost their entire time to the question. Among these is Professor Henry M. Howe, of Columbia University, who has made an exhaustive study of helmet metal, aiming to give the American soldier better protection than the soldier of any other nation.

SCIENTIFIC ITEMS

We record with regret the death of Richard Rathbun, assistant secretary of the Smithsonian Institution, in charge of the National Museum; of Henry Shaler Williams, emeritus professor of geology at Cornell University; of John Duer Irving, professor of economic geology at Yale University, while engaged in war work in France; of Henry George Plimmer, professor of comparative pathology in the Imperial College of Science and Technology, and of Ludwig Edinger, director of the Neurologic Institute of Frankfort-on-Main.

THE SCIENTIFIC MONTHLY

OCTOBER, 1918

WEATHER CONTROLS OVER THE FIGHTING DURING THE SUMMER OF 1918[1]

By Professor ROBERT DeC. WARD

HARVARD UNIVERSITY

IT is obvious that so violent and so critical a series of military operations as those which have been taking place in the western war zone should, as a whole, continue in spite of temporary adverse weather conditions. It is, nevertheless, true that the student of military meteorology finds many noteworthy illustrations of weather controls even during the summer, which is meteorologically the most favorable season of the year for campaigning on the western front. It is to be borne in mind that the Germans had every reason for putting forth their utmost efforts during the spring and summer of 1918, in order, if possible, to gain a decisive victory before the winter should put a stop to active fighting, and before the spring of 1919 should bring the Allies a distinct superiority in man-power owing to the expected arrival of very large numbers of American troops.

May ended and June began with a spell of fine summer weather. The sun was hot, and the roads were deep in dust, which rose like smoke under the feet of the marching troops. Rains, the heavier and the longer-continued the better, were greatly to be desired by the Allied armies. For rain means mud, water-soaked bogs and swamps, and water-filled shell-craters. And rain and mud mean difficulties in the transportation of guns, of ammunition and of supplies. During the German offensive, early in the summer, delays of this sort interfered with the prompt execution of the enemy's carefully-laid plans, and gave added time for the Allies' reserves to gain in strength. Later on, when the enemy was making his forced retirements, bad weather and difficult transportation made it very

[1] Continued from the July, 1918, number of THE SCIENTIFIC MONTHLY.

much harder for the Germans to move back their artillery and ammunition, an enormous amount of which fell into the hands of the Allies. Mr. Philip Gibbs put the case very clearly in a despatch cabled to the New York *Times*.

> Last year in Flanders the rain, that began in August and hardly ceased until the end of November, created such foul conditions for the British troops that rapid progress in attack was utterly impossible, in spite of courage and will power reaching to the very heights of human nature. That was the British tragedy and German luck. Now, for the great offensive in the west, the enemy has again been favored by the weather. All through February and March, when the German armies were massing and making secret preparations for the assault on our line, the days and nights were dry and mild; the ground firm; the roads good, and all conditions favorable for the movement of men and guns. It has lasted like that ever since, with hardly a break, and the splendor of the last two months has given the enemy all the advantage for his plans and organization of attack.

A heavy rain storm on June 9 and 10 was noted as having temporarily delayed the Germans during a new advance, but another spell of fine weather immediately followed, again favoring the enemy by keeping the ground hard and dry. The New York *Times* correspondent, under date of June 13, cabled "the weather still holds good, but if the deluge comes it will for once be in our favor, and the more mud the merrier." After the middle of June (19th to 24th) there was about a week of showery, cloudy weather, but the month ended, and July began, with a spell of fine weather, interrupted, after the usual summer fashion, by showers or thunderstorms, which are noted as having benefited the French crops.

A new German offensive was launched on the morning of July 15. This had been expected for many days. As in previous instances of starting an enemy offensive, it is probable that the time was carefully chosen as a favorable one on the advice of the German meteorological experts, of whom there are reported to be sixty at the front.

The dominant fact in the later portion of the summer campaign was the steady and at times rapid retreat of the German armies. In this retreat, as above noted, rain and mud played an important part. As one correspondent put it (July 23), "there was a heavy rain to-day in the north of France, and each drop of it will alter a little, perhaps, the history of this war. . . . So let it rain."[2] Obviously, bad weather and deep mud also retarded the advance of the Allies, and hampered their artillery fire, as, *e. g.*, during the first week of August. The enforced abandonment of immense quantities of ammunitions and

[2] Philip Gibbs, in the *New York Times*.

supplies and of many heavy guns by the enemy was, however, a far more critical result of the meteorological conditions. The high water stages of the French rivers were a serious factor for the enemy to deal with. Recent rains had caused a flooding of the Vesle. The German rear-guards could not ford the river and had to fight for their lives. Most of them were killed, and the rest were taken prisoners. The rise of the river seems to have disorganized the whole German plan for protecting the withdrawal of the army. On the other hand, one despatch noted the fact that the Germans also were favored by the weather, which "transformed the banks of the Vesle into swamps and morasses," enabling the enemy to make "a stiffer stand here than was to be expected." The rains, swollen rivers and mud of the first week of August, which retarded the Allied pursuit and prevented them from bringing up their guns, ammunition and supplies, were probably a more important factor in slackening the Allied advance than was the resistance offered by the Germans.

Many illustrations might be given of the part played by weather conditions in local engagements. Thus, a German surprise attack, to regain Bouresches, was made on a dark cloudy night (June 13), but had been anticipated by the American troops who realized that the weather was ideal for just such an attempt. A French-American counter-attack along a broad front on the early morning of June 18 was wholly unexpected by the enemy, who had been driven to shelter in his dugouts by a violent thunderstorm which burst shortly after midnight. The noise of the storm drowned out the noise of the Allied barrage fire, and the Allied tanks took up their positions unnoticed. The frequent night fogs of the western front have often played a part in the fighting. On July 15, the Germans on the north bank of the Marne advanced at dawn under cover of a fog. Again, on July 30, a heavy fog favored a German attack on the north bank of the Ourcq. An important combined British and French attack on the German lines between Amiens and Montdidier caused the enemy to retreat on the first day over a front of more than 20 miles. This attack took the enemy completely by surprise. A thick fog had begun to form early the night before, and by dawn had completely covered not only the valleys but the higher ground also. At daylight, the fog "lay so thick it was impossible to see more than 30 yards" in any direction. Following a short but intense artillery preparation, the Allied troops advanced through the fog, taking the enemy completely by surprise. The men in advance of the attacking troops "were met only by rifles and machine guns, firing vaguely through the fog." By nine o'clock in the morning the fog was lifting, but the enemy was in retreat. At dawn on August 21, the British smashed into Gen. von Below's seventeenth army during a heavy fog, on a front extending more than ten miles from the Ancre River to Moyenneville. The infantrymen and the tank crews "could scarcely see 100 ft. ahead of them." The fog was most favorable to the attacking troops, for it effectively concealed them from the eyes of the enemy, who suffered heavy casualties and lost many guns. Some of the British tanks and battalions are reported to have lost their direction, and this led to some confusion, but the advantages due to the fog were far greater than the disadvantages.

In mid-August (14th) "glorious weather" was reported on the Picardy battlefront. The Allied airplanes were able to observe the enemy's movements, and to know where he was concentrating his reinforcements. "Stifling weather" prevailed during most of the fighting around Lassigny (third week of August). The men fought "under a scorching sun"; stripped to the waist. Heavy rains fell late in August, but, in spite of this handicap, the Allied troops pressed on in their general advance.

A part of the responsibility which the United States is taking in the war is the increasing contribution which we are making to the Allied military meteorological service overseas. Several expert meteorologists, commissioned as officers of the Signal Corps, have been in France for some time. Three hundred Army meteorological observers, especially selected, and trained for their work at the Agricultural and Mechanical College of Texas, have recently been sent abroad. The War Department, it is announced, plans to train 1,000 men in all for this highly important service. Once a day a summary of weather conditions over the United States is cabled from Washington to the Headquarters of the American Expeditionary Force in France. The regular forecasts of weather conditions on the western front, based in part upon these observations, are now regularly used by American officers in planning airplane activity, artillery work, and military operations generally. In connection with meteorological activities overseas, it is significant that Sir Napier Shaw, who has for nearly fifteen years been director of the British Meteorological Office, has recently been appointed scientific adviser on meteorology to his government, for the duration of the war.

Although the summer has only just ended, the need of keeping the American troops overseas warm during the damp and chilly autumn and winter months has already been given serious attention. That the lack of an adequate fuel supply in France will lead to much suffering on the part of the men is inevitable. Although many of the American troops are accustomed to much greater outdoor cold at home than they will ever experience on the western front, they are used to *dry* cold, and to warm houses.

The Austrian drive began June 15. Offensive operations had been attempted several times in the late spring, but the lingering snows of winter, snowslides, and deep-flowing mountain torrents prevented any large scale campaigning. A June 7 despatch had referred to the Austrian "spring drive" as imminent, the floods in the Piave, resulting from melting snows, having subsided, but bad weather on June 13 was reported as still hindering operations. The morning selected for the Austrian advance was "more than usually" foggy in the mountain sector. The snow still lying in the mountains was "heaped up into immense mounds by the bombardment," and the Italian troops wore white overalls as a protection in the snow. Bad weather during the next three days limited operations, and the heavy rain helped to minimize the effects of the gases, which were used in large amounts by the Austrians.

The most striking meteorological factor during the whole summer campaign on the Austro-Italian front was the flooding of the Piave River within a few days after the Austrian advance across it. This flood, the result of the heavy rains which fell for about a week in the mountains and on the Venetian lowland, turned the river from a by no means formidable military obstacle into a rushing torrent. Thirteen out of fifteen pontoon bridges built by the enemy were swept away. It thus became extremely difficult, if not altogether impossible, to supply such of the Austrian troops as had crossed to the western bank (reported as numbering about 40,000) with reinforcements, artillery, ammunition and food. In fact, the troops on the western bank were soon completely isolated, such bridges as were not swept away by the flood being bombed by British and Italian aviators. One report noted that the isolated Austrians were for a time fed by means of airplanes. In the face of persistent Italian counter-attacks, with their bridges washed away or destroyed, and all efforts to rebuild them proving futile, the enemy was obliged to recross the raging Piave under the most difficult and dangerous conditions, in great disorder, all along the line from Montello to the sea. Thousands of the enemy were drowned, or shot in the water. The Austrian loss was put at about 200,000 killed, and 20,000 taken prisoner. The defeat of the enemy on the west bank was complete, and the Italian line was restored up to the water's edge. The Austrian War

Office, under date of June 24, announced: "A position has arisen by reason of the height of the water, and bad weather, which has caused us to evacuate Montello and some sectors of the other positions which we had won on the right bank of the Piave." Answering criticisms on the subject of the retreat, made in the Hungarian Parliament on June 29, Major Gen. von Szurmay, Minister of National Defence, said: "No one could have foreseen the heavy rain which caused the Piave to rise."

It is, however, manifestly unfair to the splendid work done by the Italian armies to leave the impression that the Piave floods alone were responsible for the Austrian retreat. The enemy's advance was doubtless checked before the floods began. The latter, however, made it impossible for the Austrians to keep anything that they had previously gained on the west bank. It was natural enough that the Austrians should have attributed their defeat to nature, and not to their opponents. Thus, a war correspondent of the Vienna *Neue Freie Presse* (July 2) said, "not the Italians, but the rain triumphed. Nature," he continued, "interposed its inexorable and cruel veto."

There is little to record regarding the operations in the Balkans. Bad weather was stated in several of the early summer despatches to be responsible for the inactivity. Regarding the Allied operations in Albania, a Paris War Office despatch of July 24 said: "Our attacks have succeeded by reason of perfect preparation and the bravery of our troops, who, in the course of engagements carried out sometimes in snowstorms and sometimes under an unbearable sun in a very difficult country, have by their skill and resolution taken indisputable ascendency over their adversary."

The important war activities on the former eastern (Russian) front have been in connection with the landing of Allied troops on the Murman Coast. This northern region gains its chief importance because it has an ice-free port, the result of the presence of a warm ocean current (Gulf Stream drift) alongshore. From this port, a railroad of strategic value runs to Petrograd.

No large-scale military operations have been reported from Mesopotamia, where the heat of the summer is such as to make active campaigning extremely difficult and dangerous. In spite of many climatic and topographic handicaps, however, a British force succeeded in reaching Baku early in August, but details of this march are not yet available. They will be of very unusual interest when they are made public. As fuller information comes to hand regarding the earlier operations in Mesopotamia, the extraordinary difficulties under which the British Expeditionary Force has been carrying on its important and almost forgotten advance in that land of heat, and dust, and floods, stand out in a clearer light. No correspondent has had a better opportunity to see what has actually been accomplished by the British forces in Mesopotamia than Mrs. Eleanor Franklin Egan, whose admirable articles in the *Saturday Evening Post* have given a vivid and accurate picture of the country itself, as well as of the activities of the British Expedition. Mrs. Egan notes that in a book of instructions to British officers regarding equipment for Mesopotamian service the following advice is given: "To spend a year in this detestable land you will require three outfits of clothing—one suitable for an English winter; one suitable for an English summer, and an outfit suitable for Hades." In Mesopotamia, "climate gets more attention than any other one thing, and it is the first thing to be taken into consideration in every move that is made." During the late spring, summer and early fall, temperatures of over 110° F. are regularly reached, and under canvas the thermometer often reaches 130°. No records are available of the loss of life due to the heat during the first campaign in 1915, when no adequate preparations to meet this inevitable emergency had been made, but in the summer of 1917, 519 men of the Expeditionary Force died of heat and sunstroke, in spite of every possible precaution. Ice plants are now provided wherever there are British troops. Every hospital has a special sunstroke hut or tent which is always kept ready for the instant treatment of all cases. Sun helmets and "spine pads" must be worn throughout the hot months, and not until some time late in November do the orders of the day give the British soldier permission to leave these off after four o'clock in the afternoon.

In striking contrast with the intense heat and dryness of the Mesopotamian summer are the spring rains, and the floods resulting from the melting snows far up in the Armenian mountains. These floods, spreading far and wide over the lowlands, played an important part in the early days of the expedition, and are to be expected every year at about the same time. "Nobody who has ever lived through a spring and early summer in Mesopotamia," says Mrs. Egan, "doubts the story of the Flood." Another meteorological feature of this desert, as of other deserts, is the mirage. In the early days of the Mesopotamian campaign there was one engagement in which a mirage played a conspicuous part in turning the fight to the advantage of the British. The latter were being hard pressed. Their commanding officer was on the point of ordering a retirement, when suddenly the enemy were seen to be in full retreat. The Turkish commander, deceived by a mirage, saw what seemed to him to be heavy British reinforcements approaching, and directed his troops to retreat at once. It was only a British supply and ambulance train, 'magnified and multiplied by the deceptive desert atmosphere." The Turks stampeded, and were pursued by bands of nomadic Arabs for a distance of nearly ninety miles across the desert. It is reported that the Turkish commander discovered his mistake a few days later, and committed suicide.

From Palestine there have been no reports of either military or meteorological interest. Doubtless there, too, military activity has been greatly curtailed by the heat and drought of the summer. One belated communication, from Jerusalem, notes the fact that the winter (1917–18) was "long and cold—so the poor Tommies think. But it has been the best winter since the war set in. We have had no snow."

In aviation, it is increasingly evident that weather conditions which earlier in the war were regarded as prohibitive for flying, are now interfering less and less, at least so far as bombing is concerned. High winds, low clouds and fog, and heavy rain, decidedly lessen aerial activity, and spells of fine weather always greatly increase it, yet month by month, as the reports come in, it is evident that in the intensity of this modern warfare, flying must be done in practically all weather. Nevertheless, aerial reconnaissance and photography, and direction of artillery firing from airplanes, can not be effectively carried out unless there is a reasonably clear view of the ground. The advantage which the prevailing westerly winds give to the enemy aviators on the Western Front is readily recognized. A London despatch, dated July 23, notes that

> the weather admittedly plays an important part in the defense of England against German air raids. The time will shortly arrive when more or less settled conditions can be expected to prevail, and with the approach of that date speculation grows keen as to what "the long-range bombing season" is likely to bring forth.

One of the new developments in aviation is "cloud formation flying," which has been decribed by Brig. Gen. Charles Lee, of the British Aviation Mission now in this country.[3] "Cloud flying is to-day a necessity," although until recently pilots have hesitated to go into clouds except for defensive purposes. The machines go in formation through the clouds, meeting again above the clouds. There the formation is continued on a compass bearing to the objective. The machines then come down through the clouds; bomb the objective; go up again, and come home.

[3] *New York Times*, August 18, 1918.

The use of gas shells, instead of the clouds of chlorine gas which the Germans so generally employed in the earlier days of the war, has in no way overcome the importance of the wind direction as a factor in a successful gas attack. There are several reports of a change of wind during a gas attack, which drove the gases back to the enemy lines. On June 10, on the western front, "the wind changed its direction, and tens of thousands of poison gas shells fired by the Germans did more damage to themselves than to the Allies." On July 15, a Paris despatch noted the favorable weather conditions which prevailed for the Allied armies.

> For once the Germans are not favored by the elements. The sky is overcast, the weather is unsettled, and, most important, the wind is southwest. This is a vital gain for the defense, for it makes it difficult, if not impossible, for the Germans to make extensive use of gas, on which they usually count. Cohesive action is out of the question when troops are muzzled for long hours with masks. Officers can not communicate orders, and each man is thrown on his own resources. As a result, weight of numbers, which is always on the side of the attacking army at the beginning, becomes the deciding factor.

Again, on August 6, in the Fismes sector, a change of wind to the south blew the gas back from the American lines and towards the enemy.

In connection with gas attacks in general it is worth recording that at the very beginning of the use of gas clouds the importance of a knowledge of the wind direction was recognized by the British and French troops in the trenches. Various devices were employed to serve as wind vanes. Anything that could easily be seen by the enemy naturally drew fire. A simple vane was then devised, consisting of a stick with a thread about a foot long fastened at the upper end of it, and with a small piece of cotton wool at the end of the thread. The strength of the wind was indicated by the rise of the cotton wool from a vertical position. Night was soon found to be the best for chlorine gas attacks, because the moving air then has a greater tendency to flow down any slopes, and to keep the gas cloud near the ground. By day, on the other hand, the general tendency of the air is upward, and this is likely to dissipate the gas.

The question of the most favorable weather conditions for the use of gas, and for general military operations on the western front, is one which can easily be answered by any one who has some knowledge of European weather types. The Germans want a weather type distinguished by high pressure over northern or northeastern Europe. This gives them clear skies, and generally light *easterly* winds, blowing toward the Allied lines. This is a fairly "settled" weather type. It comes on slowly, and the German meteorological experts, with the help of such weather maps as they are able to construct, can usually predict the continuance of this weather type for several days. This is, doubtless, one of the principal reasons why the Germans have on the whole so distinctly had the best of the weather situation ever since the war began. On the other hand, the Allies on the western front need southwesterly winds for their gas attacks. These usually occur during the passage of an area of low pressure; are therefore apt to be of fairly high velocity, and to be accompanied by clouds and rain. Furthermore, this type is characteristically of rather short duration. The advantage in this matter thus clearly lies with the Germans. At the end of August it was noted that the Germans were using little gas because the wind was unfavorable.

The destruction, by Commander Rizzo, of an Austrian battleship[4] off the Dalmatian coast early in June was favored by a fog, which prevented the attacking Italian motor boats from being seen as they worked their way through the screen of enemy destroyers. In our own waters, the German submarine which attacked an ocean-going tug and its convoy of barges off Cape Cod on July 21 approached unseen in a fog.

The importance of the food supply of Germany as a factor in the duration of the war gives interest to all reports regarding the German and Austrian crops, although too much weight should certainly not be laid on the cabled news. An Amsterdam despatch of June 7 mentioned a "sudden cold wave" over Central Europe, with severe frosts, which caused widespread damage to grain, fruit and potatoes. In a despatch from London, June 27, reference is made to *snow* from one to three inches deep in several parts of Germany. From Zurich, July 5, a report comes of violent rain-storms and abnormally low temperatures in Austria-Hungary, with "severe snowstorms and frost in Bosnia, Herzegovina and Dalmatia." The snowfall continued for several hours, and greatly damaged the crops. It may be noted in connection with these reports of snow in summer, that brief snowfalls, coming chiefly in thunderstorms, are not uncommon on mountains and high plateaus, even in the hottest season of the year. Later Amsterdam and Zurich reports (July 8 and 10) mention severe floods in many parts of Austria and Southern Germany. The Danube at Vienna reached the highest level in thirty years. A more detailed report (July 22) notes that in Germany spring drought and heat were followed by frosts early in June, one third of the potato crop being killed and other vegetables and fruits being severely affected. Trade reports generally agreed in saying that the crop outlook in both countries was unfavorable.

[4] Probably two battleships were destroyed.

IDENTIFICATION OF INDIVIDUALS BY MEANS OF FINGERPRINTS, PALMPRINTS AND SOLEPRINTS

By G. TYLER MAIRS

BROOKLYN, N. Y.

A FINGERPRINT may be defined as an impression from the ridge crests of the friction-skin of the ventral surface of a digit. As the terminal phalange is the only one constantly exhibiting a "pattern" configuration, it is the one utilized for making identification records, although an identification may as accurately be made from an impression of either remaining phalange, or the palm of the hand or the sole of the foot. An impression may be naturally or artificially made. By "naturally" is meant the absence of any transfer medium other than nature's perspiration residuum. A natural print is also sometimes called a "latent" print, because it is often invisible, and, to make a permanent record available for inspection and comparison, it must be visualized and fixed by one of the usual methods. A natural print may be intentionally or unintentionally made.

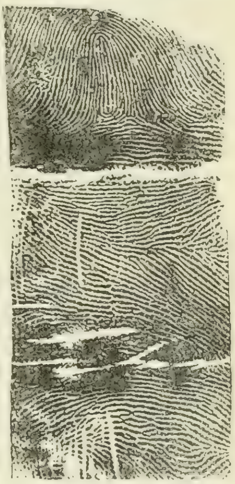


FIG. 1. A *rolled* digital impression. The apical portion is the "fingerprint" of commerce.

An artificial impression may be intentionally or unintentionally made, but the medium for recording it is externally applied and is not nature's skin excretions; for example, paint on the hand of a painter; grease on a mechanic's hand; blood on the hand of a butcher; ink on a printer's hand; or the surface is purposely inked as in commercial and institutional spheres. Artificial impressions made with oil, cold cream or other invisible medium must be visualized and fixed as are latent prints.

Mechanically, there are two kinds of fingerprints: *plain* and *rolled*. The *plain* impression is the one used exclusively by the Chinese, by Purkenje, and later by Herschel. This is made by placing the bulb of the finger flat upon the inking surface and then upon the receiving surface, the resulting impression being elliptical in shape, the long axis being that of the finger itself. The *rolled* impression is made by placing the digit on the inking surface, radial side in contact, the finger-nail perpendicular to the inking surface, then rolling the bulb of the finger until the ulnar side is in contact and the nail is again perpendicular but reversed in position. The bulb being thus inked, the same operations are repeated on a paper form suitable for recording the impression. This operation produces a cylindrical projection of the ventral surface of the digit which graphically delineates the ridge configuration in all its minutiæ.

Thus it will be seen that a friction-skin impression (finger, palm or sole) is a graphical record, by personal contact, of an external physical characteristic capable of being recorded for future reference. It possesses no occult powers of character revelation, but in its gross and minute features is so permanently individual that it is an unerring revealer of personal identity throughout one's lifetime and as long thereafter as the cutis is preserved.

Galton states that:

> With regard to the durability of the epidermic ridges they are still present and plainly seen in many Egyptian mummies.

Wilder says that:

> In an experiment made by him upon the feet of an infant belonging to the prehistoric cliff dwellers of Southern Utah, where bodies were not even embalmed, but simply dried in the rarefied mountain air, the thenar and apical patterns could be definitely traced after a comparatively simple preliminary treatment.[1]

The evolution of the use of the fingerprint and palmprint for personal identification, from the superstitious ceremonial of the ancient Chinese to the refined science of to-day, is, strange to say, a matter of the last sixty years, especially the last thirty years, since Sir Francis Galton placed the fingerprint, and Dr. Harris Hawthorne Wilder, zoologist, placed the palm- and soleprints upon firm scientific foundations. For the Oriental history of their use the reader is referred to Galton's "Finger Prints," Chapter II., and to Mr. Berthold Laufer's "History of the Fingerprint System" (Smithsonian Report, 1912, pp. 631–652). Reading these together, it would seem that the potency of a finger- or palmprint lay more in the ceremonial factor of personal contact necessary in making them, together with the fear of the consequences following a repudiation of a mark so solemnly made, than in any realization of

[1] Dr. H. H. Wilder, "Scientific Palmistry," Pop. Sci. Mo., November, 1902, p. 53.

their inherent individuality. Yet a desire or intent to identify through their use is evident, for their language contained words expressing the act "to identify," also nouns indicating the patterns we call the "whorl," "loop" and "arch."[2] But such identifications were evidently accomplished by written description in the case of babies in foundling homes,[3] and by smudgy and indifferent prints for adults, each verified, evidently without the use of the magnifying lens, as it probably at that early date had no general commercial distribution, if indeed it were known outside of educated and wealthy circles.[4] Therefore,

[2] Laufer, Smithsonian Report, 1912, p. 639 and footnote.

[3] *Ibid.*, p. 639, ". . . There follows a description of the bodily parts including remarks on the extremities, formation of the skull, crown of the head, birth marks, and design on the fingertips, for later identification. . . . Each Chinese mother is familiar with the finger marks of her newborn." The quality of this "familiarity" may be better imagined after examining the next newborn without a magnifier.

[4] "Lenses, Their History, Theory and Manufacture," *Optical Journal*, Vol. XIX., May, 1907, page 644, by Mr. J. J. Bausch and Mr. Henry Lomb.

In this historical sketch no indication of Oriental genesis or use is made. The first use of spectacles is placed at about 1285, the invention of d'Armato, of Florence. In Part II., page 728, "Lenses, among the Ancients," they say:

"In point of antiquity lenses as aids to imperfect vision lead all others . . . and still they are comparatively modern, for although we have no authentic records, the consensus of opinion seems to place the invention of spectacles in the thirteenth or fourteenth century. We can say with certainty that the Greeks and Romans of antiquity were unacquainted with glass lenses of long focus, nor do the larger collections in European museums contain any examples, although there have been found in various places convex lenses of short focus made of glass or of rock crystal. There was found in a grave in Nola a plano-convex piece of glass about 4.5 cm. diameter mounted in gold; in Mayence one of 5.5 cm. diameter; a similar one in Pompeii; a bi-convex one in England; finally the oldest lens we have, a plano-convex lens found in Ninevah, of rock crystal. . . . It is remarkable that all these are convex lenses. The fact that lenses have been so seldom found, that the one is mounted in gold, leads to the assumption that they were the rare possessions of wealthy and prominent people. While these lenses were not spectacle lenses in our sense because of their short focus, still we are forced to assume that they were used as burning and magnifying glasses. Passages in Plinius and Seneca show us that the Greeks and Romans were well acquainted with the magnifying power of a globe filled with water, but they ascribed to the water, not to the curved surface, the fact that by means of such an object they could decipher small illegible script. . . . Cicero mentions an 'Iliad' of Homer written on parchment which was comprised in a nutshell. Pliny tells that a Milesian executed in ivory a square figure which a fly covered with its wings. Unless their vision surpassed that of the most skilful modern artists these facts prove that the magnifying power of lenses was known to the Greeks and Romans two thousand years ago."

an identification must have contemplated, in the case of babies at least, only the most superficial resemblance between two "tou" (whorls), or two "ki" (loops), or two "lo" (arches). Of course an arch could be distinguished from a whorl or a loop without a magnifier, but to distinguish between two arches for instance, having a degree of likeness closely approximating identity (see Fig. 10 *a* and *b*), the absence of the magnifier would certainly preclude any such accurate discrimination as is absolutely necessary to-day. Aside from the prints themselves, this absence of any realization of and reliance upon the individuality of the friction-skin configuration seems clearly shown by Rashidudden, the famous Persian historian, who wrote in 1303 as follows (extract from "Cathay," by H. Yule, Vol. III., p. 123):

> Extracted from the Historical Cyclopedia of Rashidudden. . . .
>
> Lastly, the business arrives at the sixth board, which is called Siushtah. All ambassadors and foreign merchants when arriving and departing have to present themselves at this office, which is the one which issues orders in council and passports. . . .
>
> When matters have passed these six boards, they are remitted to the Council of State, or Sing, where they are discussed, and the decision is issued after being verified by the Khat Angusht or "finger-signature" of all who have a right to a voice in the Council. This "finger-signature" indicates that the act, to which it is attached in attestation, has been discussed and definitely approved by those whose mark has thus been put upon it.
>
> It is *usual* in Cathay, when any contract is entered into, for the outline of the fingers of the parties to be traced upon the document. For experience shows that no two individuals have fingers precisely alike. The hand of the contracting party is set upon the back of the paper containing the deed, and *lines are then traced around his fingers up to the knuckles* in order that if ever one of them should deny his obligation this *tracing* may be compared with his fingers and he may thus be convicted.

Here the fingerprint is not even suggested, but a sort of ceremonial is used involving the five fingers, the desired psychic effect being accomplished by very formally tracing lines "around his fingers up to the knuckles," evidently such as the children of to-day trace in playing the game of *tit-tat-toe*. To us, this is a most crude method of identification, but it must have worked or it would not have been "usual," for the psychology of fear was doubtless as potent then as now, although perhaps not so clearly understood. At any rate, this ancient use of fingerprints, finger-outlines and handprints has none but historical interest for us. Nothing of any scientific value has as yet come down to us by virtue of its own worth or momentum as it were, *e. g.*, the silk worm and silk. Galton observes (1897):

No account has yet reached me of trials in any of their courts of law about disputed signatures, in which the identity of the party who was said to have signed with his fingerprint had been established or disproved by comparing it with a print made by him then and there.

Fifteen years later (1912) Mr. Laufer observes:

Indeed, it is striking that we do not find in any author a clear description of it and its application. The physicians in their exposition of the anatomy of the human body do not allude to it, and it is certain that it was not anatomical or medical studies which called it into existence. It formed part of the domain of folklore, but not of scholarly erudition.

In this connection Mr. Laufer makes (p. 645) an interesting citation from A. H. Smith's "Proverbs and Common Sayings from the Chinese," thus:

The Chinese, like the Gypsies and many other peoples, tell fortunes by the lines upon the inside of the fingers. The circular striæ upon the finger tips are called "*tou*," a peck; while those which are curved, without forming a circle, are styled "*ki*," being supposed to resemble a dust pan. Hence the following saying:

"One peck, poor; two pecks, rich; three pecks, four pecks, open a pawnshop; five pecks, be a go-between; six pecks, be a thief; seven pecks, meet calamities; eight pecks, eat chaff; nine pecks and one dust pan, no work to do—eat till you are old."

How different the contributory beginnings of the present-day scientific identification! It was *a physician* in his exposition of the anatomy of the human body who first called attention to the friction-ridge patterns—"M. Malpighi, 1686 A.D., quoted by Alix, 1867, and by Schlaginhaufen, 1905."[5] Again, in 1823, another physician, J. E. Purkenje, in a now famous thesis, partially translated by Galton, went still farther and described and classified the various ridge configurations as shown by "plain" impressions.[6] The late Sir William J. Herschel makes an additional citation from this thesis which is interesting; he says:

Referring to "the varieties of the tonsils, and especially of the papillæ of the tongue, in different individuals" (no mention of fingers) he finishes his sentence and his essay by saying: "From all of which (varieties) sound materials will be furnished for that *individual knowledge of the man* which is of no less importance than a general knowledge of him is, especially in the practise of medicine." Herschel adds: "No part of his essay conveys an inkling of identification by means of any of the individual varieties on which he always lays stress, not even his pioneer work in the classification of the markings on fingers."[7]

[5] Wilder, "Bibliography of Friction-skin Configuration," *Biological Bulletin*, Vol. XXX., No. 2, page 249.

[6] Galton, "Finger Prints," pp. 85–88 and plate.

[7] Herschel, "The Origin of Finger Printing," p. 35 (1916).

Concerning the labors of the late Sir William J. Herschel in the application of the idea of friction-skin identification, Sir Francis Galton, writing at a time when the facts considered were a matter of Galton's personal knowledge, states his conclusions thus:

> If the use of fingerprints ever becomes of general importance, Sir William Herschel must be regarded as the first who devised a feasible method for regular use, and afterward officially adopted it.[8]

No allusion is made to the "discovery"[9] of their use by Herschel, the emphasis being on "the first to devise a feasible method for their regular use." Galton had already cited their prior use in his introductory chapter, saying:

> The second chapter treats of the previous employment of fingerprints among the various nations, which has been almost wholly confined to making daubs, without paying any regard to the delicate lineations with which this book alone is concerned. Their object was partly superstitious and partly ceremonial: superstitious, so far as a personal contact between the finger and the document was supposed to be of mysterious efficacy; ceremonial, as a formal act whose due performance in the presence of others could be attested.[10]

Again in Chapter II.,

> Though mere smudges, they serve in a slight degree to individualize the signer. . . . The ridges dealt with in this book could not be seen at all in such rude prints, much less could they be utilized as strictly distinctive features.[11]

Read in connection with Galton's conclusions, Herschel's "Origin of Finger Printing" tells us how the idea of this as a "feasible method" developed in his mind, and gives the evolution of the method "for regular use." "There was nothing very original about that, as an idea," says Herschel, concerning his taking of Konai's handprint.[12] The change of method came quickly, but the idea of judicial sanction after "many years." Herschel says:

> Trials with my own fingers soon showed me the advantage of using them instead of the whole hand for the purpose then in view, *i. e.*, for securing a signature which the writer [maker] would obviously hesitate to

[8] Galton, "Finger Prints," Ch. II., p. 28.

[9] Herschel, "The Origin of Finger Printing," page 32. Here Herschel claims only the "discovery of the *value* of finger prints."

[10] Galton, introductory chapter, page 3.

[11] Galton, Ch. II., p. 23. Also Laufer's "History," Plate 3, showing two thumb smudges on a Tibetian promissory note. The print on Plate I., recorded as late as A.D. 1839, is reasonably clear. Its clearness may have been intentional.

[12] Herschel, "Origin of Finger Printing," page 8.

disown. [The old idea of fear again utilized.] That he might be infallibly convicted of perjury if he did, is a very different matter. That was not settled, and could not have been settled, to the satisfaction of courts of justice, till, after many years, abundant agreement had been reached among ordinary people [jurors?]. The very possibility of such a "sanction" to the use of a fingerprint did not dawn upon me till after long experience, and even then it became no more than a personal conviction for many years more.[13]

The researches of Sir Francis Galton were begun in 1880.[14] Their results were epochal. Pre-Galtonian prints were exclusively the "plain" impressions of to-day, amply sufficient for identification, but not for that precise classification so necessary for the modern Fingerprint Record File. Galton's introduction of the "rolled" impression or cylindrical projection of the finger; the utilization of the "minute triangular plot" or delta (Wilder's tri-radius) found in all rolled impressions (except that of the arch) as "corner stones" of his classification system; the substitution for a single "plain" impression of a complete series of ten rolled impressions, with plain impressions of the fingers as a check on printing the rolled impressions in proper sequence; together with his researches concerning the individual persistence of the ridge configuration (the results of which have been accepted as proof of persistency) made possible the present-day scientific systems of fingerprint identification. His conclusions on persistency have been amply confirmed by the late Sir William J. Herschel's series of impressions from two of his own fingers, the first taken in 1859, at the age of twenty-six years; the second, in 1877, and the third, in 1916, at the age of eighty-three years, a total interval of fifty-seven years, and, as he remarks:

For length of persistence they can not at present be matched.[15]

As Herschel gave of the fruits of his labors to Galton, so, in turn, Galton gave to Sir Edward Richard Henry, G. C. V. O., Commissioner of Police of the Metropolis, London, England. Sir Henry says:

In the system here described, many of his (Galton's) terms have been adopted, definitions accepted and suggestions followed whenever practicable.[16]

Upon this Galtonian foundation Sir Henry built the present

[13] Herschel, "Origin of Finger Printing," page 9.

[14] Galton, "Finger Prints," Ch. I., page 2.

[15] Herschel, "The Origin of Finger Printing," page 30.

[16] Henry, "The Classification and Uses of Finger Prints," 1913, page 5.

FIG. 2. A series of ten apical dermatographs (fingerprints) taken in conformity with the Henry System of Finger Print Classification.

extensively used Henry System of Finger Print Classification, which enables one familiar with its intricacies to make a set of ten apical impressions or dermatographs, classify it, and produce the person's history record (assuming one on file) in a period of time varying from five to fifteen minutes. Under this scientific system nothing is required of the subject save the set of ten apical dermatographs. Given this and nothing more, no name, no address, no physical description or photograph, the identifier "solves for x," to use an algebraic term. A record being produced, the subject's medical history, for instance, in the case of a hospital or clinic for the feeble-minded or insane, is at once available, no matter how long the interval between treatments, or the changed facial appearance of the subject, or similarity in names.

Galton in his "Finger Prints," Chapter IV, page 57, says concerning the ridges covering the palm of the hand and the sole of the foot:

> Having given but little attention to them myself they will not be again referred to.

Opposite, on Plate III., Fig. 6, are displayed four palm outlines and one showing the general configuration on both palm and fingers.

In this field of investigation Galton's mantle fell on one of his American correspondents (also a correspondent of Bertillon) who has confined himself to the palms and soles, and of whom it may fairly be said, to paraphrase Galton: If the use of palm- and soleprints ever becomes of general importance, Dr. Harris Hawthorne Wilder, zoologist, must be regarded as the first who devised a feasible method for their regular use and afterward promulgated it. In one of his first papers on the subject Dr. Wilder says:

> The great individual variation of these parts in the human being is not without significance and furnishes an excellent illustration of the *biological truth that the perfection and constancy of an organ are directly proportional to its necessity in the life of the organism* . . . that only useful and important parts retain a certain normal form in the various individuals of a given species, and that, as they become of less importance, they tend more and more to *vary individually,* the range of variation increasing with time and the degree of uselessness, if such an expression may be allowed; conversely, an organ that is seen to possess marked individual variation is shown to be of secondary importance, and may be either a rudimentary organ, that is one on the way towards a greater usefulness in the future and in which the variations represent the numerous experiments or attempts to find the form best adapted for a special purpose, or, again, it may be a vestigial organ, or one in which its point of usefulness

is passed and in which the variations represent various degrees of degeneracy, or stages in its gradual eradication from the organism.[17]

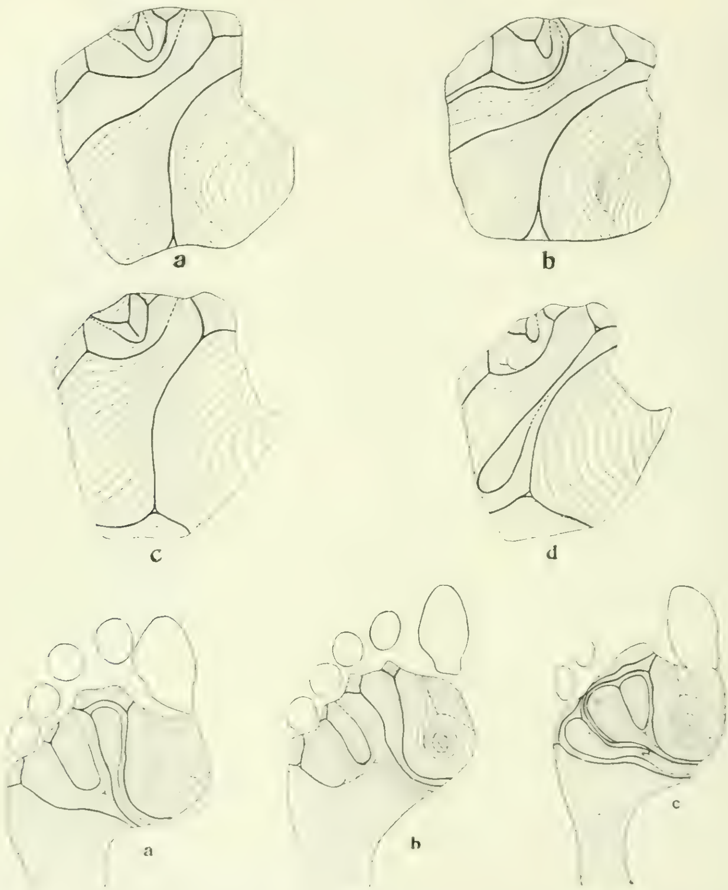


FIG. 3. Tracings from four left palms and three left soles, showing the great individual variation. (From H. H. Wilder's "Palm and Sole Impressions," POPULAR SCIENCE MONTHLY, Sept., 1903.)

In a subsequent paper almost a year later, in which the subject is dealt with in more detail, he says:

These ridges and their peculiar disposal are an inheritance from our arboreal ancestors, and appear to be formed in the oldest primates by the coalescence of single units which arrange themselves in rows.[18] Whether

[17] Wilder, "Scientific Palmistry," POPULAR SCIENCE MONTHLY, November, 1902, pp. 46–47.

[18] Wilder, "Palm and Sole Impressions," POPULAR SCIENCE MONTHLY, Sept., 1903, p. 396. In a footnote Dr. Wilder says "This and other morphological points of which I shall make use in this article are from an unpublished paper on the morphology of the subject by an associate in my department, Miss Inez L. Whipple. At my suggestion Miss Whipple has

or not this phylogenetic or racial stage is now passed through in each human embryo in accordance with the law of biogenesis has not as yet been shown, but it is certain that the ridges are seen fully formed and in their adult condition in a four-months' embryo, and that no change can afterward take place in any detail.

As these surfaces are thus *individually variant* and as their condition is *absolutely permanent through life,* they offer the best criteria for a system of individual records, especially since they may be so easily recorded by means of printed impressions. All these points have been shown by Mr. Galton, who has taken as a basis for his system the markings that cover the balls of the fingers, his "finger tips." The present paper considers the remainder of the ridged surfaces and is thus seen to be *an extension of the Galtonian system to new territory.* Whether ultimately the universal personal records which will surely become necessary in the near future will be based upon a part or the whole of these surfaces is of no real moment, and it is with the idea of being of genuine assistance to Mr. Galton, and without any attempt at rivalry, that I offer in the following pages a method of recording identity by means of palms and soles.[19]

In a subsequent paper, entitled "Palm and Sole Studies," published in *The Biological Bulletin* (Vol. XXX., Feb., 1916, page 135), the subject is introduced as follows:

In the study of the details of the configuration of the friction ridges found covering the surfaces of the human palms and soles there opens up a field of the greatest value to the biologist. *Varying greatly individually;* still following the lines laid down for them in more primitive mammals, yet modified and varied as the result of mechanical causes; showing markedly and with certainty a direct inheritance from the immediate parents as well as from generations more remote; they may be used with great profit by the morphologist, the ethnologist, or the student of genetics, while, as the surest and most positive characters of an individual, they may serve the authorities in the identification of a human body, living or dead.

Undoubtedly the patterns are complicated, and many new conceptions, and the new terminology which expresses them, confront the beginner, as in any new field; but this much once accomplished, there opens up to the investigator an almost endless series of new phenomena the study of which in the few years during which the subject has received special attention has been no more than begun.

Continuing, this paper considers such subjects as "A Primitive Palm Print"; the "Heritability of Friction-skin Characters"; Palm and Sole Markings in both duplicate and fraternal twins, also conjoined twins or those which have never separated completely.

The morphological investigations by Miss Inez L. Whipple

undertaken the comparison of the human conditions of palm and sole with those of the lower primates and other mammals, and has studied also the ontogenetic development of the parts in man and other forms. This work is of the greatest value in the present connection and will be published in full in a short time."

[19] Wilder, "Palm and Sole Impressions," page 396.

(now Mrs. H. H. Wilder), previously referred to, were eventually published (in English) in a foreign scientific publication[20] under the title given below. This paper has proved to be "the fundamental paper on the comparative morphology of the ridge patterns of the palms and soles, and includes the study of the relief of the ridge surfaces in all mammals, and the growth of the ridge surfaces as modified by this. This paper with that of Schlaginhaufen, 1905, are of first importance in the scientific study of human friction ridges."[21] It is certainly most unfortunate that such a fundamental work as this is to the professional fingerprint identifier should be practically unavailable owing to the fact that it was snapped up by a foreign scientific publisher.

A satisfactory digest of this treatise is almost out of the question as every section and paragraph is essential. Space will permit for no more than the table of contents, to show its broad scope and exhaustive treatment; and a few extracts from the text concerning the ridges and apical ridge patterns in man:

THE VENTRAL SURFACE OF THE MAMMALIAN *CHIRIDUM*, WITH SPECIAL REFERENCE TO THE CONDITIONS FOUND IN MAN.

By Miss Inez L. Whipple

With Preface

By Professor Harris Hawthorne Wilder, Ph.D.

Department of Zoology, Smith College, Northampton, Mass.

TABLE OF CONTENTS

[20] *Zeitschrift für Morphologie und Anthropologie*, Stuttgart, Bd. VII., pp. 261–368 (107 pages), 1904.

[21] Wilder, "Bibliography of Friction-skin Configuration," *Biological Bulletin*, Vol. XXX., p. 251.

PART III. Epidermic Ridge Patterns in Prosimians and Primates.
- A. Preliminary classification.
- B. Typical primary patterns.
- C. Modified primary patterns.
- D. Secondary and false patterns.

The process of ridge formation and their distribution with relation to the pads is exhaustively treated in Part II., Sec. *B*. After devoting fourteen pages to the careful examination of ridge formation in the lower mammals, in which the develop-

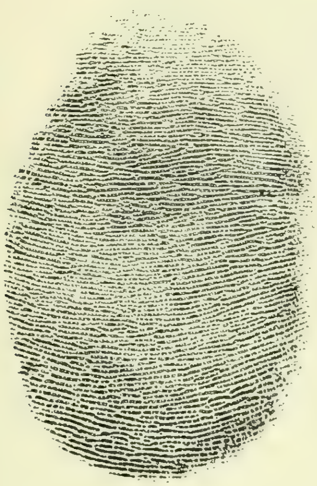


FIG. 4*a*.

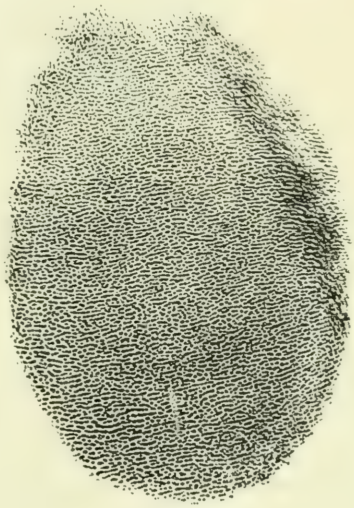


FIG. 4*b*.

FIG. 4. Dermatographs from the human heel (left, female) showing in *a*, a normal condition, the unit elements being mostly all fused into ridges, only a few one, two and three unit ridges being present; in *b*, the opposite condition is shown, it being difficult to find a ridge of more than four or five units, the single elements having never fused into ridges. (From H. H. Wilder's collection, Nos. 722 and 754 respectively.)

ment is traced from the simplest epidermic structure, the scale or wart, the most common form of which is a single sweat gland and its pore opening near the middle of the structure (The "island" or "unit ridge" of the identifier); and the fusion of these elements by one of three observed methods to form the ridge (Fig. 4 *a, b*); and demonstrating that the concentric whorl is the primary pattern, Miss Whipple says regarding the ridge development in the higher primates and man:

Although in the higher primates the complete covering of the surface of the chiridium by ridges seemed at first to preclude the possibility of obtaining any evidence of the method of ridge formation, the fact that in lower forms the transition stages from simple epidermic structures such as warts and rings to fully formed ridges occurs in the regions which are less exposed to pressure, suggested the possibility of finding in the narrow transition area between the ridged region and the skin of the dorsum, especially in embryos, some suggestion as to this process. As the elevation of the ridges is due largely to the rather late development of the stratum corneum, it was difficult to find a stage which was sufficiently advanced to render the ridges distinguishable externally and which would at the same time show the simpler epidermic structures. An advanced human fetus

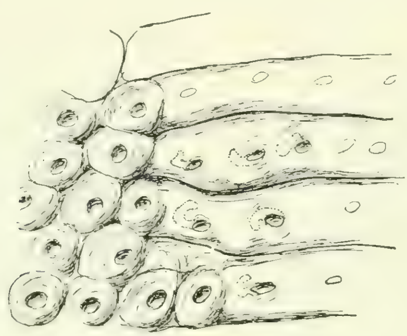


FIG. 5.

proved the most satisfactory for this purpose, and the best results were obtained from the transition region along the sides of the middle phalanges. Fig. 5 shows a camera drawing of a surface preparation of the epidermis of this region. Upon the side of the digit the orifices of the sweat glands are wide and each is surrounded by an elevated rim of the stratum corneum, the whole structure being that of an epidermic wart. These warts appear, however, to be arranged in rows, and the drawing shows a rapid transition from separate warts to ridges, one feature of this transition being the increased length of the coiled ducts of the sweat glands and a lateral compression of their orifices. Except that the transition is a narrow one, the process of ridge formation differs in no particular from that of *Midas lagothrix.* Moreover these warts having been demonstrated in the embryo, it seems safe to conclude that the little separate elevations continuing for a short distance the course of the ridges in the transition regions of the adult skin, usually particularly well seen upon the inner side of the terminal phalanx of the second finger (Fig. 6*a*), are actually primitive warts, examination with a lens demonstrating the opening of a sweat gland in the center of each. In some cases these warts seem to be grouped or fused into rings suggesting the conditions in *Didelphys* and *Lemur;* usually, however, they occur singly. The very frequent occurrence of "islands" in the primate friction-skin also suggests the development of ridges phylogenetically from separate components (Fig. 6*b*).

Three monkey embryos, one an *Alouatta*, the other two Platyrrhine forms (species undetermined), showed along the edge of the friction-skin similar transition stages from warts to ridges.

Concerning the function of the epidermic ridges (Part II., Sec. *D*), after extended observations and discussion, the investigator says:

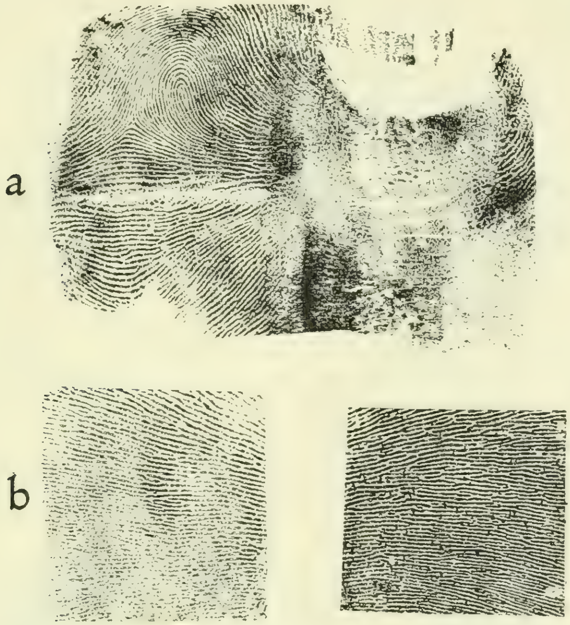


Fig. 6.

The general principles, then, which are involved in the function of ridges are:

1. That the function is primarily to increase resistance between contact surfaces for the purpose of preventing slipping, whether in walking or in prehension.

2. The direction of ridges is at right angles with the force that tends to produce slipping, or to the resultant of such forces when these forces vary in direction.

3. The shape of the pad elevation, the direction of flexion, and the direction of motion are the factors determining the direction of the slipping force, and therefore the direction of the ridges.

Again, " Incidentally the ridges acquire an important tactile function."

In Part III., Sec. *C*, is discussed Modified Primary Patterns; the various types of modification, and their probable cause,

although in doing so it must be borne in mind that a single type of pad modification seldom occurs unaccompanied by others. We may consider these types, however, to be four in number:

1. Failure of divergents, resulting in triradii becoming extra-limital or obliterated. (See Fig. 7*a* and *b*.)

2. Reduction of pads, resulting in degeneration of triradii.

3. Flattening of pads, resulting in a deviation from the concentric arrangement of ridges upon the pad area.

4. Fusion of pads, resulting in the coalescence and in the exclusion of triradii.

FIG. 7. Two apical graphs in which (*a*) one triradius has become extralimital, and the other nearly so; in (*b*) both triradii have become obliterated. In each case an "accessory degeneration triradius" has developed in connection with a loop formation. At the extreme lower corners unit ridge elements may be seen.

Continuing, and referring to group (2), Miss Whipple says:

The modification of patterns which are due to pad reduction are probably the most frequent of all pattern modifications. As reduction has pro-

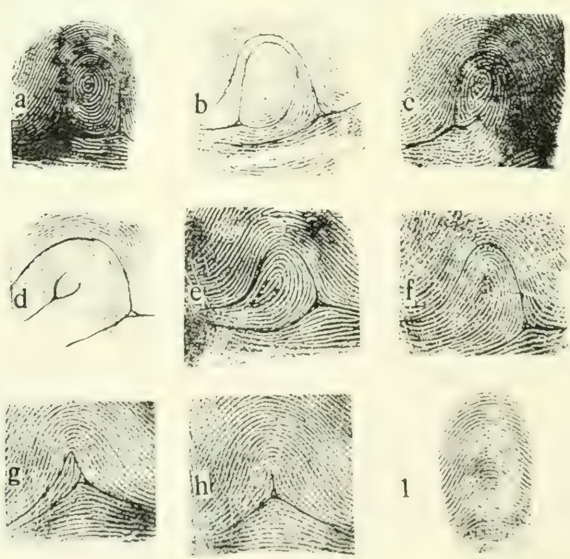


FIG. 8.

ceeded farther in man than in most monkeys (excepting the Anthropoids) *we may select from different individuals of the human species cases which illustrate every step in the process.* The series given in Fig. 8 show how, in the apical pads, beginning with the slipping of one or both of the embracing radiants of one triradius within those of the other, a variation involving at first only a few ridges (*b*), one triradius may approach nearer and nearer to the center of the pattern (*c*, *d*, *e*), its radiants embracing fewer and fewer concentric ridges until the triradius finally suffers complete degeneration, leaving the pattern known in Galton's terminology as the "loop" (*f*) which has only one triradius, the loop opening in the direction of the divergent of the triradius which has degenerated. Again, by a similar *series of minute variations*, this remaining triradius may approach more nearly to the middle of the pattern, until the loop involves but a single ridge, from which condition it is only a step through Galton's "tented arch" to the "simple arch" in which the last vestige of the second triradius has disappeared. These transition forms in the apical patterns were fully recognized and described by Galton as constituting a slight obstacle to a perfectly systematic classification of fingerprints. . . . It should also be noted that there may occur a simultaneous approach of both triradii to the center of the pattern, the pattern remaining typical in form but reduced in size.

This type of modification is then traced in palms and soles. Under group (3),

Types of pattern modification which are due to a flattening of the pad, a condition which is in some instances correlated with reduction, and in others with extension of the pad area. With the change of pressure upon a pad naturally accompanying such a change of form, very decided modifications in the disposition of ridges occur leading in the direction of the establishment of parallel straight ridges, such as we would expect to find upon a flat surface. The flattened, reduced apical pads both of man and of a few of the monkeys were found to illustrate one very common method of attaining this end. It will be seen from the series shown in Fig. 9 that

FIG. 9.

this line of variation may begin by the displacement of only a few ridges at the center of the pattern, the result being the establishment of a spiral rather than a perfectly concentric pattern. Following this may come a greater and greater amount of variation from the concentric arrangement until a double loop (vortex duplicatus of Purkinje) or even an S-shaped figure is formed. In rare cases more often seen in the apical patterns of the human foot and in the proximal patterns this line of variation has proceeded so far that the pattern has become separated into distinct loops and an accessory degeneration triradius is introduced (see Fig. 7*a* and *b*), that is a triradius not originally present in the typical scheme but formed incidentally in the process of degeneration of the pattern.

Modifications from this same cause occurring in the palms and soles are then considered at considerable length and in great detail.

From this brief biological review it will be seen that any friction-skin impression or dermatograph is really much more than a record of merely external epidermic characteristics, for these features are in turn conditioned upon internal tissue structure of the dermis, the configuration of which is determined and fixed during early embryonic life, and is therefore capable of being associated with but a single individual. Except for a change of size proportional to the growth of the bodily parts, or changes acquired during postembryonic life by external causes such as deep cuts or burns, or from disease of the tissue evidenced by a felon, boil, etc., the configuration remains unchanged through the individual's life.

What then is required to establish an identification; what is the process; how do these biological or anatomical conditions satisfy the requirements?

For guidance, let us consult an authority[22] on the principles of identity evidence:

. . . In the process of identification of two supposed objects, by a common mark, the force of the inference depends on the *degree of necessariness of association of that mark with a single object.*

For simplicity's sake the evidential circumstance may thus be spoken of as "*a* mark." But in practise it rarely occurs that the evidential mark is a *single* circumstance. The evidencing feature is usually a group of circumstances, which as a whole constitute a feature capable of being associated with a single object. Rarely can one circumstance alone be so inherently peculiar to a single object. It is by adding circumstance to circumstance we obtain a composite feature or mark which as a whole can not be supposed to be associated with more than a single object. The process of constructing an inference of identification thus consists usually in adding together a number of circumstances, each of which by itself might be a feature of many objects, but all of which together can conceivably coexist in a single object only. Each additional circumstance reduces the chances of there being more than one object so associated.

Continuing, he says, in discussing the terms identity, alike, similar, and resemblance:

We remember to have read in a judgment of the Indian High Courts (unfortunately we can not now give the reference) that the judges considered the case was not proved because the evidence only established *likeness* and not identity. . . . terms such as "exact likeness," "precise similarity" are misleading. For as soon as you have removed all internal difference and resemblance is carried to such a point that perceptible [material] difference ceases, then you have identity. As soon as you begin to analyze resemblance you get something else than it; and when you argue from resemblance, what you use is not the resemblance, but the point of resemblance, and a point of resemblance is clearly an identity.[23]

[22] John H. Wigmore, "Principles of Judicial Proof, General Principle of Identity Evidence."

[23] "Principles of Judicial Proof," John H. Wigmore, Little, Brown & Co., Boston, Mass., 1913, pages 64–67.

Conceiving a fingerprint, or any friction-skin impression, as "*a* mark," what is the "degree of necessariness of association" of that mark with the particular individual whose dermatograph it is?

Dr. Wilder has stated for us the biological truth that the perfection and constancy of an organ are directly proportional to its necessity in the life of the organism; that only useful and important parts retain a certain normal form in the various individuals of a given species, and that as they become of less importance they tend more and more to *vary individually.* Mrs. Wilder has traced this degeneration of mammalian pads and the consequent individual variations in their friction-skin configuration, and has shown us that it has progressed farther in man than in most other mammals, so far, "that we may select from different individuals of the human species cases which illustrate every step in the process." We have seen that *this process is composed of a series of minute variations, constant in the individual,* but progressive and variable among mammals as a whole; and that in the individual the ridges are the result of the coalescence of simple tissue structures and are formed and their configuration fixed in a four-months' embryo.

Since it is inconceivable that these minute dermal structures should themselves be identical or coalesce identically in any two instances, the inevitable conclusion seems to be that the "degree of necessariness of association" of this graphic mark with the individual is *absolute;* that even the possibility of the same or different individuals, having on any two parts of the friction-skin areas identical ridge configurations, is *nil.* Any dermatograph or impression of the friction-skin configuration is therefore a graphic record, by personal contact, of inherent anatomical or dermal characteristics, exclusively individual in the person possessing them, and constant through his life.

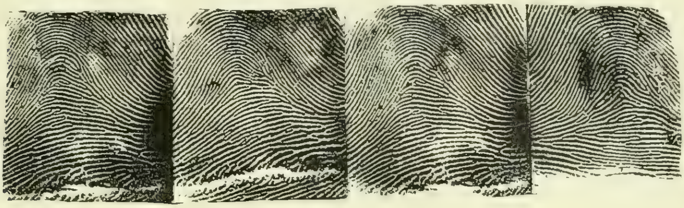
But as Professor Wigmore points out, an "evidential mark" usually consists of a group of circumstances, each of which by itself might be a feature of many objects, but all of which together can conceivably coexist in but a single object only; and that the process of constructing an inference of identification consists in "adding circumstance to circumstance."

Analyzed, any friction-skin impression, or more specifically, any *apical dermatograph,* may be thought of as the record of a group of anatomical or dermal circumstances, called by Galton "ridge characteristics." In its gross features it may represent any of the stages of progressive mammalian variation as shown by Mrs. Wilder and grouped by Sir Edward Henry, on the basis of certain gross likenesses, as whorls, accidentals, twin-loops, lateral-pocket loops, central-pocket loops, ulnar loops, radial loops, tented arches, and the simple arch, the ultimate stage of degeneration. It therefore follows that these "marks" or types of configuration may well be a feature of many objects or fingers (in fact we find them so) ;[24] so that the repetition of an impression of the same type only raises a suspicion that the two graphs may be from the same digit (or friction-skin area). Aided by a good magnifying glass, a careful comparison of each anatomical circumstance or ridge characteristic, its form and relative position in the configuration, of both dermatographs is therefore necessary. For, if the impressions be *not* from the same digit (or friction-skin area), the record of material anatomical circumstances necessarily associated with the individual in question (*e. g.*, Fig.

[24] For the mathematics of this variability of types the reader is referred to a fifty-seven-page article on the "Association of Finger Prints," by H. Waite, M.A., B.Sc., in *Biometrika* (Vol. X., No. 4, May, 1915), pages 421–478. In addition to the text there are over one hundred statistical tables, enough to satisfy the most ravenous "figure shark." On pages 432–433, Mr. Waite says: "It is convenient at this stage to summarize a few of the most important points which have been brought to light in the foregoing pages. These are: (*a*) A greater divergence of types in the right hand than in the left. (*b*) A clustering of the same type in the hands of an individual. (*c*) The uneven distribution of the various types in the different fingers, especially the almost entire absence of radial loops except in the index. (*d*) The differentiation of types in the two hands, in particular the large excess of whorls in the right hand and of arches in the left thumb. (*e*) Where there is any significant difference in the means, standard deviations and coefficients of variation in the numbers of the ridges in the loops of the two hands those quantities are always greater for the right hand than for the left. (*f*) The relationship between digits of the same name on opposite hands is closer than that between any others which are more widely separated. The relationship between the thumb and any other digit is less close than that of any pair not including the thumb."

"We may thus conclude that the left hand in its distribution of patterns is differentiated from the right and that the individual fingers are associated in a differential way with special types. We know that the right hand is differentiated from the left in use, and it would seem reasonable to suppose, even if we can not account for the adaptation to use, that the fingerprints have been differentiated in accordance with this use differentiation. It may be suggested that the fingerprints, if differentiated in accordance with diversity of use of the several fingers and of each hand, follow a law of differentiated utility, and not as the bones a law of maximum general utility of the finger."

10 *a*) will be absent from the graphs alleged to be his (Fig. 10 *b* and 10 *d*), and it will be found impossible to locate any minute dermal circumstances or characteristics identical to both configurations, the graphs being considered merely alike or similar, according as the resemblance is near or remote.



a *b* *c* *d*

Fig. 10. Four rolled apical dermatographs: *a* is from the right middle finger, *b* from the right forefinger, and *c* an additional graph from the middle finger of the same hand; *d* is from a different individual. Note that even graphs *a* and *c* are not between themselves identical, but only alike; no material differences occurring in their common contact areas, the identity of the individual is unerringly inferred and established by adding dermal circumstance to circumstance.

But, if the dermatographs be from the same digit (or friction-skin area) the record of anatomical circumstances necessarily associated with the individual (Fig. 10 *a*) will be found in the common contact area of the graph truly his (Fig. 10 *c*). It will, therefore, be possible by comparing both configurations to add dermal circumstance to circumstance and to carry the resemblance to such a point that material difference ceases in the common contact areas, and from them to a common cause, the individual digit; for all the minute dermal circumstances taken together (in these two graphs nearly 100 pairs) can conceivably coexist in but a single finger; and the finger conceivably belong to but a single individual.

THE MAN OF SCIENCE AFTER THE WAR

By Professor D. FRASER HARRIS, M.D., D.Sc.
DALHOUSIE UNIVERSITY, HALIFAX, N. S.

PROBABLY nothing less than a war such as this could have shaken the British race out of its comfortable mental inertia in regard to all things scientific. The English generally had no interest in science, even though it had conferred on them such extremely convenient adaptations of pure science to the needs of everyday life as the telegraph, the telephone, the electric light and the motor car. Science, however, does seem to be coming into its own. For the first time in the history of the British Empire, this Cinderella amongst the things of the mind is being taken from the kitchen and led to her place on the throne.

Men who have been speaking of war as "applied chemistry" are now considering that it would be a good thing if the treasures of science, so horribly misapplied, could be utilized in the future systematically, openly, advisedly for the beneficent aims of peace. For modern life is begun, continued and ended in science; it is applied science from morning to night, from birth to the grave.

Men are asking themselves: If it was in the power of science to make war so frightful, is it not within her essentially beneficent capabilities to make the coming day of peace fuller, richer and more glorious than ever day in the past has been?

It can not be denied that science as science has only very recently been allowed to have an independent existence in the British, national, intellectual system. The time is within the memory of some of us when the attempt to introduce laboratory teaching into the University of Oxford was met with furious resistance; and when at length studies in practical chemistry were instituted, they were alluded to as "stinks."

History was repeating itself, for Leo Africanus, writing in the early part of the sixteenth century, thus described the chemical society of the learned Arabians at Fez, "there is a most stupid set of men who contaminate themselves with sulphur and other horrible stinks." The attitude of England's premier university was in precisely the same spirit as that of the ex-priest who, on demanding the execution of Lavoiser, declared that the Republic had no need of chemists. This was in 1794; but fifty years later Oxford made it very clear that she too and all that she stood for in English life had no need of chemists or of any other kind of scientist. This was the traditional, mental attitude of educated Englishmen right up to the mid-Victorian era. The English gentleman knew no science, did not want to know any, and honestly thought that his country did not need to know any. We are all too apt to imagine that what we don't happen to care about is not worth while other people's caring about. The English gentleman certainly seemed to get on very well without science, as his ancestors had done before him; and where were there any gentlemen so perfect as those of English birth? The Englishman spoke, like one of the characters in "Trilby," contemptuously of all foreigners as "damned." He had his ancestral seat and his large rent roll, and his scores of servants, so that he never wanted for daily food, nor needed to soil his hands from one year's end to the other. If he did want a profession for a younger son, were not the Church, the Navy, the Army, the Diplomatic or Civil services all open to him? Everything else, including science, might be left to beastly, eccentric, long-haired "foreigners." In the Navy and Army, whatever else he was, he was brave; but he left any science which those services required to those far beneath him, to those specially paid to bother about "beastly technical details." As regards the practice of medicine, an applied science, he held exactly the same view as the ancient Roman who regarded that occupation quite unworthy of a gentleman. The author remembers well when, in the early nineties, he once filled up a form under the heading "Profession" with the word "physiologist," his father exclaiming, "But that's not a profession!" He was perfectly right from the mid-Victorian standpoint; it was not a profession in the sense that the Church, Fighting or the Law were professions. Where were the ancient privileges, social recognition, pensions or fees for physiologists? There was a day when it was perfectly true that the world had no need of physiologists. I was told the truth when I was once informed that as far as my occupation was concerned with social recognition, I might just as well have been a hangman.

Science had not yet come into her own.

A very great deal of all this has been changed with the inevitable onward march of the army of seekers after truth. Science became less an affair for amateurs and more the concern of serious men. The founding of University College, London, the instituting of degrees in pure science—B.Sc. and D.Sc.—by the University of London, did a great deal to foster the study of pure science in England and give it academic status. The uprising of the school of biology at Cambridge under Foster and F. M. Balfour was all in the same direction; but in some nostrils at Oxford science still stinks, and—it is no profession.

When one says that the man of science is necessary to the national life, one generally thinks how science underlies our great trades and chemical manufactures and all the activities of our complicated social system, railways, steamships, wireless telegraphy, gunnery, aviation and the untold wonders of to-morrow. But the man of science is as necessary to national welfare in an infinitude of less conspicuous and more familiar ways. There is scientific farming and there is scientific marketing; there is a science of dietetics as surely as there is a science of agriculture.

Science is looking into everything, focusing her light upon everything. When the light of nature fails, then science steps in; she illuminates and directs our paths; she allures "to brighter worlds" and leads the way.

Science, therefore, in the national interests must be encouraged. But there is no such thing as encouraging science in the abstract; it is the men of science, themselves, who have to be encouraged; and encouragement means, to put it brutally, being paid salaries on which they can think and work without financial worry. This is put brutally, but it is not so brutal as the being presented with bills to be paid out of an inadequate income.

The man of science is intended to research, every one will admit; but in whose time and with whose money? We may as well be frank about it. If he is a professor at one of the universities, he probably has all his day filled up with his teaching and administrative duties. In such a day, what time is there for research? He has to teach for a living; his time is not his own, but the governors' of the university. Suppose for a moment that all his day is not occupied with university duties, is it his *duty* to research in the university's time? Most people would reply that it certainly is. But not every professor is appointed with explicit instructions to do research when he is not teaching. He may not be capable of doing any research at all; may never have done any; he may not have been appointed because he could do research, but for some quite other reason. It is a nice point: unless it is definitely understood that the professor is expected to do research, he is using the university's time for non-university pursuits. For the research in question may not benefit the university at all; it may, conceivably, benefit some other institution, or, inconceivably, the professor himself. But whatever or whoever is benefited, almost all research in universities is done in university time and with university money, so that we shall suppose that there is tacit permission given by the university authorities for such work. It is, however, perfectly possible that the amount of time available when the university teaching duties are done, and the time in the home circle passed, is quite insufficient for the long stretches of work which almost every research demands. You can not follow out any line of work in odd periods of isolated ten minutes, the worker must have hours of uninterrupted work at a stretch. It is precisely this that the teaching professor can not have; either his teaching or his research must suffer.

The only solution is for the universities to acknowledge that they are institutions quite as much for the prosecution of research as for the teaching of young people either the foundations or the heights of science. It should be made quite clear that the members of the staff are fulfilling their university duties quite as faithfully when they research as when they lecture, and that their salaries will not depend on the number of teaching hours per week, but on the cost of living in the particular city in which the university happens to be. Probably the only satisfactory solution of the teaching *versus* research problem is for the universities to recognize teaching professors and research professors, teaching assistants and research assistants. It should, in fact, be acknowledged that it will be regarded as a credit to the university if certain of its professors research rather than teach, as was the case with the late Lord Kelvin. Lord Kelvin's forte was not teaching the elements of physics to junior students who knew no mathematics; yet this was the daily duty actually set before the greatest physicist since Newton. Had Lord Kelvin not shed such great luster on his alma mater by the brilliance of his reputation as an original worker, he would have come within a very little of being put down as a failure. He researched, however, in the university's time; but as far as I know there was nothing in his Lordship's commission about research as a part of his duties.

Both the teaching members and the researching members of the staff should receive such salaries as would make them independent of worry regarding the financial *modus vivendi.* The teaching professor should not have to research in order to convince himself that only by so doing is he carrying out his entire duty; the researching professor ought not to have to teach in order to obtain a salary to enable him to live.

The importance of the researches done at the Rockefeller Institute of Experimental Medicine is a proof of the great value to science of the endowment of an institution whose staff is not burdened by teaching as the only means to a livelihood. An eccentric Scottish professor once said: "The university would be a fine place if it were not for the students!"

When we touch the subject of salaries, we come to a question likely to evolve more heat than light. Broadly put, it may be said that professors of science subjects are not paid salaries commensurate with their highly specialized attainments, nor such as enable them to live in the style expected of other dwellers on the same social stratum. It is of course quite foreign to the subject to say that they are not paid as highly as all sorts of persons whose mental attainments are inferior. There is no general scheme of paying salaries according to the degree of attainments salaries are paid on the basis of the scarcity in the "market" of the kind of person to receive them. Now since there is no market for professors in the same sense that there is for clerks or day laborers, and since there is always a relatively large number of trained men willing to work for a small salary because they know very well that they can not get a large one, professors are compelled to take quietly what is given them and to ask no questions. This is no new grievance; the smallness of professors' salaries has long been a standing joke in the comic papers. It is indicative of the small regard in which men of science are held. Hitherto their researches have been seized on and commercialized for the benefit of other and more worldly wise individuals. It is this sort of thing which will be changed after the war. The man of science must be recognized as the most important person in the post-bellum community, a person without whom the capitalist would have no discoveries to commercialize.

We should have a Minister of Science, whose duties would be amongst others to see that scientific men were encouraged, subsidized, promoted, rewarded and pensioned. For why should state recognition, encouragement, promotion and rewarding be reserved for sailors, soldiers, diplomatists and lawyers? Why should it be so entirely correct to be paid for legal opinion, and such "bad form" to be remunerated for scientific advice? Because, it may be replied, the law is an ancient, respectable profession, and science is so recent, it is not a profession at all.

This medieval state of affairs can not go on indefinitely; it was all very well for the day when there was no science to foster, but it is out of place in an age which lights its cities by the invisible, speaks to the antipodes without wires, flies in high heaven like the eagle, and descends to the abyss like a sea monster. Much that now falls under the supervision of the Home Secretary could be transferred to the Science Minister. The first concern of the science office would be the place of science in the schools of the Empire, the still burning question of the rival claims of science and the classics. It ought to be perfectly possible to instruct boys in as much of Greek and Latin as would make them know the origin of the words in English derived from those languages, without necessarily making the boys read entire Greek and Latin authors in the original. Through our national physiological momentum we have been educating boys as though they were all going to be teachers of the classics; we have continued on the same educational lines as those laid down by Linacre and Erasmus when America had just been discovered and printing just invented.

The Science Office will see to it that science receives official recognition in all entrance examinations whatsoever, and is not handicapped by receiving fewer marks than the classics or any other subject.

Science must have its place on every curriculum, not on sufferance or by-your-leave, but by right of its inherent dignity and in virtue of its essential usefulness. Why is a knowledge of science so useful to the modern community? Because, apart altogether from the way in which it makes for technical efficiency, it is a means second to none for the training of the intellectual powers. It trains us in accuracy of observation, in the power of drawing trustworthy conclusions, in the habits of precise, critical thinking—and these are not small things.

Science, the true, is the patient, loving interpretation of the world we live in, it is a striving to attain not merely to an understanding of the laws whereby the world is governed, but to the enjoyment of the order and beauty which are everywhere revealed.

Amongst the many unspeakably sad things which this war has brought about, the prostitution of science and the destruction of things beautiful are not the least lamentable, for

> Outraged science shudders that her glorious treasures
> Should be so corrupted by the sons of men;
> Beauty's gentle spirit grieves as it grieved never
> For those scenes of Beauty that can not come again!

FACTORS IN ACHIEVEMENT

By Dr. P. G. NUTTING

IN the increase and diffusion of organized knowledge and in its application to special problems for the national welfare, the selection and training of individuals of course plays an important part. The capacity for unusual achievements is in part born in the individual and in part the result of his environment, (1) inherited tendencies and (2) education in a broad sense. The individual favored in both respects with capacity for achievement may or may not accomplish great results according to the (3) incentives to activity he may possess or develop and according to certain (4) fortuitous factors, ideas and impulses coming apparently from nowhere, which may influence his choice of activities.

From the point of view of practical work, the capacity for success depends almost entirely upon but two factors—fertility of mind to originate ideas and judgment to select from these the most vital and effective. With an energetic use of both, worthy achievement is assured, the importance of activity and practical experience lying in the fact that its effects are strongly cumulative, each bit of experience enhancing ability to achieve more. Hence, the considerable effect on national achievement of such an apparently trivial factor as climate. In a well-organized democracy, each individual should have equal opportunity to acquire (1) knowledge through study, assimilation and deduction of fundamental principles, (2) skill through application of these principles to practical problems and (3) incentives to productive effort. These are the essential qualifications of the expert and since, in any highly efficient democracy, all problems of moment must be handled by experts, the fundamental problem is the application of organized knowledge to bring about such a condition, the "rule of common sense."

1. *Inherited Tendencies.*—With equal opportunity to acquire knowledge and skill, the proper choice of vocation depends chiefly upon inherited traits. Usually but a few traits are dominant and the proper vocation is not difficult to determine within rather narrow limits. An occasional individual possesses a wide variety of overlapping tendencies and is

capable of achievement in a variety of callings. Many others exhibit no dominant mental characteristics, being fitted only for work in the less skilled crafts and trades.

As stated above, the ability to grasp and correlate ideas is a proper measure of mental power. Now some classes of ideas are better and preferably correlated than others and this preference is a necessary and sufficient criterion of natural fitness. The musician is keen in associating auditory impressions, the mathematician in abstract logic, the physicist and chemist in physical and chemical laws, and so on. This choice of class or classes of ideas to be correlated is instinctive in that it is born, not made, and characteristic in that it is not precisely the same in any two individuals. It varies with age, but at a given age (say twenty) it is a safe basis of judgment. The somewhat detailed classification below will at least illustrate the application of this principle.

The *creative* type of mind is probably the least complex. The scientist, artist, engineer and professional man must be capable of a high degree of abstraction, hence must be individualistic rather than gregarious in his tastes. The ideas which dwell in the mind of the writer and which he instinctively ponders and correlates are stories and plots. The artist is keen on form and color—visual impressions—the musician on sounds. The ideas which grip the mind of the scientist are abstract fundamental relations between cause and effect. The engineer and professional man in general ponder concrete problems and applications of fundamental principles. It is even possible to differentiate between the lawyer, the physician, the agriculturalist, the mechanical engineer, the banker and other types of engineer in early youth by means of the tastes which they exhibit for different classes of problems.

On the other hand, the *administrative* types, be they commercial, political, protective or pedagogical, are gregarious rather than individualistic. Their tastes do not run to abstract ideas so much as to personal relations. They are keen to make and keep friends, are good "mixers" and entertainers, fond of activity and are experts on behavior. The commercial type of individual instinctively suppresses his own feelings and wishes to please others—and make a sale. The executive type is keen to anticipate conditions and relations between others. The good teacher is fond of the society of those less well informed and keen on making his own ideas plain to others. He must of course have a goodly supply of certain classes of ideas and be a good practical psychologist.

In addition to determining fitness for a particular life work, inherited traits have a great deal to do with eminence in a given calling, although perhaps not dominant factors. Fertility of mind, ease of assimilation of new ideas, the tendency to activity and general smoothness and precision of mental operation are largely born in the individual rather than acquired and have a great deal to do with success in life. All are usually in evidence in early youth, if at all. None are of consequence, of course, unless coupled with a proper education, mental, physical and moral, and with proper incentives to activity. And all these characteristics, whether inherited or acquired, are of little avail without an intimate knowledge of the complex conditions of modern life obtained by daily contact with them.

2. *Acquired Knowledge.*—To be a vital factor in achievement, education should provide not only a book knowledge of fundamental principles, but skill in applying these principles. One extreme of education is represented by the individual with purely academic training, resulting in mere breadth and depth of impotent knowledge, possessing neither the ability nor the incentive to use it. At the other extreme is the self-made individual with a thorough first-hand knowledge of certain classes of problems and of certain basic principles applicable to them. There can be no question as to which is of greater value to the nation, but both are far from ideal.

The best education consists in a steady, life-long assimilation of ideas coupled with a deduction of principles. The acquisition of learning should go hand in hand with an application of that learning to special problems. The natural method is (1) the analysis of a problem, (2) the application of known principles followed by (3) the deduction of new principles or extensions of the old. The laboratory method used in teaching most sciences in this country is a close approximation to this method. The older education, aiming at training in interpretation and expression, was good as far as it went in a certain field of achievement, but the field was narrow. The best education should provide the maximum knowledge, skill and incentive possible to the individual in his chosen field of endeavor. Its aim is to produce experts—experts in the application of fundamental principles. Its methods are to teach those principles through their application. And the most important part of the education is the inculcation of the principle of the method itself. Agassiz taught the gold expert by giving him a turtle to study! He learned the method and this knowledge with the fixed purpose of becoming an expert and doubtless considerable natural ability were the essential factors in his success.

Our students waste much valuable time and learn wrong methods of study because our system leads them to work by the day rather than by the job. The installation of a piecework system would require better teachers and probably more of them, but would result in incalculable benefit to the nation and a great saving of time to the student. Students who attend college chiefly for the social or athletic advantages it offers should not be tolerated. Teachers should be thoroughly versed in the basic principles of the branch taught and in the proper methods of acquiring knowledge. Whether the subject taught be mathematics, language or biology the first aim should be to see that the student gains a real command of the subject. Proper teaching will result in better teachers and finally in better taught students.

3. *Incentives to Activity.*—Under normal conditions the average individual operates on low gear, seldom rising even to second. Any one who habitually operates on high and is reasonably endowed with intelligence and common sense is reasonably certain of great achievement. Our present problem is to outline the incentives tending to induce us to put forth our best efforts. If we but put forth our best efforts, our future is assured, either as individuals or as a nation.

Take the most talented and energetic scientist and isolate him, say on a desert island. Give him a library and a laboratory, but no companions and in a few months or years he will run dry of ideas and become barren. We are so constituted that continued productiveness is conditional upon intercourse with our colleagues. In many respects our activities are like the individual cells in our muscles—we function properly only in contact and cooperation with our fellows. The problem of incentives is therefore complex and primarily one of interrelations.

In any great achievement two factors are essential, a motive (or several motives) for doing it coupled with capacity to accomplish the desired results. In each motive may be recognized a more or less continuous incentive and an idea or impulse coming apparently from nowhere (vide infra). Every one has his favorite category of incentives. There are at least six classes of these and any scheme of classification is about as good as any other. From the purely *mechanical* point of view one is acted upon by various forces due to conditions existing among our surroundings. Life is a series of actions and reactions resulting from unbalanced forces. Action is greater or less according to inertia, plasticity and elasticity. Purely *physiological* considerations lead one to think of cell charge and discharge as the basis of activity. In health, rest and food lead to charged brain cells ready to react to a nerve stimulus. Impurities tend to break down these nerve cells in chains or groups, giving rise to definite ideas. Emotions tend to polarize the charged brain cells so that a more copious discharge may result.

From the standpoint of *mental* engineering our activities are a series of problems, many of these are nearly identical with problems solved many times previously and are largely taken care of by habit, while others are original and require working out. Ideas come to us and we follow them up through a logical chain to a definite end point. Unable to solve a problem, we take it up again and again, contact with the problem and with the work being a powerful incentive to continue. Our interest in any problem is in proportion to the possibilities we see in it and in lesser degree to the headway we are able to make with it.

Incentives are in better alignment from the *sociological* point of view. Our strongest incentives are the winning and retaining the respect and esteem of those with whom we are in contact. We are impelled (by instinct) to fill our place in the social organization much as a cell fills its place in a nerve or muscle. Those who care little or nothing for the esteem of their fellows are criminals and outlaws. To enhance the esteem of our fellows we contract to deliver certain results and, knowing the price of failure, the filling of our contract is a powerful incentive. The attainment of the social freedom usually connected with abundance of money is a powerful incentive to some. Emulation influences many. The strongest of all incentives are self-preservation and the stern necessity of living up to a standard, the standard of our fellows or one set by ourselves perhaps.

On an ethical or *moral* basis, our incentives are those of principle and duty. Our one fundamental duty is to be our best selves and live up to our possibilities. The hope of reward in the form of pleasure or happiness or the fear of discomfort are strong incentives in the less highly organized mind. To others, the satisfaction resulting from duty well performed is a sufficient incentive for any labor in achievement, even to the sacrifice of life itself.

From the *psychological* viewpoint, incentives plus impulses are the stimuli to mental exertion. A series of more or less related impulses leaves in our minds that which is common to all of them in the form of a more or less permanent incentive. Upon that incentive depends the nature and extent of our reaction to fresh ideas as they come, our wish or will to develop the idea toward certain objectives or to suppress it into desuetude. We develop methods of inviting and forcing ideas of our choice, repeated reactions of similar nature lead to the formation of habits and of character. Experience teaches that the giving way to impulses of a certain nature (*e. g.*, that of doing our best) is always approved by our judgment and an incentive to continue the same behavior is formed. In other words, incentives determine the volitional choice of conduct. The volitional factor ranges from almost nothing in the case of the instinctive incentives to practically the whole of those incentives which are matters of judgment and principle. When under emotional stress we react much more readily and strongly along the lines of our dominant incentives.

Apparently, a strong line of good incentives can not be created; it must be built up by careful and persistent effort and that effort must itself be the result of incentive. With the adolescent, the aims and examples of friends and acquaintances and the teaching of parents are powerful formative factors. Youths pattern their lives after those they admire almost instinctively with little reason or judgment.

A powerful factor in achievement is the inhibition of such contra-incentives as habit. In a sense, men are like snakes and other reptiles—in order to make the best progress it is essential that they periodically shed a skin or shell of habit. A simple and natural method of doing this is to move into new surroundings and form new acquaintances from among a set of entire strangers. The formation of a new set of habits automatically dispenses with the old set. Fresh incentives arise and are given free play while old incentives are rejuvenated. By this means, achievement is frequently enhanced many fold.

The practical means of enhancing our incentives are very limited. We may stimulate ourselves to some extent by moving into new surroundings. We may contract with others or with ourselves to deliver certain results. No inconsiderable stimulus comes at times from merely getting started, mere contact with the work itself engendering interest and application. After the dominant point of view has once been located among the six classes above outlined, best progress may be made by confining attention to that one line of appeal. If the boy tends to think in terms of moral principle appeal to his morals. If he is gregarious, teach him through his friends, and so on.

The strongest of all incentives—self-preservation, the struggle for existence, competitive rivalry and the instinct to attain and retain the respect of our fellows—lie nearly or quite beyond our control. But it is frequently quite possible to imagine these as existing in greater measure than is actually the case and so spur ourselves from the field of fatuous content into increased activity and achievement. The story is told of a hen that was unable of herself to fly over a fence, but by inducing a dog to chase her was able to clear the fence and to spare! The incentive of the hen roost was insufficient, but that of self-preservation was ample for the task to be accomplished.

4. *Fortuitous Factors in Achievement.*—Among the contributory factors leading up to any great event in the world's history may always be found ideas and impulses coming to certain individuals apparently from nowhere, vital in initiating whole series of events. Cæsar hesitated at the Rubicon, but finally obeyed the impulse to cross and end the Roman republic. Many a great war started from an impulse to conquer the world, coming to some individual ruler. Had Lincoln not obeyed the impulse to take on Douglas in debate, it is quite probable he would never have been president and one of the dominant characters in history. Any man of great achievement can recall many instances of fruitful lines of activity originating in some impulse. Since such impulses are frequently very important factors in achievement, it is well to scrutinize them with care, attempting to discover some general pattern, some laws of appearance and the best means of utilization.

Countless impulses come to every one during his whole life, dozens during each waking hour in fact. Of these, a considerable portion may be traced directly to suggestions made by our associates, others arise from our personal needs and desires. Many, however, simply flash into consciousness much as do words, faces or the solutions of problems. Impulses involving action are either inhibited or acted upon and our whole lives may hinge upon the result of the decision. Such impulses must be common to the whole animal world that is capable of voluntary action. They range in quality from mere reactions to abstract ideas and in number from a few per day to many per minute. The frequency of occurrence of high-grade abstract ideas and impulses is a measure of mentality. That frequency is higher the more intimate our association with our fellows. During periods of isolation, in fact, we quickly run nearly dry of both ideas and impulses. The advanced civilization attained by the Greeks may be attributed in large measure to these gregarious habits of association and discussion, resulting in a stimulation of the production of ideas and impulses.

Every impulse involves a decision to do or not to do a certain thing or to do this rather than that. As we habitually lean toward decisions of a certain nature, our whole lives are affected. The one who is prone to follow up impulses involving activities just within the limits of his powers will make the most rapid progress, come nearest to living up to his possibilities and make the most of his life and endowments. This is the whole secret of useful activity, of having the correct philosophy of life to make the proper decisions between impulses of trained judgment and great achievements in general. A good teacher is one who begets impulses in his students to undertake difficult tasks and to do their best in accomplishing them. Inherited tendencies to have original ideas and impulses and to undertake carrying out the most telling of these are our most valuable heritages.

Of the influences at our command which breed valuable ideas and impulses, not much is known. Helmholtz stated that the solutions of difficult problems most frequently came to him in walking up a certain hill on a sunny morning. To most of us, however, such ideas and impulses doubtless come most frequently during animated discussions with our colleagues. Alcoholic beverages are notoriously inhibitive in their action. They may appear at the time to be effective, but cold judgment shows that this conclusion is illusory. Narcotics undoubtedly have a temporary stimulating effect on originality, but with reverse after effects. The incentives to activity discussed above are, almost without exception, effective in generating fresh ideas and impulses, productive effort and originality being developed together. Our judgment of fresh impulses in selecting those worthy of further effort is partly instinctive, largely the result of a philosophy of life (of what is most worth while) developed during adolescence and partly the result of education and experience. Happy is he who instinctively takes a broad and far-sighted view of what is best worth while and who strikes while the iron is hot.

Summary.—The individual of great achievements is one with the thorough grasp of fundamental principles of the scientist, the ability to analyze and solve difficult concrete problems of the engineer or the originality to conceive and the skill to create the ideal or approximations to the ideal of the artist. He requires a heritage of originality and keen vision, unerring judgment obtained by proper education and experience, tireless enthusiasm and energy to accomplish desirable ends and finally a continual flow of worth-while ideas and impulses. Any one with suitable inherited qualities, striving for a maximum of achievement and usefulness to the nation, may properly devote himself to the acquisition of sound judgment and of ample incentive to activity. Thus are experts made and the leading nation of the future will be a nation of experts occupied in furthering the interests of that nation.

RELIGION AND SOCIAL CONTROL

By Professor CHARLES A. ELLWOOD

UNIVERSITY OF MISSOURI

RELIGION has fallen upon evil days, and civilization upon still worse ones. To superficial scientific thinking there may seem to be no connection between the state of religion and the present disturbed state of the world. For have we not been assured, very often in the name of science, that all religions are false and harmful to social progress? Self-styled "rationalists" have repeatedly asserted that science can find nothing in religious beliefs except superstition, error, or "the will-to-power" on the part of some privileged class. On the other hand, representatives of religion have not infrequently proclaimed it to be outside of the field of science, and have sometimes resented its scientific study almost as if it were a species of "sacrilege." Both attitudes have made difficult a truly rational, scientific and objective understanding of religion as a social phenomenon.

But the question of religion will not "down," either through scientific or religious obscurantism. More and more men are beginning to ask the meaning of religion in human life. Can civilized society, they ask, afford to dispense with religion? Or is religion something which enters necessarily into the warp and woof of civilization? In the reconstruction of our civilization which we now face it is time that scientific thinkers have some definite opinions to offer in answer to such questions. For if religion is a vital element in civilization, nothing could be more foolish and short-sighted than ignorance and indifference regarding its forms and functions.

Real science, however, in seeking to understand religion as a social fact rather than to pass upon the validity of any of its particular doctrines, is far from taking a hostile or an indifferent attitude toward religion. The most unprejudiced anthropologists and sociologists would probably agree with Professor Hobhouse, one of the most careful social thinkers of our time, when he says:

> The element of religion is common to all forms of society . . . as an element involved in the social consciousness itself and as a factor strengthening its hold upon the minds of men.[1]

But if this is so, and if science exists to serve humanity, then again it is time that the scientific world realizes the part which

[1] "Social Evolution and Political Theory," p. 128.

religion plays in social life, particularly as a means of social control.

But what is civilization, and what is religion, and why are they vitally related? Civilization, as we have seen,[2] is a complex of acquired habits. It is not innate in man, but each generation has to acquire the ever-increasing mass of habits and traditions which make it up. But these habits and traditions can not be passed on successfully from generation to generation in human society without strong social sanctions or adequate means of social control; for many of them call upon the individual to restrain his animal impulses and even to sacrifice himself for the good of his group. The social values which these habits and traditions represent accordingly, especially those which involve sacrifice of individual interests for group interests, have to be brought to the consciousness of the individual in the intensest way; or else proper social adjustments and habits will not result. Hence develops the whole machinery of social control—government and law on the side of the external acts of the individual, religion and morality on the side of the internal motives and beliefs. The most ancient of these means of social control is probably religion. As soon as the habits of any primitive group were reflected upon in connection with the welfare of the group they became inevitably associated with the elements of "luck," of good fortune or bad fortune, of safety and danger, to the group—in brief, with the whole mysterious, wonder-working powers of nature. Thus superhuman sanctions became attached to those habits of action which were found to be safe and to conduce to group welfare. They became, in other words, the "mores" of the group; and the "mores" thus imbedded in religious sanctions became all-powerful. Out of them were developed all the other agencies of social control. It is for this reason that we find primitive science and art, as well as primitive government, law, morality, and education all associated with religion—often, indeed, indistinguishable from it. Social control was thus primitively a religious control. And through all the subsequent centuries religion has been the core of social control, because it has been at the heart of the standards, the values, the "mores," of every civilization. We know, indeed, of no civilization which long endured that did not have a religious setting for its mores; nor of any which long endured after this setting was dissolved. When the religious sanction for the mores crumbles and disintegrates, the mores lose their vital hold upon the individual, especially those which demand self-restraint and self-sacrifice.

[2] THE SCIENTIFIC MONTHLY, November, 1917, p. 439.

and the civilization of which they are a part itself crumbles and disintegrates. The reason why this happens will become more evident as we proceed.

What, then, is religion, and why does it have this peculiar effect upon the mores? Fundamentally it is man's valuation, in an ethical sense, of his world, especially of that unknown part which is not covered by his work-a-day experience. It is a projection of man's social and personal values into the universe as a whole. Man must have a way of meeting every crisis in life; and life is ringed about with crises. He must necessarily make adjustments both toward the known and toward the unknown. He must of necessity have beliefs in regard to all of the adjustments which he has to make; for from beliefs and values come adjustments and attitudes. Some sort of valuing attitude he must have, therefore, toward the "*X*" realm of experience. Now religion is just this valuing attitude toward the unknown powers which are behind the phenomena of the universe and the desire to come into right relationships with those unknown powers. It does not particularly matter what formal definition of religion we may accept. We may subscribe to Professor Frazer's definition that "religion is a propitiation or conciliation of powers superior to man which are believed to control the course of nature and of human life";[3] or we may accept a more recent definition that "religion is man's attitude toward the universe regarded as a social and ethical force."[4] The essential thing is to see that religion arises as soon as man tries to take a valuing attitude toward his universe, no matter how small and mean that universe may appear to him. Some sort of religious attitude is necessary as long as men think and feel with reference to their world as a whole, and do not, ostrich-like, refuse to confront the reality in which they live and move and have their being.

Now in projecting social and personal values into the universe religion universalizes and makes absolute those values. Accordingly, just as the rationalizing processes of the intellect give man a world of universal ideas, so the religious processes give man a world of universal values. The religious processes are, indeed, nothing but the rationalizing processes at work upon man's instincts and emotions rather than upon his percepts. Man is the only religious animal simply because through his powers of abstraction and reasoning he alone is able to universalize his values. What science does for ideas, religion, then, does for the feelings; it universalizes them, and in uni-

[3] "The Golden Bough," second ed., Vol. I., p. 63.

[4] Barton, "The Religions of the World," p. 3.

versalizing them, it brings them into harmony with the whole of reality. It thus harmonizes man on the side of will and emotion with his world. Hence the noticeable individual effects of religion. It is the foe of pessimism and despair. It encourages hope and gives confidence in the battle of life to the savage as well as to the civilized man. It does this because it braces vital feeling; and it braces vital feeling, psychology tells us, because it is an adaptive process in which all the lower centers of life are brought to reinforce the higher centers. The universalization of values means, in other words—in psycho-physical terms—that the lower nerve centers pour their energies into the higher nerve centers, thus harmonizing and bringing to a maximum of vital efficiency life on its inner side. It is for this reason that religion taps new levels of energy, gives strength and confidence in oneself and in one's world, and often enables men to perform deeds far beyond what are commonly regarded as normal human powers.[5]

Now this fact that religion releases fully the energies of the individual in periods of crisis, braces his vital feeling, and helps him to face the issues of life and death with confidence in himself and in his world, is of course of the greatest social significance. For a social life without crises which demand self-effacement and self-sacrifice on the part of the individual is unknown and probably impossible. The dream which the hedonistic philosophers of the nineteenth century had of a "pleasure economy," a social order in which there would be no need of sacrifice on the part of the individual, because the difficulties and evils of life would be all overcome, has for the present, at any rate, been rudely shattered. The World War has shown that there is as much need of faith, loyalty, self-sacrifice, and self-devotion in the world as ever. And in the increasing complexity of human social life in the future there will probably be as much call for heroism, self-devotion, and self-sacrifice as in previous generations. Men will always need, in other words, for efficient, worth-while human living full command of their adaptive powers; and highest among these standing side by side as it were, the one intellectual and the other dominantly emotional, yet often in these latter days made strangely to antagonize each other, are reason and religion. However, the particular problem with which we wish to concern ourselves is not this energizing of life through religious beliefs and emotions, but rather the preservation of social order.

Religion has been from the first a powerful means of social

[5] For the psychological elaboration of these facts the classical work is, of course, James's "Varieties of Religious Experience."

control, that is, of the group controlling the life of the individual for the good of the larger life of the group. Psychologically it functions, as we have seen, to universalize values and make them absolute, so that they come into the consciousness of the individual in the intensest way. But the values thus universalized and made absolute are almost always those which come to the individual through the tradition of his group. They are values, in other words, which have been built up through the common life and transmitted from generation to generation because they have to do with the life of the group. They are social values. Again, it is the human world about him to which the individual has to adapt himself first of all. Hence values and feelings have more need to be universalized and made absolute on the side of the social environment; for it is to that environment that there is the most imperative need of adaptation. The life of the group must be a real working unity. In confronting its environment and the many foes which are often found there, the group must have unity of action; hence it must have unity of feeling, of values, among its members. The group as a whole needs this inner harmony on the side of feeling if it is to command the full energy, the unfailing devotion, of all its members. Its values, its emphasis upon the meaning of life, of service, and of sacrifice need to be brought to the individual in the intensest way—with that absolute sanction which only religion gives. Hence the group, like the individual, is under the psychological necessity of universalizing its values if it is to realize a full and efficient life as a group. As a part of the cultural complex of every group it is the function of religion, accordingly, to universalize values approved by the group. Religion from the start, in the stricter sense of the word, therefore, has been a social matter; and attempts to attach superhuman sanction to values, beliefs, or practises of which the society does not approve have always been branded as "black magic," or as "superstition," or as "heresy."

Hence the close connection between the customs or mores of the group, as we have already pointed out, and religion in the social sense. As a social fact religion is, indeed, not something apart from mores or social standards; it is these as regarded as "sacred." Strictly speaking there is no such thing as an unethical religion. We judge some religions as unethical because the mores of which they approve are not our mores, that is, the standards of higher civilization. All religions are ethical, however, in the sense that without exception they support customary morality, and they do this necessarily because the values which the religious attitude of mind universalizes and makes absolute are social values. Social obligations thus early become religious obligations. In this way religion becomes the chief means of conserving customs and habits which have been found to be safe by society or which are believed to conduce to social welfare.

As the guardian of the mores, religion develops prohibitions and "taboos" of actions of which the group, or its dominant class, disapproves. It may lend itself, therefore, to maintaining a given social order longer than that order is necessary, or even after it has become a stumbling block to social progress. For the same reason it may be exploited by a dominant class in their own interest. It is in this way that religion has often become an impediment to progress and an instrument of class oppression. This socially conservative side of religion is so well known and so much emphasized by certain writers that it scarcely needs even to be mentioned. It is the chief source of the abuses of religion, and in the modern world is probably the chief cause of the deep enmity which religion has raised up for itself in a certain class of thinkers who see nothing but its negative and conservative side.

It is not our purpose, therefore, to enlarge upon this negative and conservative aspect of religion, but to discuss it as having to do with social control in a higher sense. We should remember, however, that order is the indispensable foundation of progress in society, and that even purely as a conservator of customary social values and standards religion has a great function to perform. It acts as a sort of "equilibrator" or stabilizer for social institutions. It prevents waywardness in individual character and aids in securing that conformity to type, that similarity of belief and of action, which is the essential of social solidarity. As Ward said, it acts very much in the social life as instinct does in the animal world. It insures social order and so lays the foundation for social progress.

There is no necessity, however, for the social control which religion exerts being of a non-progressive kind. The values which religion universalizes and makes absolute may as easily be values which are progressive as those which are static. In a static society which emphasizes prohibitions and the conservation of mere habit or custom, religion will also, of course, emphasize the same things; but in a progressive society religion can as easily attach its sanctions to social ideals and standards beyond the existing order as to those actually realized. Such an idealistic religion will, however, have the disadvantage of appealing mainly to the progressive and idealizing tendencies of human nature rather than to its conservative and reactionary tendencies. Necessarily, also, it will appeal more strongly to those enlightened classes in society who are leading in social progress rather than to those who are content with things as they are. This is doubtless the main reason why progressive religions are exceedingly rare in human history, taking it as a whole, and have appeared only in the later stages of cultural evolution.

Nevertheless, there are good reasons for believing that the inevitable evolution of religion has been in a humanitarian direction, and that there is an intimate connection between social idealism and the higher religions. There are two reasons for this generalization. The social life becomes more complex with each succeeding stage of upward development, and groups have therefore more need of commanding the unfailing devotion of their members if they are to maintain their unity and efficiency as groups. More and more, accordingly, religion in its evolution has come to emphasize the self-effacing devotion of the individual to the group in times of crisis. And as the complexity of social life increases, the crises increase in which the group must ask the unfailing service and devotion of its members. Thus religion in its upward evolution becomes increasingly social, until it finally comes to throw supreme emphasis upon the life of service and of self-sacrifice for the sake of the group; and as the group expands from the clan and the tribe to humanity, religion necessarily becomes less tribal and more humanitarian until the supreme object of the devotion which it inculcates must ultimately be the whole of humanity. Again, religions have, for the most part, in the later stages of culture, after they have passed through the period of ancestor worship, gotten their social ideals from the family life; and sociology shows that the social and moral ideals of higher civilization in general also have come from the primary forms of association, such as the family.[6] Now social idealism is an attempt to realize in the wider social life these primary ideals which are gotten from primary groups; and as the higher ethical religions got their ideals from the same source they have the same aim. The higher, or so-called "ethical" religions, are, therefore, but manifestations of social idealism imbedded in religious feeling and accompanied by more or less formal religious sanctions.

A somewhat detailed study of religious development would of course be required to throw a fuller light upon the necessity, the universality, and the function of religion in human society.

[6] Cooley, "Social Organization," Chap. IV.

No one can understand religion, as has been well said, without understanding other religions than his own, any more than one can understand language without understanding other languages than his own. The scientific student of religion must recognize, as Marett says, that there is a "soul of truth" in all religions.[7] At any rate no religion lies in utter isolation from other religions, and from the most highly developed to the most lowly there are intellectual clews running back which are of the utmost value for the understanding of the relations of religion to civilization. Let us very briefly sketch, therefore, the evolution of religion.

If we take the commonly accepted seven stages of religious evolution, namely, pre-animism, animism, totemism, ancestor worship, polytheism, henothism, and monotheism, it is not difficult to see that they not only embody man's valuation of his world but also the social values of the age which they represent. Thus in the pre-animistic stage we have every reason to believe the conception of the "sacred" arose, as illustrated, for example, in the Melanesians' conception of "Mana." This word was used by the Melanesians to signify a power or influence not visible, and in a way supernatural, showing itself in connection with both persons and natural objects.[8] Fear and reverence were always attached to any person or thing which manifested "Mana," and thus such persons or things were "taboo"; and upon this idea of taboo the whole conception of the "sacred" as a means of social control seems to have been built up. The world was filled, in other words, with a mysterious, wonder-working energy which was the source of all success, luck, or good fortune, and which must be dealt with in a certain way in order to insure these desirable effects both for the individual and for the community. The American Indian had much the same conception in such words as "Manitou" and "Wakanda," and among many other primitive peoples we find parallel conceptions. Nothing was more important for the individual or the community in this stage than to put itself into right relations with this mysterious, wonder-working power which assured good or bad fortune. Hence already, though there were no "gods," the whole mental and social machinery of religion was at work with respect to the mores in the way which we have already described at the beginning of this paper.

The second stage of religion came when this mysterious, wonder-working power was conceived of as a "double" or a "spirit" which resided in men, animals, and things. This

[7] "Anthropology," Chap. VIII.

[8] Codrington, "The Melanesians," p. 118 f.

stage is known as "animism." The mysterious, wonder-working power was conceived as able to exist apart from the object in which it resided. Thus was born the conception of the "soul," a conception which was bound to be reached by man's power of abstraction, but which was made easier through man's reflection upon the experiences of his dream-world. Out of the dualism of the ordinary and the extraordinary, the natural and the supernatural, grew the further dualism of the physical and the spiritual; and the mysterious, wonder-working powers were identified with the spiritual beings, the "souls" or "doubles" of men, animals, and things. A further step in the development of religion is shown in animism, because man now more definitely interprets his world in terms of himself, of his will, and of his values. This stage prepared religion to develop and emphasize the subjective element, and to make it the chief element in social control.

A third stage of religious development was "totemism," in which animals or plants became the chief objects of religious veneration. The totemic stage arose naturally from the animistic, and marked a broadening of man's knowledge concerning his world. It was correlated with the hunting stage of economic development. Man was surrounded by animals, he hunted animals, he lived on animals, he thought in terms of animals, and therefore, he mainly worshipped animals. It was the zoomorphic stage of religion. The mysterious wonder-working power was the animal or plant which was regarded with religious reverence and conceived of as having some mysterious relation to the group, which usually bore its name. Kinship and religion now become definitely allied, and hence we may say that this was the first stage in which religion came to have an organized control over all the forms and relationships of social life. Art, education, and food-getting, also, now come under well-defined religious control.

The fourth stage of religious development, the hero-ancestor-worshipping stage, did not arise until the patriarchal family and pastoral industry, together with the power of the war chief, emphasized the human element. Thus the anthropomorphic stage of religious evolution was reached. The mysterious, wonder-working powers were now conceived to be the souls of departed heroes or ancestors. Each family had its own gods and its own domestic worship. This stage fostered the development of the domestic virtues, accordingly, and of the social ideals derived from the domestic virtues; but it had a great drawback in that, by apotheosizing the departed ancestor, it emphasized too much the values of the past. Religion took on an ultra-conservative nature and made possible such static civilization as was, for example, illustrated for centuries by the Chinese. The abuses of religion, from a social point of view, now begin to appear.

When small ancestor-worshipping groups were welded into city-states or small nations, the gods of the different groups, who included not only the heroic ancestors of the past, but also many nature spirits whose worship had survived from animistic times, formed a "pantheon," and we have the stage of religion which is known as "polytheism." In this stage there is a classification of gods. Not every blade of grass had a god, but there might be a god of the grass. Neither did every man have a god, but there was a god for practically every social activity of man, a god of war, a god of love, etc. All were highly personalized beings, and the community of gods was conceived as more or less like the community of men, though often idealized. This stage was really transitional, and is marked by a confusion of ethical and religious conceptions and values. There was in it, therefore, the opportunity for the sanction of all sorts of practises, and the abuses of religion become more manifest, as seen, for example, in the various practises of idolatry.

Out of polytheism slowly developed another intermediary stage of religion known as "henotheism," in which one of the gods of the pantheon was chosen by a people as its particular national god, without their denying at first, however, the existence of other gods. Gradually the other gods came to be regarded as "false gods" and the national god as the true god. All monotheistic peoples have passed through this henotheistic stage, though students of religion have sometimes failed to recognize it. The early Jews, for example, before the later prophets were unquestionably henotheistic. This national stage of religion[9] served greatly to unify peoples in strong nationalistic groups. It is a serious question whether our civilization is not yet mainly in this stage of religion. Religion in this stage is crudely anthropomorphic, and the deity is thought of as having the national character of the people with very definite human traits.

True monotheism is reached only when the mind of man sees that there is but one universal existence from whence all things, including his own mind, have proceeded and of which they are a part. Monotheism, in other words, is the recognition of the infinite as God, that infinite and eternal energy from

[9] Some special term like "henotheism" is certainly needed to designate the strongly marked "national" stage of religious evolution.

which all things proceed and to which all things return. Such a conception has tended in our civilization to take the form of an ethical theism, and probably rightly, since mere "energism" satisfies neither the emotions nor the intellect of man. The one distinctive contribution which modern science, indeed, has been able to make to religious thought on the theological side is the recognition of the fact of "creative evolution," that the energy of the universe is "an ascending energy." Thus under ethical theism the highest social values have been readily given a religious sanction, that is, universalized or projected into the universe. Hence social idealism has been stimulated by ethical monotheism as never before in the history of civilization.

Now this rough outline of the development of religion shows clearly enough that religion has evolved with the social and mental life of man; that it is a thing which changes with the whole cultural complex which we call "civilization"; and that changes in religion have had much to do with changes in man's social and cultural life in general. Clearly enough, too, human history has been, from one point of view, a struggle to attain to a rational and truly social religion—such a valuation of all the experience of life in terms of the universe as accords with man's reason and yet intensifies his social values. Only to an absolute skeptic would the great revolutions in religion appear other than as steps in social and cultural progress. But what will the next revolution in religion bring forth? Will it not be "atheism," as so many have said?

It hardly needs to be pointed out to the student of civilization that we have scarcely yet attained to a true ethical monotheism; that we left henotheism behind but yesterday, and that still the peoples of the world are prone to relapse into it. Ethical monotheism may, indeed, be a form of religious consciousness to which the masses of mankind never can attain, but if cultural progress continues religion should develop in this direction, if we can judge from its past history. Monotheism is not outgrown; we have not yet grown into it. We need a more social and ethical form of it rather than a theological and metaphysical conception merely. The religious revolution which now confronts us, in other words, concerns the transition from theological to ethical monotheism, from a metaphysical to a social conception of religion.

But it may be asked, why should social values be expressed religiously? Is not the fact that they are social values, built up from the real experiences of mankind, sufficient sanction for them without attaching to them theological or mythological notions? This form of the question, however, indicates a misunderstanding. For a religious sanction given to social values does not necessarily imply the attachment to them of any *definite* theological notions; it only implies that they are made universal and, as it were, absolute. The history of the evolution of religion shows this very conclusively because *theological notions have constantly changed, but religion has remained.* It is true that there is a minimum of theology and of metaphysics which remains in all religion and which is necessary to it. But the same statement is equally true of science. Religion refuses to negate the universe, to deny the reality of existence, of life, or of mind. But equally so does science. Religion can not build itself upon negations; but neither can science, nor art, nor education, nor any of the other practical social activities of mankind. All such practical social activites are necessarily built upon a common-sense, constructive attitude toward "the system of things." Religion assumes, of course, that the system of things is not alien to ourselves. We can not rule theology out of religion altogether, any more than we can rule metaphysics out of science; but the place of theology in religion during the past few generations has been much exaggerated, and this has been one of the main impediments to the attainment by our civilization of a rational and humanitarian religion. The recognition that religion is a thing which exists independent of *definite* theological doctrines is necessary, therefore, for its free development, though this statement should not be interpreted to mean that we can build a religion, any more than anything else, upon a negative attitude toward life, mind, or the universe at large.

The religious problem, then, is not the problem of merely maintaining religion in human life. For reasons which we have seen there is probably no such problem as that; for if we do not have a rational and ethical religion, the mind of man is such that we are bound to have irrational and unethical religion —if not a religion of social progress, then a religion of social retrogression and barbarism. The religious problem of our age is what the religious problem of every age has been, the problem of getting a religion adapted to the requirements of our present social life. But the requirements of social life are at present so much more complex than in any other period of human history that a socially superior religion is needed. The modern man lives in a more complex world in which the difficulties of adjustment are so great that pessimistic writers are wont to tell us that humanity has about reached its limits of adjustment. At the same time higher intellectual development makes it more necessary for the modern man to see a meaning in things beyond mere appearances if he is to adjust himself successfully to them. Finally, the delicate interrelations of all parts of our civilization make a stronger and more universal good will necessary, if social calamity is not to overtake us. Never before in the history of the world, then, did rational social values need more the sanction of religion than at present, because never before did they need to come to the consciousness of the individual in intenser form. The limits of adjustment have, of course, not been reached by humanity; in fact no one can scientifically set the limits of possible human adjustment. But in the new and complex world in which we now live, in which the interdependence of man and man reaches to the uttermost bounds of the earth, we need more of the guidance of reason and at the same time a stronger motivation for making complex social adjustments. In other words, while we need science, we need, not less, confidence in our world and universal good will towards men. That is to say, we need religion and morality not less than science, to meet the problems of more complex human living together. Those who are interested in the development of an harmoniously adjusted social life for humanity as a whole can not afford, therefore, to ignore religion as a means of social control; for, as we have tried to show, the more complex social life becomes the more impossible is an adequate social morality without a correspondingly high development of social religion.

Obviously, it is only a rebirth of humanitarian ethics which can save the world from its present welter of seemingly unending class, national, and racial struggles. But humanitarian ethics demands more in the way of self-sacrifice from the individual than class, tribal, or national ethics. It makes the least appeal of any system of morality to the natural egoism of the individual because it concerns the largest possible human group, having to do with the welfare of many individuals of whose existence the average individual knows nothing directly through experience, and concerning whose welfare he can have tangible ideas only through the exercise of the liveliest imagination. Humanitarian ethics, in order to be successful, must be supported by a religion which will stimulate a humanity-wide altruism in the individual. It must have the support of a religion of humanity. The social significance, then, of the attempt to develop in the higher stages of social and cultural evolution a humanitarian religion, a religion which sets up the love and service of humanity as the highest manifestation of religion, is nothing less than that *it is the process by which social evolution is endeavoring to transcend individual, class,* *tribal, and national ethics and to replace these by a social, international, humanitarian ethics.* This is the significance of the religious problem and of the truly progressive religious movements of our day.

But in the meanwhile retrogressive tendencies have also shown themselves in the religious life of western civilization—tendencies which threaten to defeat the normal evolution of religion into the humanitarian type. What then is to be done? The creation and establishment of a new religion under the complex conditions of modern life is almost out of question, because there would be little chance of such a venture becoming successful in time to perform the services which are needed for the control of our world-wide civilization. Nor is such a venture necessary; it is only necessary that the leaders of religion of our day grasp the social significance of religion in our civilization and give it the positive humanitarian trend which the situation demands. Fortunately, the most advanced religions of our time have already attached themselves more or less formally to the cause of humanitarian ethics. This is especially true of the most advanced Christian sects. All that is needed, therefore, is that the churches of to-day should drop theological disputation, recognize that their essential work is the maintenance and propagation of rational social values, and teach clearly that the only possible service of God must consist in the service of men, no matter what their class, race, or nationality may be. In this work the churches would not only forget their traditional differences, but it is probable that they would rally to their support a very large part of those who are now their active opponents.

Let the recognized basis of religious fellowship, in other words, become full consecration for the service of mankind, and all the irrational, unsocial, and unprogressive elements in our religious life would then disappear. We should then have a religion adapted to the requirements of our social life, and a basis of social control adequate for the highest civilization. There have been many stirrings in this direction in religious circles within recent years, but they are as yet far from fruition. After this war is over, if not before, however, it is to be hoped that we shall take seriously in hand the reconstruction of our religious life along humanitarian lines. For an actually realized humanitarian religion, sanctioning and enforcing a humanitarian ethics, would be our surest guarantee of establishing social justice and future good will between classes, nations, and races, and the surest preventive of the recurrence again of such a calamity as the present war.

THE METHOD OF NATURE

By Professor I. W. HOWERTH

UNIVERSITY OF CALIFORNIA

NATURE is creative. This is no new and profound idea originating in the mind of M. Bergson; it is a patent and familiar fact lying on the surface of things. Creation is merely the production of something new. Man creates, but only by application of the creative principles of nature. Nature's creations do not differ in any essential respect from the created products of man. When two or more chemical elements combine by chance in certain proportions the result is something new, something entirely different from either constituent; a product manifesting new properties; it is a creation of nature. Such, for instance, are all the gases, liquids and solids, which go to make up the visible universe. Some of these man recreates by a process of creative synthesis, as, for instance, in synthetic chemistry.

If, then, we conceive the existing universe as having been evolved gradually and naturally, that is, from the operation of inherent forces, and from diffused matter consisting of a few elements or of one; or, in other words, if we accept the current doctrine of evolution; we must recognize that all the various forms of matter, with all their peculiar properties, have come into existence at certain definite times in the past in a natural manner. From a state of existence *de potentia* they passed, sometime and somewhere and for the first time, into a state of existence *de facto*. They were, therefore, at their initial appearance, absolutely new creations. The order of their appearance was more or less serial. Roughly speaking, it was perhaps as follows: the atom, the molecule, the inorganic compound, the organic compound, protoplasm, protists, plants, animals, man, society. The principle involved is that of combination. Nature creates by compounding. Creation is permutation.

Nature, then, is not only "*durch und durch causalität*," as Schopenhauer declared; it is through and through creative. All that now exists, whether in the inorganic, organic, or social worlds, save the relatively few products of man's intelligence, is the outcome of a natural creative process and the manifestation of a natural creative power.

Confining attention, for our present purposes, to the creative principle as manifested in the organic and social worlds, we find it marvelously exemplified in the manifold and myriad forms of plant and animal life, and in the social groups and institutions which have come into existence spontaneously.

With respect to plants and animals there are now known and classified more than two million species, and the number is increasing every day. In the classification of Linnæus, made in 1758, we find included only 4,136 species of animals. In modern classifications the number is multiplied more than a hundred fold. A recent writer places it at 716,000. A speaker at the American Society of Zoologists in 1912 gave a total of 522,400. Jordan and Kellogg, in their book entitled "Animal Studies," state that there are 300,000 named species of insects known to zoologists, and that this number represents only one fifth, or possibly one tenth, of those living throughout the world. Herbert Spencer, in 1852, on the authority of Humboldt and Carpenter, placed the number of animal species at 320,000 and of plants at two million, and declared that

> If to that we add the number of animal and vegetable species that have become extinct, we may easily estimate the number of species that have existed and are existing on the earth at not less than ten millions.

Now what created all these forms of life with their infinite variations? Nature. The orthodox religionist would use the interrogative "who," and answer, "God;" and there need be no objection to that reply. But inasmuch as science deals only with secondary causes, not at all with ultimates, the scientific answer must be as given; and there should be no objection on religious grounds to the answer thus made.

Nature, by a distinctively creative process, then, brought into existence all the various species of plant and animal life, and animal and human societies, too; and controls them all in so far as they are not products of conscious human effort. We are aware that an objection may be raised to thus objectifying nature and apparently separating it from its products, but such separation appears to be a necessity of speech, and, aside from noting the possibility of such objection, it need not detain the argument.

Now, nothing is produced, accomplished, or achieved without some describable mode or way of procedure. The mode or way in the process of human achievement is denominated method, and, by a figure of speech, we may employ the same term in describing the creative process of nature. What, then, is nature's method of creation?

In spite of modern criticism of the Darwinian hypothesis, which appears oftentimes to be over-refined or misdirected, it may be said that the method of nature is most adequately described as a process of natural selection, meaning by that expression all that may be rightfully implied. Darwin himself admitted that other factors are involved in the process.

Taking natural selection, then, as the most important means or method of natural creation, we wish to point out some of its most conspicuous characteristics, the range of its application, and the folly of relying upon it for the realization of desirable human ends.

The first element which reveals itself in an analysis of the principle of natural selection is a "multiplication of chances." This is required to furnish opportunity for selection and is occasioned by the fertility of nature. Nature brings into existence many more organisms than can possibly survive. This is necessary in order to secure the requisite number and kinds of variants in a given type of organism to secure survival of the species and progressive adaptation. But it means, so far as any special and particular result is concerned, an enormous waste. The first, and most obvious, characteristic of nature's method is its extraordinary wastefulness.

To appreciate the waste of nature one has but to compare its potential with its actual achievement in the perpetuation of a given type of organism. Among microorganisms the possibilities of increase in number are most astounding. A minute form of life, *hydrotina,* is capable of producing offspring with such rapidity that, in a single year, they would form a sphere whose limits would extend beyond the confines of the known universe. A certain infusorium, *stylonichia,* is said to be capable of producing in six and one half days a mass of protoplasm weighing one kilogram. In thirty days, at the same rate, it could produce a mass a million times larger than the sun, the weight of which in kilograms would have to be represented by a figure followed by forty zeros.[1] A plant which produces only two seeds a year, and there are few, if any, that are not more prolific, would have in the twenty-first year, if none was destroyed, 1,048,576 descendants. A horse-chestnut tree may produce a ton of pollen. A housefly lays a hundred and twenty eggs, and there are twelve to fourteen generations in a season. Counting twelve generations only, a single fly, if all its offspring survived, might be the parent

[1] For these and other striking illustrations of the potential fertility of nature, see Morgan, "Heredity and Sex," p. 2; Marshall, A. M., "Lectures on the Darwinian Theory," pp. 39–40.

of a family numbering 4,253,564,672,000,000,000,000. A salmon lays 15,000 eggs, an octopus, 50,000, a large shad, 100,000, a codfish 1,000,000, an oyster 2,000,000, a conger eel 10,000,000, a tapeworm 1,000,000,000. In 1864 a man living on a sheep ranch near Melbourne, Australia, imported, from the Kew Gardens in London, three pairs of rabbits. In 1906, forty years afterwards, Australia shipped to Europe 25,000,000 frozen rabbits, and 96,000,000 rabbit skins. Horses were introduced in Buenos Ayres in 1537. In forty-three years they had spread to the Straits of Magellan. Fertility diminishes as we rise in the scale of animal life, but even the human being is capable of reproducing with such rapidity that from a single pair, doubling once in fifty years, there would be in three thousand years a sufficient number of human beings to cover the whole surface of the earth, land and sea, and piled on top of one another eight hundred deep. Such are some of the illustrations of the potential natural increase of organisms.

Notwithstanding this enormous fertility of nature, in spite of this enormous multiplication of chances, it is a well-known fact that the number of any given species remains, as a rule, practically the same from year to year. What becomes of the surplus? Why is it that "of fifty seeds She often brings but one to bear"? Obviously the surplus production is wasted, at least so far as the perpetuation of the given species is concerned. Says Asa Gray:

> The waste of being is enormous, far beyond the common apprehension. Seeds, eggs, and other germs, are designed to be plants and animals, but not one of a thousand or of a million achieves its destiny. . . . But what of the vast majority that perish? As of the light of the sun, sent forth in all directions, only a minute portion is intercepted by the earth or other planets where some of it may be utilized for present or future life, so of potential organisms, or organisms begun, no larger proportion attain the presumed end of their creation.[2]

Nature's economy, then, is no economy at all; its order is disorder; its method is the absence of method, if that word be defined in terms of human procedure. The most conspicuous characteristic of nature's mode of action in the process of creation, or of perpetuation, is waste.

This waste is manifested not alone in the number of material products destroyed but also in the amount of time required to produce a given result. Lamarck perceived this. He said,

> For nature time is nothing. It is never a difficulty, she always has it

[2] "Darwiniana," by Asa Gray, New York, 1877, pp. 372–373.

at her disposal; and it is for her the means by which she has accomplished the greatest as well as the least results.

It required millions of years to fashion the earth, millions to populate it with the lower orders of life, perhaps a million to develop man, and thousands of years to produce a civilized people. The method of nature is slow.

Still another, and perhaps more significant fact, is that the method of nature is uncertain, so far as the realization of results desirable to man is concerned. This arises from the absence in all purely natural processes of the aims and purposes of man. All movements of nature, as far as we are able to trace them, are in the direction of balance or adjustment. As to whether the resulting conditions, or the products created thereby, are profitable to man, nature is wholly unconcerned. Whatever else it may be, nature is not Providence. According to the law of probabilities, it must sometimes happen, of course, that in the manifold activities of nature, and in the multiform products resulting from those activities, something will be found conforming to human desires, and certain processes will be directed toward the achievement of desirable human ends. Nevertheless nature is aimless, and the human benefits resulting from the operations of nature's method are wholly accidental.

Such, then, are the leading characteristics of the method of nature; it is wasteful, slow, and aimless, therefore uncertain so far as the production of desirable human results are concerned. Let us now observe the range of its operations.

Obviously the method of nature applies to all movements, and to the creation of all products, in which intelligence is not involved. Such, for instance, are the creation and movements of the planets, of the clouds, of the waves of the sea, of the earth and the convulsions in its crust, and the creation and development of all plants and animals in a state of nature. It should be equally obvious that it applies, also, to all incidental, that is, all unintended, results of intelligent action. But much that happens in human life is incidental to the pursuit of conscious ends; it falls outside of the purposive; it is fortuitous, accidental, and belongs, therefore, in the realm of nature; and anything resulting from it is achieved by nature's method.

With this understanding it is easy to see that many, if not most of the movements of society, whether progressive or regressive, take place in accordance with the method of nature; they are unintended, wholly incidental to the human pursuit of other ends. For it is an obvious fact that individuals in pursuit of strictly personal ends, and corporate bodies in the pursuit of corporate ends, may affect society for good or ill. So far as society is thus affected it is under the control of nature. Social movements thus produced, social products thus created, are without conscious intent on the part of anybody. As a matter of fact most social movements, most of the social progress of the past, and much of that of to-day, are, socially considered, unconscious and unintended.

Society to-day, then, is still, in large part, under the domain of nature, and the progress achieved is still largely the result of the operations of nature's method. Such progress is, therefore, wasteful, slow, and uncertain. War between social groups, and for national rather than social purposes, and business competition for corporate or individual ends, are often socially progressive in results, but the progress achieved by them is attained by nature's method, and is therefore as wasteful, slow, and uncertain as any of the other operations of nature.

With some of the lower organisms, the domesticated plants and animals, the method of nature has long since been supplanted by artificial selection, and the other more economical methods of mind. Waste is eliminated, development is hastened, new types are developed, change is directed toward a predetermined goal.

The same thing might be and should be true of social change. As society is a product of nature, and its movements subject to natural law, it may be modified by the intelligence and will of man. Its progress, as achieved by the method of nature, is wasteful, slow and uncertain. We should no more rely upon the method of nature to bring about a high form of civilization than we should rely upon that method to bring into existence the particular types of plants and animals most serviceable to man. He who hopes that the natural method of social development will of itself produce democracy, for instance, or permanent peace, or that the brotherhood of man will inevitably be reached as a natural goal, is in like case with the foolish optimist who expects a good crop to be grown without cultivation or a Micawber who expectantly waits for something favorable to turn up. It is man's prerogative to supplant, in the whole field of natural phenomena, the method of nature by the method of mind, and thus to control social events and social progress as he has long been controlling the progress of the domesticated plants and animals, and many of the processes of the physical world.

If this idea, and this possibility, ever should become realized, they must necessarily involve, as a preliminary step, the development of a social consciousness as distinguished from the narrower group consciousnesses which now prevail, and in which the latter will merge. This necessarily means a league of nations, and the surrender, on the part of national groups, of independent national sovereignty. To the idea of the necessity of such a league many have already come. The conception is generally limited, however, to that of a league to secure and maintain international peace. But, if the method of nature is to be supplanted in the progress of society, the functions of such a league must be carried far beyond the establishment and maintenance of peace. It will not be enough to create a league within which the method of nature is to operate in the wasteful, even though peaceful, struggles of groups, in a "war after the war." There must be definite, constructive purposes looking to the elimination of strife and petty jealousies, and the organization of all the resources of society in the interest of human happiness. The internal operations of society must also be brought under social control, and social control, no matter where it is exercised, means the supplanting of nature's methods by the more economical methods of intelligence.

A league of nations, then, is necessary, and we do well to urge its formation. But if social progress is ever to become orderly, if we are ever to eliminate its terrible waste, if social change is ever to become certainly progressive, if we are to approach with even pace the social conditions of which already many have dared to dream, the method of nature must be supplanted everywhere throughout the realm of human interests, and society become a work of art, and not remain as it now is, largely a product of nature. Can this be done? Is man, who controls with such wonderful results the physical forces, and who determines in large measure the destiny of all lower creatures, powerless to determine the destiny of society? Shall it be said of Man, as it was said of the Son of Man, "He saved others, himself he cannot save"? The achievements of science in every domain of natural phenomena, the gradual extension of a social art based on a science of society, deny it, and give ground for a more optimistic social philospohy.

THE CHEMISTS OF AMERICA

By Dr. BENJAMIN HARROW

COLUMBIA UNIVERSITY

AT a recent meeting of the Washington Academy of Sciences, the chemical representative with the British mission in this country told the audience that the side with the best chemists will probably win the war. This is worth remembering when our statesmen fill themselves, the newspapers, and the people with war knowledge.

Perhaps some will take our Britisher to task for giving undue importance to his sphere of activity. If so, let the facts speak for themselves. Until shortly before the outbreak of the war the nitrate supply of the world came from Chili. With it the world's supply of fertilizer was satisfied; with it, nitric acid, and hence our various modern explosives, were manufactured. But the deposits, like those of coal, have their limits; and the world's needs were emptying the nitrate deposits even faster than those of coal. The situation was alarming but not hopeless, for at this point the chemist stepped in and suggested a solution. Approximately eighty per cent. of the air we breathe contains nitrogen. But this element, in the free state, is useless for most purposes—whether to feed the soil, or feed man, or prepare munitions. And to combine it with oxygen to get the necessary nitrates is not an easy matter. However, the chemists attacked the problem. Particularly so the chemists of Germany.

As soon as war was declared, Germany's supply of Chili saltpeter was cut off. But by that time her chemists had solved the problem of the fixation of nitrogen—as the process by which the nitrogen of the air is converted into nitrates is called.

There is much plausibility in the assertion that the militaristic clique in Prussia awaited but the solution to this problem before finding a convenient pretext for war.

When, after the battle of the Marne, defeat stared the Prussians, who helped them to stave off defeat? The chemist with his gas. And when our allies had developed effective counter-measures for this added horror of modern warfare, the German chemist introduced the gas shell. It is now being pretty generally conceded by those in a position to know, that the recent German drives on the western front have been made possible not merely because of added numbers from the East, nor because of Von Hutier's new form of attack, but to a large extent on account of a prodigal expenditure of "mustard" gas. Re-read the story of the evacuation of Armentières.

What has saved Germany thus far is not her organization, nor her generals. It is her chemists. Every one talks of Hindenburg and Ludendorff. But how many have heard of Baeyer and Fischer?

Let not the reader, however, get the impression that Germany has a monopoly of chemists. By no means. Germany has made much of her chemists, whereas we have neglected ours. The German government, through its industrial organizations, has constantly encouraged them to further efforts; our statesmen, steeped in Greek, Latin or Tammany classics, have not.

But the dawn of a brighter day is arising. The world tragedy has opened the eyes of our people. When peace and goodwill once again reign among us, let us hope that the leaders of at least two of our great democracies will take the lesson to heart—not, indeed, to encourage their scientists to devise further, and more horrible means for conducting warfare, as is done by the present German government, but to encourage our plodding philosophers in the search they love best—unfolding the secrets of nature, thereby adding to the knowledge and happiness of the world.

* * * * * * * *

Chemistry in America is a very young product. It probably received its impetus from the Englishman, Priestly, the discoverer of oxygen, who came to these shores in the latter part of the last century, and from Robert Hare, the inventor of the oxy-hydrogen blowpipe. The flame was kept a-burning by a succession of well-known teachers at Harvard and Pennsylvania, among whom may be mentioned Cooke and Wolcott Gibbs. The more modern period was ushered in by Charles Eliot in Boston, Ira Remsen at Johns Hopkins, Frederick Chandler at Columbia, and E. F. Smith at Pennsylvania.

From small beginnings the science has enlarged a thousandfold. Our American Chemical Society has a membership of 10,000. It publishes an erudite journal, devoted to recording the results of research by its members; a chemical abstracts, embracing a digest of the world's chemical literature; and an industrial journal which, in the last four or five years, has become unrivaled.

Germany has for so long appropriated the ideas of some of the master minds of Britain and France, that it is a rather welcome sign to find the Americans turning the tables upon the Germans now. Some of our leading chemists have received their post-graduate training in Germany. These men are making use of their training with a vengeance. Apart from their immediate services to the government, these men have, during the last twenty-five years, trained the younger generation to a degree which has called forth the admiration of their German masters. Even before the war, the number of American chemists at German universities showed a marked falling off. Our post-graduate departments at Harvard, at Chicago, at California, at Columbia, at Johns Hopkins, at Yale, at Michigan, and others, have become the serious rivals of those at Berlin and Munich, Bonn and Heidelberg.

The chemical advisers of the government are directing, and the larger body of chemists are actively engaged in work on explosives, on gases, on foods, on iron and steel, on copper, on aluminum, on fertilizer, on dyes, on drugs, on rubber, on leather, on paints, on glass, on fats and soaps, on paper, on cement, etc. Who are some of these men, so indispensable for the successful prosecution of the war, and just as indispensable for the development of our country after the war?

In the mathematical branch of the science—that more particularly concerned with the fundamental properties of matter—we probably lead all other countries. Willard Gibbs (Yale), one of the profoundest mathematicians of the century, was the forerunner. Closely following upon him came Edward Morley (Western Reserve), whose work on the composition of water is among the classics in chemistry. At present there is T. W. Richards (Harvard), winner of the Nobel prize, and the great authority on the weight relationships of the elements; G. N. Lewis (California), the energy exponent, now with the oversea forces; and workers on the theories of solution and other kindred subjects; H. N. Morse and the late H. C. Jones (Johns Hopkins); W. D. Harkins (Chicago); W. D. Bancroft (Cornell); E. W. Washburn (Illinois); J. L. R. Morgan and James Kendal (Columbia); M. Rosanoff (Pittsburgh), etc.

Closely associated with these, but particularly well known as the authors of successful text-books, may be mentioned A. Smith (Columbia); J. Stieglitz (Chicago); and C. Baskerville (College of the City of New York).

In the analytical field—the detection and estimation of the elements and their compounds—we have F. W. Clarke (U. S. Geol. Survey), particularly well known for his work on chemical geology; F. A. Gooch (Yale), originator of several well-known appliances in the laboratory; W. F. Hillebrand (U. S. Geol. Survey), the author of a splendid work on rock analysis, etc.

In the field of organic chemistry, where we are introduced to glycerin, carbolic acid and toluol, leading on to the chemistry of modern explosives, we have M. Gomberg (Michigan); M. T. Bogert, in charge of the chemical service section of the National Army, and J. M. Nelson (Columbia), T. B. Johnson (Yale), W. A. Noyes (Illinois), C. S. Hudson (U. S. Dept. of Agriculture), etc. This branch of the science suffered a grievous loss a short time ago by the death of J. U. Nef (Chicago).

Again, in the most recent offshoot of organic chemistry, the application of the science to physiology, to biology and to medicine in general, we are easily the leaders. There come to mind the names of such men as O. Folin (Harvard), who has revolutionized clinical chemistry; P. A. Levene and D. D. Van Slyke (Rockefeller Institute), R. H. Chittenden and L. B. Mendel (Yale), E. V. McCollum and W. Jones (Johns Hopkins), W. J. Gies (Columbia), H. D. Dakin (Herter Laboratory), C. Funk, C. Alsberg (Chief Chemist, U. S. Dept. of Agriculture), K. G. Falk (Harriman Research Laboratory), P. B. Hawk (Jefferson Medical College), A. E. Taylor (Pennsylvania), G. Lusk and S. R. Benedict (Cornell), A. P. Mathews (Chicago), etc.

Closely associated with these, but more narrowly restricted to foods, may be mentioned H. C. Sherman (Columbia), H. W. Wiley, and W. D. Bigelow.

Among those particularly interested in its agricultural aspects are O. Schreiner (U. S. Bureau of Soils), C. B. Lipman (California), and T. J. Lipman (Rutgers).

Though J. Loeb (Rockefeller Institute) and W. J. V. Osterhout (Harvard) are directors of departments of biology and botany, respectively, their researches are wholly biochemical in nature.

As might be expected, in the industrial field, where the inventive genius finds an immediate and successful outlet, the American chemist has done wonders. Every student who takes a course in elementary chemistry knows how Goodyear vulcanized rubber, how Hall revolutionized the manufacture of aluminum, how Frasch devised an ingenious method for extracting sulphur from the Louisiana ores, how Castner invented his electrolytic process for the production of caustic soda, used in enormous quantities in the manufacture of soap, how Acheson discovered carborundum, artificial graphite, and deflocculated graphite, and how Baekeland discovered bakelite, used in electrical appliances, phonographic records, etc. And now younger America, in the shape of W. F. Rittman, is busily engaged in perfecting a process for "cracking" petroleum under pressure, whereby an amazing number of raw products necessary for explosives, and dyes, and motive power, are formed. And again, one of Parr's students at Illinois has developed a method of extracting the dye from the wood of the osage orange, which dye is now used for the khaki uniform cloth of the American Army.

But this is not all. Bucher, of Brown University, and the chemists of the General Electric Company, are rapidly concluding their researches into a practical method of extracting the nitrogen from the air; Day, of the Geophysical Laboratory, is preparing an optical glass which is superior to the German product; and various biochemists are putting on the market Salvarsan, substitutes for cocaine, adrenalin, and dozens of other German-made substances badly needed by our medical men.

And so the story goes.

* * * * * * * *

A most encouraging augury for the future is the close cooperation that is beginning to exist between the universities, on the one hand, and the industries, on the other. For much of this our thanks are due to the late R. K. Duncan, for some years the director of the Mellon Institute at Pittsburgh, and the originator of the Mellon Industrial Fellowships. Incidentally, Duncan's two or three books on popular chemistry remind one of a Huxley or a Tyndall.

An even better sign of the times is the research laboratories that our industrial corporations are establishing. A model of its kind is the chemical laboratory of the General Electric Company. Its two chief chemists, W. R. Whitney and I. Langmuir, are among the leaders in their profession in this country.

THE JURASSIC LAGOONS OF SOLNHOFEN

By Professor EDWARD W. BERRY
THE JOHNS HOPKINS UNIVERSITY

THE aim of the true paleontologist is the elucidation of the history of the earth, and by the term earth history I do not mean merely the physical history, but also the biological history, so that the result will be a complete picture of the relations of land and sea, the inhabitants of both, the climate, and the steady progress of events—both organic and inorganic.

Such a picture is one of almost infinite complexity, as we at once realize when we endeavor to comprehend the mutual relations of a single flora and fauna to one another and to their physical environment in even a small area of the earth's surface at the present time. If it is almost impossible to arrive at correct results in dealing with a contemporaneous flora and fauna, how much more difficult is it to deal with the often fragmentary remains that represent a mere fraction of the life of five or ten million years ago.

Shall we then merely accumulate bricks and wait for the master builder of the future to build our temple? Already the bricks have accumulated in piles, mountain high, that threaten to bury us, and we sigh for the master builder that never comes. The older paleontologists, taking their cue from the scholasticism of medieval speculation, drew pictures of Carboniferous or Jurassic landscapes and seascapes with a facile hand, but they were mostly catastrophists, and their materials were largely subjective rather than objective, so that to-day their results are considered largely fanciful.

It is a most useful practise for the scientist to follow the example of mercantile concerns and to periodically take an inventory of stock on hand, make up a balance sheet and write off the discarded theories, hypotheses and misunderstood interpretations of facts with which his subject rapidly becomes cluttered. For some geological times or in some areas the record is so imperfect that the task is hopeless. For other times and in certain favorable regions we can gather the various threads derived from a study of the sediments, from the fossil animals and fossil plants, and weave these threads into a definite pattern.

Such a region, a region with one of the most remarkable known assemblages of life—from earth, air and sea—is that of the lithographic stone quarries of South Germany. There is scarcely a museum throughout the world that does not contain some specimens from the Solnhofen lithographic stone, and while the Solnhofen quarries are less rich in fossils than others in the immediate vicinity, as for example those of Eichstädt, little attention has usually been given to exact horizon or locality.

Johannes Walther has given us an exhaustive summary[1] and drawn a picture of the life and environment of the late Jurassic at the time the lithographic stone was being deposited which in many ways should serve as a model and an inspiration for similar attempts for other times and in other areas. This scholarly work leaves little to be desired in the way of facts. The interpretations of these facts, however, made before we knew very much about the origin of such fine-grained calcareous muds as formed the commercial lithographic stone, are not always the only or the most likely deductions permissible.

Let us first of all glance at a few of the main features of Jurassic geography before describing Solnhofen and the relics of bygone life that are found there. What we now know as the Jurassic period of earth history was called the Oolite by William Smith, the father of stratigraphic geology, because of the frequent occurrence in the rocks of this age of oolitic limestones or limestones made up of tiny calcareous concretions that resembled fish roe. These were famous building stones, so renowned even that the monuments that marked the Mason and Dixon line between the dominions of William Penn and those of Lord Baltimore were of this material imported from the quarries at Portland on the south (Dorset) coast of England.

Alexander Brongniart, in 1829, proposed as a substitute for Smith's name Oolitic, the term Jurassic because of the extensive development of the rocks of this age in the Jura Mountains. Smith had divided his Oolitic series into many subordinate zones based upon their characteristic lithology and fossils, and these he grouped into three major divisions. The lower was called the Lias, the middle Dogger and the upper Malm—these all being local quarrymen's names in England that are still largely used in geological literature. They correspond to what Leopold von Buch, another grand old man of geology, in 1839 called the black, brown and white Jurassic. The Solnhofen

[1] "Die Fauna der Solnhofener Plattenkalke," Bionomisch betrachtet, Jena, 1904.

deposits fall in the third or youngest of these subdivisions—the Malm or white Jurassic.

During the long ages of the Triassic period the Paleozoic highlands of Europe had been very largely worn away by the slow processes of erosion, and the Jurassic history is in the main one of shallow seas gradually expanding over a land surface of low relief, and culminating in the almost complete flooding of the continent. North America, on the contrary, presents a striking contrast to Europe, for it is only in the Pacific coast region, and in Alaska, Texas and Mexico, that any marine Jurassic sediments have been discovered.

The Jurassic seas of Europe were prevailingly shallow and warm. They swarmed with life of all kinds, and their sediments were predominantly calcareous. The history of these successively expanding and contracting Jurassic seas, and of the teeming life of their waters, is a long and an intricate story —too long to be attempted in the present limited space. Possibly if it had not been for the regular succession of the strata and the abundance of beautifully preserved fossils in the Jurassic rocks of England, France and Germany, we should still be ignorant of the bearing of fossils upon stratigraphic succession and correlation. Certainly the rocks of no other age show so clearly the interrelations and replacements of what are usually called faunal facies, as do those of Jurassic time as they are traced from place to place.

The Solnhofen deposits came at a time just subsequent to the maximum extension of Jurassic seas which had occurred in the immediately preceding times, the rocks of which now constitute the Oxfordian and Kimeridgian stages. That the seas still covered a goodly portion of Europe is shown by the accompanying sketch map. This stage of the upper Jurassic is known as the Portlandian (from Portland, England) or Bononian (from Bononia, the old name for Boulogne, France).

Such a map, while based upon the synthesis of a vast number of observations, is necessarily conjectural in areas where rocks of this age are absent or unknown, and it then has to be determined if they had once been present and were subsequently eroded, or whether this particular area was above the sea at that time. Moreover, errors in the correlation of distant strata are fruitful sources of misconception, and, finally, since even the map for a single stage covers some tens of thousands if not hundreds of thousands of years during which the coast lines were gradually changing, it is obvious that such a map can only approximate the true geography of any time and might aptly be compared with the awkward-looking snapshot of a running animal as contrasted with a motion-picture film of the same animal.

Turning now to the accompanying map, it will be noted that Europe was an archipelago at that time, not unlike the East Indies of to-day. The largest island, probably of a much more irregular outline than I have indicated, embraced Scandinavia, Finland and northwestern Russia. No traces of Portlandian sediments have been found in this vast region except in the lined area indicated around its margin. A shallow open sea appears to have covered most of Russia, broken by large islands in the Caucasus, and in Podolia, Kiev, Bessarabia, Kherson and Taurida, that is to say, southwestern Russia and the Roumanian border. Asia Minor was above the sea, and it is uncertain whether this last land mass extended to the northwest, or whether parts of Macedonia, Bulgaria, Serbia and Hungary constituted another large island. Ireland, Scotland and western England were above the sea, as was most of Spain and the site of the Pyrenees. There were smaller islands in the Alpine region and elsewhere in Italy, and a large island occupied the western Mediterranean, the latter sea reaching the Atlantic across southern Spain on the north and Morocco on the south.

The ancient rock-masses of Brittany and the Auvergne in France were land and it is uncertain whether or not the two were united across the Loire valley or whether the Atlantic fauna reached the Paris Basin across this area shown by broken lines on the map. Another large island extended from Norfolk across Flanders into Germany, and here also the map indicates by broken lines the uncertainty as to whether or not this island was connected with or separated from the island or islands on the site of Swabia, Franconia and northern Bavaria. The presence of traces of the Atlantic fauna in Germany has suggested that this fauna migrated in the northeasterly direction indicated by the arrow.

Along the southern border of this Swabian, Franconian, Bavarian island or islands, there were reefs, extending southwestward into France, which prevented the mingling of the Mediterranean fauna of the Danube Basin and Dauphiné with the Atlantic fauna of the Paris Basin. There were other extensive reef areas in the Alpine region, in Provence, and elsewhere at this time.

The horizontally lined areas on the map, Fig. 1, mark the range of the Atlantic or occidental fauna characterized by the ammonite genus *Pachyceras*. The NW.-SE. or diagonally lined

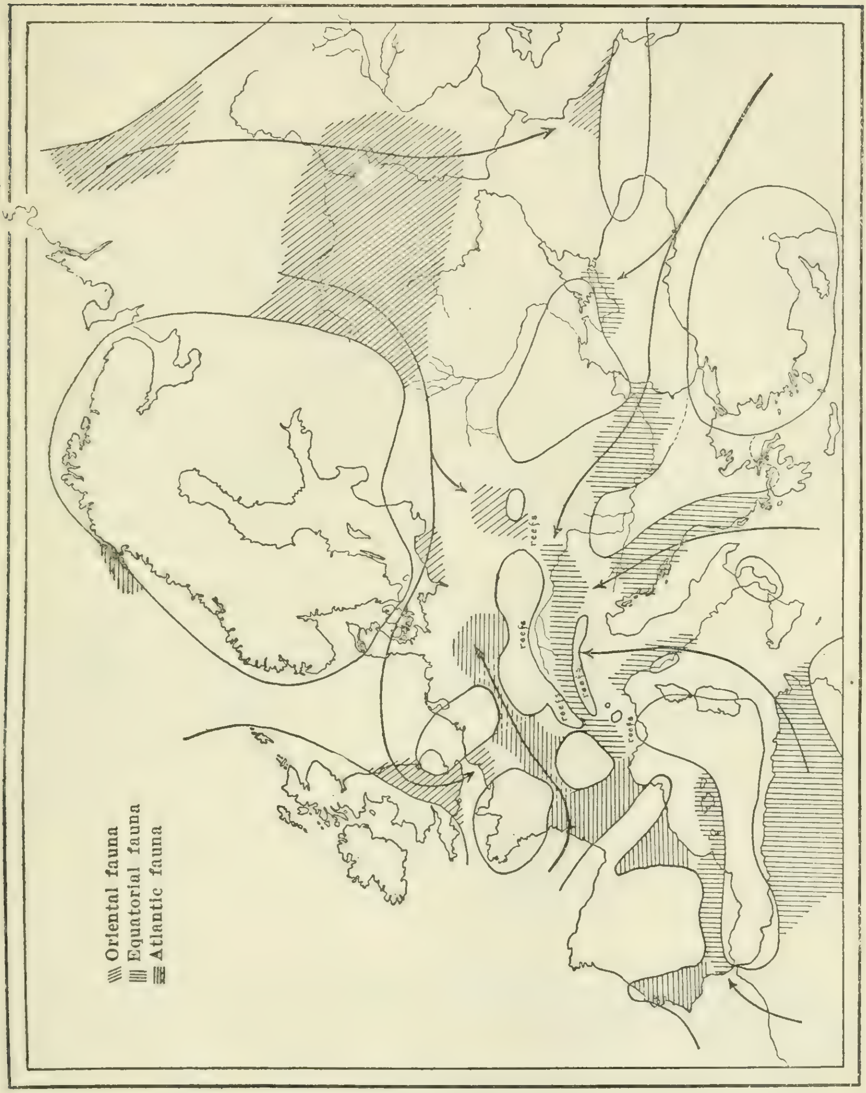


FIG. 1. MAP OF EUROPE SHOWING THE GEOGRAPHY AND FAUNAL FACIES OF THE PORTLANDIAN. (Modified from DeLapparent and Haug.)

areas mark what is known as the Volgian[2] or oriental fauna with numerous species of *Virgatites* and other ammonites along with *Aucella, Rhynchonella, Belemnites, Exogyra, Cylindroteuthis,* etc., which probably migrated as I have indicated by arrows. This fauna was formerly (*e. g.,* by Naumayr) thought to be an Arctic or boreal fauna, but this view has now been rather generally and quite rightly abandoned. The vertically

[2] Named by Nikitin in 1881 from its development in the Volga Basin.

lined areas show the range of the equatorial or Tithonian[3] fauna characterized by the ammonite genera *Oppelia, Perisphinctes, Phylloceras, Lissoceras;* by *Collyrites, Berriasella, Waagenia* and *Aspidoceras,* and by the curious brachiopods of the genus *Pygope* (*Pygope janitor* and *diphya*).

The lithographic stone comes principally from quarries on the hills bordering the valley of the Altmühl, a small northern tributary of the Danube, which it joins at Kelheim. They extend from Pappenheim to Pfalzpaint, a distance of between 15 and 20 kilometers, and are about 65 kilometers south of Nürnberg and about 85 kilometers slightly west of north of Munich. The lithographic stone is found as lenticular masses with a maximum thickness of about 75 feet in what seem to be depressions or basins in a heavily bedded dolomite or magnesian limestone known as the Franconia dolomite. The latter is rich in corals and other reef-building forms. The graphic section from Pappenheim to Eichstädt shown in Fig. 2 brings out this rela-

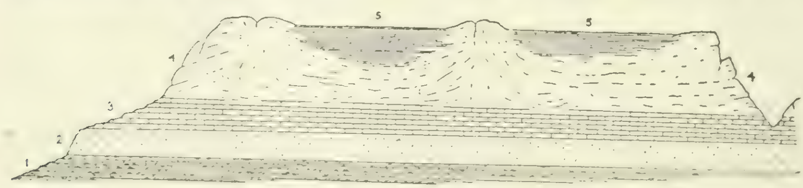


FIG. 2. DIAGRAMMATIC SECTION OF THE JURASSIC FROM PAPPENHEIM TO EICHSTÄDT. (After Walther.)

No. 1. *Aulacothyris impressa* marl
2. *Peltoceras bimammatus* beds
3. Kimeridgian sponge limestone
4. Franconia dolomite
5. Solnhofen lithographic stone

tionship and exposes several of the older and underlying beds.

No. 1 is called the *impressa* marls from the abundance of the brachiopod *Aulacothyris impressa* (Bronn) and is of Argovian age.

No. 2 is called the *bimammatus* beds from the abundance in it of the ammonite *Peltoceras bimammatus* and is of upper Oxfordian or Rauracian age.

No. 3 is a limestone, rich in sponges, known locally as the schwammkalk and is of Kimeridgian age.

No. 4 is the Franconia dolomite and is of lower Portlandian age.

No. 5 is the lithographic stone, or Solnhofener Plattenkalk, as it is called locally.

[3] Named by Oppel in 1865 from Tithon or Tithonius, the husband of Eos, the dawn, from its fauna which is prenuncial to that of the Cretaceous.

The actual relations, as seen in the field, are not as diagrammatic as might be inferred from the figure. Conditions of sedimentation varied greatly from place to place, some layers yielding the commercial lithographic stone, others merely building stone. The sequence of beds in an individual outcrop may be illustrated by the following section at Mörnsheim quarry, copied from Gümbel's "Geology of Bavaria" (1894, p. 816):

1. Soil and sandy beds with ammonites	3 meters
2. So-called fäule, rotten thin-bedded marly limestone	2 meters
3. Thick limestone bank with flints and ammonites	4 meters
4. Breccia-like beds rich in hornstone	1 meter
5. Silicious calcareous shales rich in *Terebratula, Rhynchonella, Terebratella,* etc.	5 meters
6. Rather massive siliceous limestone	5 meters
7. So-called ironstone with 260 thin and 25 thicker lithographic stone layers	20 meters
8. The so-called fäule, rotten marly limestone	10 meters
9. Irregularly bedded limestone, the so-called bottom stone	5 meters
10. Franconia dolomite. Total about	182 feet

Around Kelheim, where the Altmühl joins the Danube, the lithographic stone is replaced by a clayey coralline limestone which is known as the Diceras limestone because of the abundance of these heavy-shelled bivalves. These are found associated with a few ammonites (forms characteristic of the northwest German and French lower Portlandian and including *Olcostephanus portlandicus* and *O. gravesianus*), but many corals, echinoids, Nerineas, fishes, turtles, crocodiles, pterodactyls, etc. Coral sand is present and the cross-bedding of the sands and the shallow-water heavy shells indicate a considerable surf.

Postponing to a subsequent paragraph the description of some of the wonders preserved in the lithographic stone, such as the earliest known bird, the numerous flying lizards and the dinosaur fetus, it may be noted that the fossils collected comprise an unusual assemblage, and undoubtedly denote special conditions of sedimentation. Thus molluscs are comparatively rare; bottom dwellers are practically absent; open-sea pelagic forms are mixed with a host of lobster-like crustaceans; jelly fishes left the moulds of their radiating gastric cavities in the muddy ooze; while a variety of tracks, insects and terrestrial forms add to the confusion.

Walther, after a careful analysis of the fauna, interprets the conditions as those of coral atolls with lagoons whose muddy bottoms were partly exposed and partly tidal. The calcareous ooze as well as most of the life forms, already dead, he regards as having been swept into these lagoons by storms or unusual tides, while the interbedded clay-ironstone is considered to be wind-blown dust from the mainland which, following von Gümbel, he locates some 25 kilometers to the south of the site of the deposits in the region of the present Vindelican Alps.

It would seem to me that these Jurassic reefs were fringing reefs, or keys like those of southern Florida, rather than that they were comparable to atolls. That the mainland was much nearer than 25 kilometers is indicated by the lack of strong flying powers in the fossil bird, of which two rather complete specimens as well as isolated feathers have been found. That these birds were not carried to their calcareous tombs by currents after their dead bodies had washed into the ocean, but that they habitually resorted to these mud flats for the variety of menu there offered, is indicated by certain tracks on the surface of the mud which appear to have been made by an immature bird before its primaries were fully grown.

If storms were responsible for the wealth of organic remains accumulated in such small compass, surely coral sand would be more in evidence, as it is at Kelheim, or erratic heads and fragments of the reef corals would be commoner in the muds. In the studies inaugurated by Drew[4] and continued by Vaughan and his associates for the Carnegie Institution it has been demonstrated that the calcareous muds of the Florida keys and the Bahamas are precipitates, due to the action of denitrifying bacteria that are normally present in warm sea water, and the presumption is very strong that most if not all muds of this sort, both recent and fossil, owe their existence to the activities of such bacteria.

This then would reasonably account for the calcareous ooze that made the lithographic stone.

That a part of these muds at Solnhofen were tidal is very probable, since otherwise it is difficult to account for the host of forms of the sea-drift that came to be buried in them, but there is no evidence of tidal scour or wave action, and the waters must have been quiet and for the most part very shallow. The Jurassic *Limulus* or horseshoe crab haunted these muddy bottoms just as his modern brother is found in similar situations along the present Florida coasts or in muddy coves in higher latitudes, and the water was quite enough to preserve the trails of some of these Jurassic horseshoe crabs as well as those of some of their associates.

[4] Publication No. 182, Carnegie Institution of Washington, 1914.

Millions of stalkless crinoids of the genus *Saccocoma* of at least three species swarmed in these shallow waters and ammonite shells have been found preserved in an upright and life-like position.[5] Since the water was shallow and the bottom flat, these submerged mud flats would necessarily be exposed twice a day over wide areas by tidal action, which operated in Jurassic times with the same seeming inexorable and invariable regularity that it does to-day. It is a familiar experience that animals stranded on such mudflats seem usually to have an oriental belief in "kismet" and are as passive as if already dead. This and the further fact that many animals that properly belong in the open sea or in deeper waters are found at Solnhofen, and which must have been floated into the lagoons in a dead condition, are more readily understood than Walther's elaborate explanation, especially when it is recalled that there were decades to spare for their accumulation. They would inevitably have been smashed and not preserved so perfectly if they had been swept over the reefs by storms.

Upwards of 500 different kinds of animals have been recorded from the lithographic stone, but this is somewhat swollen by the true German thoroughness that has given every problematical scrap a binomial Latin name. Despite this, the lists are imposingly long and marvellous in the variety of life that is represented. Insects to the number of over 100 kinds were blown upon the mud flats or perished in the waters; sometimes we have preserved in stone the traces of the struggles of some mired insect in its efforts to escape. There are no fresh-water forms of life. Fishes to the number of nearly 150 kinds, mainly ganoids, have been discovered in these rocks. The crustaceans, which number over 70 varieties, are mainly lobster-like forms. The ammonites number 19 species distributed among six genera, and there were large numbers of the Jurassic ancestors of our modern squids or cuttlefishes. These number 17 species distributed among 8 genera, and some of them were very common individually and undoubtedly lived in the lagoons. Very often more or less of their soft bodies as well as their vestigial shells and pens were preserved as, for example, in *Acanthoteuthis,* in which the ink bag and the ten arms with their double rows of hooks were fossilized. There were many sea worms, free-swimming crinoids (comatulids) and brittle stars, and even such perishable and aqueous objects as jelly fishes were preserved with great fidelity in the fine-grained

[5] Rothpletz, A., *Abh. k. Bayerischen Akad. Wiss.*, Vol. 24, pp. 311–337, 1910.

ooze, where they were stranded by the retreating tide. Bottom dwellers of the sea are mostly absent and are represented almost entirely by molluscs that were accidentally washed into the basins or voided by fishes. A single dinosaur, evidently bogged, has come to light. Several kinds of crocodiles have been found, all of the long slender-snouted gavial type, and there were several species of marine turtles. The vertebrate inhabitants of the air that occur in these deposits furnish the most weird elements in the landscape that I am endeavoring to picture.

By all odds the most spectacular find in the lithographic stone was the remains of the oldest known bird—the *Archæopteryx* or lizard-tailed bird. Its uniqueness may be indicated by the fact that it alone constitutes a subclass (Archæornithes), while all other known birds are grouped in a second subclass (Neornithes). A single feather found in 1860 was named by H. von Meyer and shortly afterward a fairly complete individual was found at Solnhofen in 1861 and acquired by the British Museum. The enormous price that was paid for this specimen stimulated the quarrymen to a sustained interest in fossils and in 1877 a second and better preserved specimen was discovered near Eichstädt and is now in the Berlin Museum. Owen, who monographed the British Museum specimen, called it *Archæopteryx macroura;* Dames, who monographed the Berlin Museum specimen, called it *Archæopteryx siemensi*, while the original feather described by von Meyer had already received the name of *Archæopteryx lithographica*, which therefore has priority.

The two individuals supplement one another and undoubtedly represent the same or closely related species. They constitute one of the few great landmarks in avian paleontology, since no other known form shows so many reptilian features.

Archæopteryx was about the size of a modern crow. The head was small and flat, with very large eyes, and without body feathers except on the back and nape. There was no beak and both jaws were armed with small sharp teeth set in grooves. The nostrils were well forward and the body was long and narrow. The vertebræ were bi-convex and about 50 in number, of which only 10 or 11 are regarded as cervical (the lowest number of cervicals in any modern bird is 13). Instead of the few caudal vertebræ of modern birds terminated by a pygostyle for the support of the digitately arranged tail feathers *Archæopteryx* had about 20 elongated tail vertebræ, each of which appears to have supported a pair of tail feathers or rectrices, whose arrangement may be said to have been pinnate as opposed to the palmate arrangement of all other known birds. In the embryos of some existing birds the caudal feathers are the first to develop, the tail is relatively elongated and is said to show a pair of feather sacs for each vertebra. The hind legs were slender, wide apart and far back in position, but were otherwise much as in modern perching birds, except that the tibia and fibula were distinct, as in most reptiles. The wings were short and rounded, with three separate sharply clawed and functional fingers. The wings carried rather large flight feathers, of which six or seven pairs appear to have been primaries and ten secondaries, and there was at least one row of wing coverts. The three pelvic bones are perfectly distinct, as in most reptiles, and similarly the ribs lack the hook-like processes characteristic of modern birds.

The fine-grained mud has preserved the feathers of the tail and wings with remarkable fidelity and traces of an incipient ruff at the base of the neck and rather conspicuous quill-feathers on the legs. No traces of body or contour feathers have been discerned, so that it may be concluded that the body was naked or was covered with down or tiny feathers that were not resistant enough to be preserved.

There has been much speculation regarding the true nature and habits of *Archæopteryx* and several restorations have been attempted. That by Heilmann, while somewhat realistic, is entirely too heavily supplied with contour feathers, the tail is too massive, and the birds are depicted as tearing at a cycad cone, although they were undoubtedly carnivorous, as their teeth clearly indicate. From the position and slenderness of the legs Beddard supposed that *Archæopteryx* must have stood on all fours when on the ground, but this is in a measure negatived by the distinctly perching feet. Others have held that the absence of observable openings for the admission of air into the bones proved that *Archæopteryx* could fly only feebly if at all, but even such good modern flyers as swallows have practically non-pneumatic bones, and, moreover, we know that *Archæopteryx* resorted to the mud flats in search of food and hence must have flown from the mainland where it habitually dwelt. Finally, the well-developed feathering of the wings settles the question of flight beyond reasonable doubt. The labor of sustained flight with such short rounded wings may, however, have been compensated for by gliding, for which the wings and the quilled legs and distichous tail were admirably constructed and which historically must have preceded true flight. In an interesting

Fig. 3. Restoration of the Earliest Known Bird, *Archæopteryx*

little article by Maurice Krosby,[6] from which I have copied the attitude, but not the details, of a flying *Archæopteryx*, it is implied that *Archæopteryx* had four wings; in fact, it is called *Tetrapteryx*, a name suggested by Beebe for the hypothetical ancestral bird.[7] Undoubtedly the quills on the legs made a plane of the hind legs, but they were not flapped, while the fore-legs or true wings undoubtedly were flapped—the skeleton shows this much.

A comparison, rather remote, it is true, is suggested between the flight of *Archæopteryx* and that of the modern tinamous of South America, which have somewhat similar short rounded wings. As described by W. H. Hudson, the tinamous fly violently for a maximum distance of perhaps a mile, but usually a much less distance, and then glide to the ground, repeating this two or three times before becoming exhausted. The tinamous are ground dwellers and rapid runners, while *Archæopteryx* was, on the other hand, clearly a partially arboreal form and scarcely a runner. Its functional clawed fingers must have been habitually used in climbing about in the branches, much as a young hoactzin of South America does and they were also useful in effecting a safe landing in flying from one tree to another or at the end of a glide.

While *Archæopteryx* may be considered as about 25 per cent. reptilian, it is indubitably a true bird and a long way removed from its scale-covered and cold-blooded reptilian ancestors. There were bipedal bird-like reptiles already present before the close of the Triassic, so that there were some millions of years before the late Jurassic in which to evolve feathers and acquire the art of flying, and we know that the pterodactyls had successfully solved the problem of flight by another method in that same interval.

The present restoration (Fig. 3), which is believed to be far more accurate as to environment and detail than any heretofore attempted, shows the strand of the upper Jurassic mainland with the beach-ridges covered with a low jungle, made up largely of a mixed stand of cycads, with a few tall leathery fronded ferns, together with a scattering of taller conifers, comprising both scale-leafed (*Brachyphyllum, Palæocyparis*) and broad-leafed (*Araucaria*) types. High overhead is seen a small long-tailed pterodactyl or winged lizard (*Rhamphorhynchus*). In the foreground an *Archæopteryx* is flying. Note the slender body, the short heavily flapped wings, the pelvic plane made by

[6] *Popular Science Monthly*, Vol. 91, No. 1, 1917.

[7] *Zoologica*, Vol. 2, No. 2, pp. 39–52, 1915.

the widely spaced hind legs with their quill feathers, and the long distichously feathered tail constituting a second plane. At the right another *Archæopteryx* is shown with a small fish in its sharply toothed beakless jaws. It is perched on the crown of a *Zamites* of the *Williamsonia* order of cycadophytes. Note the long tail, the free clawed fingers of the fore limbs firmly grasping the cycad fronds and helping to sustain the long body.

Flying reptiles were evidently much more plentiful than birds during Solnhofen times, judging by the abundance and variety of their remains in these sediments, for nearly 30 different species have been described. They were weird bat-like creatures with pneumatic bones, large eyes, feeble hind limbs, and a keeled sternum for the attachment of the wing muscles like that of a modern flying bird. Their fifth finger had become enormously elongated and strengthened to support the membranous wings, which were thus exactly like the wings of a bat, with this exception, that only one instead of four fingers was elongated.

Ancestral pterodactyls go back at least as far as the Liassic or basal Jurassic. The Solnhofen forms were all relatively small and include over a score of species of the short-tailed *Pterodactylus* and five species of the long-tailed *Rhamphorhynchus*. Thus *Rhamphorhynchus phyllurus* had a total length of about 18 inches, of which two thirds was tail, and a wing spread of about 32 inches. An individual of the latter is shown, high in the air, in the accompanying restoration. Many thousands of years later, just before they became extinct, some of the pterodactyls lost their teeth and acquired bird-like bills and developed to gigantic size. Thus some of the pteranodons from the Upper Cretaceous Niobrara chalk of Kansas had a wing span of 18 feet, which is greater than that of any known bird.

Very many interesting tracks are preserved at Solnhofen, both those made on the emerged and on the submerged mud flats. These range from those of the Solnhofen *Limulus* or horse-shoe crab to that of an insect trying to extricate itself from the sticky mud, and include many that are problematical in character. One of the most well defined tracks that has been discovered and clearly that of some more or less bipedal vertebrate was early described and named *Ichnites lithographica* by Oppel. It consists of two rows of four-toed footprints at intervals of about 9 centimeters and about 7 centimeters between those of the right and left foot. Midway between the prints of the right and left foot is a small and shallow furrow of varying width and depth, apparently the trail of a dragging tail.

Alternating with the footprints and midway between them and the tail furrow are elliptical depressions with their long axes directed forward and outward. (This track is shown in Fig. 4.)

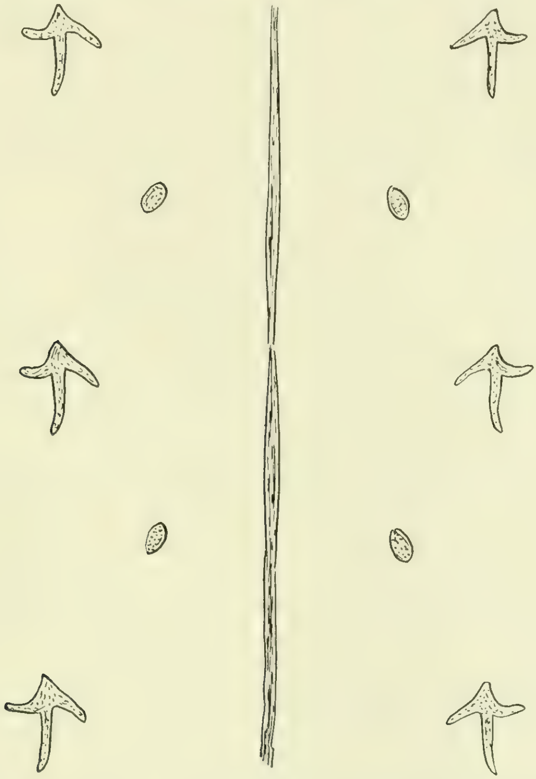


FIG. 4. PROBLEMATIC TRAIL, POSSIBLY OF AN IMMATURE *Archæopteryx*. (After Oppel.)

The question for decision is what sort of an animal made this track and how. Oppel thought that it was made by an *Archæopteryx* and many have followed him in this interpretation. Any small long-tailed animal with bird-like feet such as birds or some of the contemporaneous bird-like reptiles would readily account for the footprints and tail furrow, but how are the alternating elliptical tracks to be explained. They are too constant and regular not to have been made by the same animal that made the other parts of the trail. It has been commonly supposed that *Archæopteryx* made the whole trail by using its wings like a pair of crutches, the point of rest being the carpal or wrist joint. This is of course possible. Or it is possible that some other and as yet otherwise unknown animal made the tracks.

The chief objections to their having been made by a mature *Archæopteryx* are the small size of the footprints—much smaller than the feet of the two known specimens, the fact that the pinnately feathered tail would hardly leave a tail furrow in the mud that would look exactly like this one does, and that the wing quills would hardly permit of the wings being used as crutches. Nor is it easy to understand why the functional fore feet were not used. Moreover, if the weight rested on the wings, as assumed, the extremity would sink deep in the soft mud and hinder rather than help locomotion, as well as ruin the quills for purposes of flight. This would be equally true upon hard ground unless the quills were held in an unnatural way. It would further seem that if this were the true interpretation, the long slender body would demand that the ends of the wings rest farther apart. How the bird managed to hop at all, unless the wing-prints were one or more intervals in front of the corresponding footprints is difficult to understand. It is useless to deny the possibility of the accepted interpretation. I am, however, more inclined to think that while this trail belonged to *Archæopteryx*, it represents the trail of an immature and as yet practically flightless individual, which progressed in this way when on the ground—their small size might suggest this, and the difficulties about the wing and tail feathers would be obviated by their not having as yet become fully functional in size and possibly only sufficiently grown to permit gliding.

The terrestrial vegetation still remains to be considered briefly. Fossil plants have been known from Solnhofen since the days of Sternberg's "Flora der Vorwelt." In striking contrast to the variety and abundance of the animal remains, the traces of the former vegetation that clothed the near-by land are only occasionally met with in the lithographic stone, and even when present they are for the most part fragmentary.

The reasons for this absence of plants are to be found in the macerating action of the water, the non-deciduous character of the foliage of Jurassic plants, the activity of bacteria in the warm sea water, and most of all to the situation of the deposits, away from any estuary with its stream-borne load of land-derived débris. That these reasons are valid is corroborated by the fact that the few plants that have been discovered are such as have leathery decay-resisting parts such as cone scales and coniferous twigs, thus indicating that all the more delicate plant fragments had been destroyed, and by the additional fact that in other regions at this time where the sediments are more clearly of an estuary type as in the fish beds of

Cerin in France, a much more extensive flora as well as much disseminated vegetable matter and bitumen are present in the shales.[8]

The number of plant names in the literature would indicate that we knew a considerable flora from the lithographic stone, but a good many of these are names merely. Thus Saporta enumerated six coniferous species from Solnhofen, although at least half of these are now rightly regarded as synonyms of the remaining three. Similarly, Thistelton Dyer recorded 5 species of the coniferous genus *Athrotaxites,* although but one or two are valid.

Ignoring the doubtful impressions which have been described as seaweeds and which are without botanical value, there are at least four genera of Solnhofen ferns, so-called. The most abundant of these individually is *Lomatopteris jurensis* (Kurr) Schimper, and the others are forms of the genera *Sphenopteris, Odontopteris* and *Ungeria,* and some of them at least are not ferns, but relics of plants of the cycad or "sago-palm" alliance which frequently had fern-like fronds.

One of the most definitely identified plants is based on the characteristic one-seeded cone scales, which Dyer christened *Araucarites Häberleinii* and which unquestionably belong to the Eutacta section of the genus *Araucaria,* an antipodean group in the modern flora, but one that was world-wide in its Mesozoic distribution. Another satisfactorily determined conifer is *Brachyphyllum,* which has been entirely extinct since the Upper Cretaceous, but which was exceedingly ubiquitous throughout the Mesozoic. It had thick, club-shaped terete twigs with the leaves reduced to scales somewhat similar to those of a modern arbor vitæ or an incense cedar. Other twigs found at Solnhofen represent a cypress-like conifer variously called *Athrotaxites* or *Palæocyparis;* and *Ginkgo* and its extinct ally, *Baiera,* have also been identified, but with doubt, however.

The plants of these far-off Jurassic times are so different in every way from any that still survive that it is most difficult to picture their environment in terms of their physical requirements. We know that the climate was warm from the character of the calcareous ooze in which the fossils have been found. We presume that it was also humid from the kinds of contemporaneous terrestrial and arboreal animal life, and we also know that climates were more uniform then than now from the simple fact that the same Jurassic floras occur in the Arctic and Antarctic regions as are found in the equatorial zone.

[8] Saporta, G. de, *Ann. Soc. Agric. Lyon,* Vol. 5, pp. 87–142, pl. 14, 1873.

While it may be doubted if the reefs of Solnhofen supported a dense growth of vegetation, the mainland was more or less a jungle, although it was one prevailingly low in stature and one that might more appropriately be called a "scrub" or "bush." If we can imagine a chaparral made up of ferns and cycad-like plants with cypress-like conifers rising here and there above the general level, we shall have a fairly accurate picture of the Solnhofen woods. *Sequoia* cones have been found

Fig. 5. Two of the Most Common Conifers from Solnhofen. (After Saporta.)
a, Brachyphyllum (Echinostrobus) Sternbergi (Schimper)
b, Palæocyparis (Athrotaxites) princeps (Sternberg)

in the Portlandian of France, but all of the fossil sequoias were not giants like the California big trees. In Fig. 5 I have reproduced two of the commoner types of scale-leafed conifers that have been found in the lithographic stone, namely *Brachyphyllum* and *Palæocyparis*.

THE PROGRESS OF SCIENCE

RAPHAEL PUMPELLY'S REMINISCENCES

Raphael Pumpelly, distinguished as an explorer and geologist, has at the age of eighty-one years put through the press his reminiscences, well printed and illustrated, by Henry Holt and Company. It is an entertaining book, telling of many adventures in strange lands under conditions which no longer exist.

Even in central New York a child eighty years ago lived under frontier conditions. The family owned forests, farms and stores; the Susquehanna River and later the Erie Canal were the means of communication with the outside world. Pumpelly was sent to school in preparation for Yale College, but persuaded his mother to take him abroad, where in Germany, France and Italy there was a charm in travel which has largely vanished under modern conditions. The changes in Germany, for example, have been almost as great as in central New York and in Arizona. Then the cities were still medieval in character, grass grew in the streets, sanitation was lacking, industries were carried on chiefly by individual handicrafts, the people were simple and kindly.

Pumpelly's most exciting adventures were in Corsica, where he lived with the mountain people and became interested in geology. At Vienna he by chance attended a meeting of the German Association of Scientific Men, corresponding to our American Association for the Advancement of Science, and casually made the acquaintance of Professor Noeggerath, the Bonn geologist, who advised him to study at the Mining Academy at Freiburg in Saxony, where he spent three years.

On returning to America, after an absence of six years, Pumpelly went to Arizona to develop silver mines in the Santa Rita Mountains. The conditions in the desert with its Indians, Mexicans and outlaws seem almost incredible and were reduced to chaos by the removal of the United States soldiers at the outbreak of the Civil War. After countless adventures, Pumpelly made his way over the Old Yuma Trail to California. There he received an appointment to enter the Japanese service and had the advantage of intimate acquaintance with the country and its people when it was first opened to the outside world. He explored the mines and introduced the use of gun powder in blasting, but the anti-foreign party forced the Yeddo Government to cancel its contracts and Pumpelly went to China. There he received an imperial commission to examine the coal fields and had all sorts of adventures in regions practically unexplored and among natives to whom foreigners were almost unknown. Everywhere Pumpelly appears to have formed kindly relations with all sorts and conditions of people. He finally crossed Siberia and returned to New York at the age of twenty-eight.

Pumpelly accepted in 1866 a chair of mining geology at Harvard which he held for nine years. His first class consisted of William Morris Davis, Henry Gannett and Archibald Marvin. But he only spent a limited amount of time at Cambridge, being engaged in many enterprises and living in many places. He was on the U. S. Geological Survey, state geologist of Michigan and Missouri, and director of the Northern Transcontinental Survey. He was vice-president of the International Geological Congress, held in Washington in 1891. An illustration is here reproduced (by the courtesy of Henry Holt and Company to whom we are also indebted for permission to reprint the portrait of Pumpelly)

Raphael Pumpelly, 1900

From a photograph by Elise Pumpelly Cabot showing four distinguished directors of foreign geological surveys, together with Dr. Van Hise and the author, on an excursion which followed the congress. But all these things are passed over lightly in the book. Pumpelly was most happy in his married life and had innumerable friends among scientific men and men distinguished in other directions; but he likes best to describe adventures among strange peoples.

This he does again toward the close of the book, for at the age of nearly seventy he conducted an expedition into Central Asia for the Carnegie Institution accompanied by his son, and with the cooperation of Profesor W. M. Davis and Professor Ellsworth Huntington. They made important discoveries concerning prehistoric civilizations and geological and climatic changes. The next to last chapter tells of revisiting the Arizona desert in 1915. The final chapter discusses ancestry, heredity and environment.

THE USE OF ASPHYXIATING GAS

THE British Ministry of Information, according to the *British Medical Journal*, recently issued a communication relating to a statement sent out by the official German wireless to the effect that the idea of using poison gas in warfare originated with the British Admiral Lord Dundonald, better known to fame as Lord Cochrane. It is a matter of history that in 1812 Dundonald submitted to the Prince Regent, afterwards George IV., secret war plans which included the use of an asphyxiating gas. A committee of experts to whom this proposal was referred expressed the opinion that the mode of attack was "infallible and irresistible," but it was not sanctioned. In 1840, when there was a threat of war with France, Dundonald again submitted his plan to the British Government and offered by means of it to annihilate the French fleet. The Duke of Wellington thought well of the idea, but with his practical good sense pointed out that "two could play at that game," a fact which the Germans have learnt to their cost. In 1846 the plans were again referred to a committee, which reported that it was not desirable that any experiment should be made on the ground that part of the plans "would not accord with the principles of civilized warfare." Later, when again there was talk of war, Dundonald was asked about his plan, but once more it was rejected, the only objection to it being that it was "too terrible for use by a civilized community." Dundonald's account of the plan is given in the correspondence of Lord Panmure, who was War Minister during the Crimean War. In a memorial dated August 7, 1855, he states that when viewing some sulphur kilns in 1811 he observed that the fumes which escaped in the rude process of extracting the material, though first elevated by heat, soon fell to the ground, destroying all vegetation and endangering animal life to a great distance. With reference to the materials required for the expulsion of the Russians from Sebastopol, experimental trials had, he said, shown that about five parts of coke effectually vaporize one part of sulphur. Four or five hundred tons of sulphur and two thousand tons of coke would be sufficient. Besides these materials it would be necessary to have as much bituminous coal and a couple of thousand barrels of gas or other tar for the purpose of masking the fortifications to be attacked, with dry firewood to kindle the fires, which ought to be kept in readiness for the first favorable and steady breeze. Dundonald offered to direct the application of the plan himself, but the proposal was rejected. The use of asphyxiating gas is a very ancient device. Smoking out the enemy was one of the regular manoeuvres of war in antiquity. Polybius relates

FOUR DIRECTORS OF FOREIGN GEOLOGICAL SURVEYS, 1891

Group with the directors of the Swiss, Russian, French, and Norwegian Geological Surveys.

that at the siege of Ambracia by the Romans under Marius Fulvius Nobilior (B.C. 189) the Ætolians filled jars with feathers which they set on fire, blowing the smoke with bellows into the face of the Romans in the countermines. At the great naval battle fought in the waters of Ponza between Alfonso of Aragon and Genoa in 1435 the Genoese carried vessels filled with quicklime and red-hot cinders, the smoke from which was blown by the wind against the enemy. Leonardo da Vinci, who among his many other accomplishments was a notable military engineer, suggested the use of poisonous powders, such as yellow arsenic and verdigris, to be thrown from the topmasts of ships so as to choke the enemy. This formed a part of the war instructions given by Leonardo to the Republic of Venice in 1499, when the Turks had passed the Isonzo and threatened St. Mark's.

THE STUDENT'S ARMY CORPS

THE possibilities of organization in our educated democracy are shown by the arrangements which have been made to train students for the army in our colleges and universities. Over four hundred institutions have placed their faculties, buildings and equipment at the service of the government and in each of these a student's corps will be in training after the first of October. In the eight institutions for higher education in New York City, there may be some 20,000 men in training. If there are half so many in other institutions throughout the country there would be 500,000 recruits from whom will be selected candidates for officers' commissions and technical posts in the army.

THE War Department advises all young men, who were planning to go to college this fall, to do so. Each should go to the college of his choice, matriculate and enter as a regular student. He will have registered with his local board and opportunity will be given for all the regularly-enrolled students to be inducted into the Students' Army Training Corps at the schools where they are in attendance. Thus the Corps will be organized by voluntary induction under the Selective Service Act, instead of by enlistment as previously contemplated. The War Department announces that the students become soldiers in the United States Army, uniformed, subject to military discipline and with the pay of a private. They will simultaneously be placed on full active duty and contracts will be made as soon as possible with the colleges for the housing, subsistence and instruction of the student soldiers.

The student-soldiers will be given military instruction under officers of the Army and will be kept under observation and test to determine their qualifications as officer-candidates, and technical experts such as engineers, chemists and doctors. After a certain period, each man will be selected according to their performance, and assigned to military duty in one of the following ways: (*a*) He may be transferred to a central officers' training camp. (*b*) He may be transferred to a non-commissioned officers' training school. (*c*) He may be assigned to the school where he is enrolled for further intensive work in a specified line for a limited specified time. (*d*) He may be assigned to the vocational training section of the corps for technician training of military value. (*e*) He may be transferred to a cantonment for duty with troops as a private.

Similar sorting and reassignment of the men will be made at periodical intervals, as the requirements of the service demand. It can not be now definitely stated how long a particular student will remain at college. This will depend on the requirements of the mobilization and the age group to which he belongs. In order to keep the unit at adequate strength, men will be admitted from secondary schools or transferred from Depot Brigades as the need may require.

In view of the comparatively short time during which most of the student-soldiers will remain in college and the exacting military duties awaiting them, academic instruction must necessarily be modified along lines of direct military value. The War Department will prescribe or suggest such modifications. The schedule of purely military instruction will not preclude effective academic work. It will vary to some extent in accordance with the type of academic instruction, *e. g.*, will be less in a medical school than in a college of liberal arts. The primary purpose of the Students' Army Training Corps is to utilize the executive and teaching personnel and the physical equipment of the colleges to assist in the training of our new armies. This imposes great responsibilities on the colleges and at the same time creates an exceptional opportunity for service. The colleges are asked to devote the whole energy and educational power of the institution to the phases and lines of training desired by the government. The problem is a new one and calls for inventiveness and adaptability as well as that spirit of cooperation which the colleges have already so abundantly shown.

There will be both a collegiate section and vocational section of the Students' Army Training Corps. Young men of draft age of grammar school education will be given opportunity to enter the vocational section of the corps. At present about 27,500 men are called for this section each month. Application for voluntary induction into the vocational section should be made to the local board and an effort will be made to accommodate as many as possible of those who volunteer for this training. Men in the vocational section will be rated and tested by the standard Army methods and those who are found to possess the requisite qualifications may be assigned to further training in the collegiate section.

SCIENTIFIC ITEMS

We record with regret the death of Samuel Wendell Williston, professor of paleontology in the University of Chicago; of Maxime Bôcher, professor of mathematics in Harvard University; of Dr. Byron D. Halsted, professor of botany in Rutgers College; of F. P. Treadwell, an American by birth, professor of chemistry at Zürich, and of J. Kollmann, professor of anatomy at Basel.

It is officially announced that Yale University will receive, as residuary legatee of the late John W. Sterling, at least fifteen million dollars, which will nearly double the endowment of the university.

The new National Museum has been closed to the public by the board of regents, as all available space in the building has been occupied by the Bureau of War Risk Insurance. It is expected that the museum will be again opened when the new office building of the bureau, at Vermont Avenue and H Street, is completed. —A temporary exhibition was opened in a few of the galleries of the British Museum on August 1. The exhibition galleries were closed by order of the government as a measure of economy in the spring of 1916, and, owing to the necessity of increased precautions against air raids, all the most valuable objects have been removed to places of greater safety. The trustees, however, have deeply regretted the closing of their doors to visitors, and especially to soldiers from the oversea Dominions. An exhibition has accordingly been arranged, consisting chiefly of casts and facsimiles, which it is hoped will both be instructive in itself and representative of some parts of the treasures of the British Museum.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1918

SOCIAL CONDITIONS IN THE PIURA-TUMBES REGION OF NORTHERN PERU

By PHILIP AINSWORTH MEANS

BOSTON, MASS.

IN many parts of the world there are countries which once were the exclusive property of a semi-civilized or civilized race with a very definite cultural character of its own. Now, because of the expansiveness of modern commerce, practically every one of these countries has been invaded, either through definite and political colonization or through indefinite and non-political commercial influences, by the white race of Europe bearing with it one phase or another of its own distinctive civilization. Consequently there has grown up, during the period between about 1450 and the present, a long series of countries having a dual population and a dual culture. In some cases this quality of duality has given rise to hybridity and harmony (as in French Indo-China), but more often it has given rise to social and racial disparity and disharmony (as in Latin America). The question of whether racial contacts of this kind were harmonious or not seems clearly to have depended on both the intellectuality of the invaded race and culture and on the magnanimity and astuteness of the invading race and culture.

I purpose to examine here the present conditions in a restricted area where the race and culture contact has always been of an unfortunate character, albeit by no means so much so as elsewhere in Peru and Latin America as a whole.[1]

In the first place, it will be well to sketch rapidly the chief geographical and historical facts about the Piura-Tumbes region. It forms the northernmost section of the long coastal desert which fringes the west coast of South America from Tarapacá in Chile up to the Gulf of Guayaquil between Peru

[1] See the present author's former articles on this subject: *Science*, September 13, 1918; *Journal of Race Development*, October, 1918.

A Street in the Poorer Portion of Catacaos, Piura Valley. The houses are badly built, the materials being wood and sticks daubed over with a coating of mud.

and Ecuador. As elsewhere in this desert littoral, there are, in the Piura-Tumbes region, transverse rivers which flow through very fertile valleys from the mountains of the interior to the Pacific Ocean. In the Piura-Tumbes region these streams are three in number, their names, from North to South, being: the Tumbes River (perennial), the Chira River, (perennial) and the Piura River (seasonal). Each of the valleys is exceedingly productive and rather thickly populated for Peru. (I should incline to say that the density averaged between 20 and 40 to the square mile.)

From the earliest pre-Columbian times this region has been productive of fine cotton, fruits and vegetables. Politically, it was part of the great Chimu confederation until, about 1450, that confederation was absorbed by the Incas. The people belonged to the Yunca or Mochica stock general on the coast. In 1532 Pizarro entered the region and set up Spanish power there. Since 1550 the population has been divided, on ethnic lines, into three groups: Pure or nearly pure Indians; pure or nearly pure whites; and *mestizos* or mixed-bloods of white and Indian parentage or ancestry. (There are, besides, a few Negroes and Orientals and their descendants, but they are unim-

A Fishing Balsa at Chullillache, near the Mouth of the Piura River.

portant from the point of view of this paper.) As nearly as I can judge from my own observations and from some figures given me by two anthropologically inclined parish priests in different parts of the region, the pure or nearly pure Indians form about 50 per cent. of the poulation, the *mestizos* form 35 per cent., the pure or nearly pure whites 10 per cent. and the other races 5 per cent.

The pure or nearly pure Indians fall, on occupational grounds, into two categories. The larger is that which devotes itself to agriculture, and the smaller is that which follows the sea, gaining a livelihood from fishing or as sailors. The agricultural category dwells for the most part on the huge landed estates into which the valleys and the intervening deserts are

The Chief Plaza, Catacaos, Piura Valley. The tower to the right is all that is left of the parish church, destroyed by an earthquake some years ago.

largely divided. They act as laborers for the owners of the estates, receiving a wage of about a *sol* or a *sol* and a half a day (fifty cents equals one *sol*). The working day is about ten hours, the working time being arranged so as to permit of a siesta during the mid-day heat. Each family has its own house and lot. There seems to be no lack of food, and the relations between the laborers and the employers seem to be genial.

The state of the Indians, however, is by no means idyllic. Their houses are too often merely wretched huts made of old corn-stalks, canes or gasoline-cans. The people have in general no sense of how to keep either their persons or their houses clean. Vermin and animals roam freely all over the hut, often dropping in close proximity to the food. The cooking utensils

A Street in the Village of Chulucanas, Piura Valley.
These houses are unusual, having tiled roofs.

are usually gourds or old tin cans and are usually in a condition of remarkable filthiness. There is absolutely no privacy in these houses and a large family often sleeps indiscriminately huddled together. It is not to be wondered at that diseases and bad habits are quickly communicated under these conditions. Clothes are often merely dirty rags.

On some *haciendas*, and in some Indian households, the situation is far better. The houses in some of the villages on the *haciendas* of Sojo and Macacará,[2] in the Chira Valley, are a

Some of the People of Chullillache, near the Mouth of the Piura River.

[2] The property of Don Miguel Checa and Don Alfredo Checa-Eguiguren.

great deal cleaner and more spacious than those of which I have spoken above. They are also better built, and the people have good clothes, which they change quite often, keeping themselves reasonably clean into the bargain. On a number of other *haciendas* similar conditions prevail, the *haciendas* in the Chira Valley being, on the whole, better conditioned than those in the two other valleys. This is probably due to its greater accessibility and to the fact that absentee landlordism is here at a minimum.

The maritime Indians live, for the most part, on land which has no formal possessor. They work for themselves or for the headman of their community, not for a white employer. Their houses are of the most primitive description; driftwood, old bits

A COTTON FIELD ON THE HACIENDA SAN YSIDRO, NEAR SECHURA, PIURA VALLEY. This hacienda, belonging to the Perez-Vasquez family, is managed by Don Victor Chavez, and is one of the best of the smaller haciendas in the Piura Valley.

of tin cans, bundles of dried grass and similar material being used in combination. Chullillache, a small port, or rather roadstead, near Sechura in the Piura Valley, is a typical community of this description. Colan, between Payta and the mouth of the Chira River, is another. About 400 souls live at Chullillache. In the early morning, before sunrise, all the men and boys go out to sea on their *balsas*, raft-like craft provided with a mast and sail. They take their nets (beautifully made) and with them encircle a good area of water. The circle is gradually reduced until the catch, almost always plentiful, is made. The *balsas* return home about noon. The women then aid in the cleaning and drying of the fish, which is later sent up the valley to Sechura, Catacaos, Piura and other towns, on donkey-back.

A Large Irrigation Ditch on the Hacienda of Sojo, Chira Valley. This hacienda, belonging to Don Miguel Checa and Don Alfredo Checa y Eguiguren, is one of the largest and finest in Peru. The large white house in the background (two miles away) is the mansion of the hacienda.

The population of the larger towns consists, with the exception of a small proportion of pure Indians who go out to work their fields every day, of *mestizos* and a few whites. The houses of this class are mostly built of *adobe*, often whitewashed, and from the front they look fairly substantial and sophisticated. Inside, however, a great degree of filth and slovenliness is often encountered. The clothes of the *mestizos* are much better made and more numerous than those of the Indians (except the richer class of Indians already alluded to). Proximity to market and to shops where canned food can be bought tends to make their diet better than that of the country folk. Though most of the *mestizo* class is occupied in shop-keeping, hotel-keeping and kindred employments, not a few of them are landowners, lawyers and clerics. The richer and more educated ones, of course, often have really good houses, well furnished and often provided with a good piano or with a victrola.

The temperament of the Indians is, in most localities, one of joviality and good humor. When skilfully superintended they work industriously enough, but when left to themselves they become spasmodic in their activities. On the whole their health and vitality are good, though *viruela* and smallpox are not unknown. Vaccination is now compulsory and is fairly well enforced. I saw very little venereal disease in the Piura-Tumbes region. The clean dry air of the desert tends to keep all illnesses at a minimum, although the conditions of living are often bad. Most of the children now get at least some instruction in reading and writing, but illitearcy is common among the older folk. At Tumbes and Morropón I found the health conditions to be much worse than they are elsewhere. Bad irrigation, unaccompanied by proper drainage, has brought about a number of bodies of stagnant and pestiferous water. Malaria and various forms of anemia are common in both those places.

Among the *mestizos* illiteracy is unusual, but many of them, and especially the women, have a peculiar bovine stupidity caused by a total lack of any sort of stimulating mental exercise. Unlike the Indians, the *mestizos* are given to unduly heavy drinking. One sees surprisingly little drunkenness in the Piura-Tumbes region, and most of what is seen is confined to the *mestizo* middle class.

The whites chiefly fall into two groups: the land-holding gentry, and the professional men and their families. Socially, of course, it is difficult to distinguish between them. They are all well educated and delightful, being among the most genuinely hospitable people in the world.

It is a difficult matter to exaggerate the power for good and likewise for evil which rests in the hands of the land-holding portion of the white upper class. On their vast estates the *hacendados* rule with unquestioned authority, using a system of overseers and headmen which has its roots in the ancient Inca régime. I am prepared to say that the great majority of the *hacendados* in the Piura-Tumbes region do not abuse their power, but neither do they avail themselves of the almost limit-

THE MAIN HOUSE ON THE HACIENDA OF SOL-SOL, PIURA VALLEY. This hacienda belongs to Senator Victor Eguiguren, and it is typical of the more old-fashioned type of hacienda-house.

HOUSES AT CHULLILLACHE, NEAR THE MOUTH OF THE PIURA RIVER. The logs on the right were brought all the way from Guayaquil for the purpose of building balsas.

less opportunities for bettering the condition and brightening the lives of the Indians and *mestizos* on their estates.

What Peru (and by implication other Latin American countries) needs just now is benevolent paternalism systematically striving to build up a wholesome, sane and virile peasantry, similar to that of France or to that of Switzerland and that of parts of Italy. I am well aware that paternalism of any sort is generally looked upon in this country as anti-democratic. But is it really anti-democratic? Those who declare it to be so lose sight of the very important fact that in a large proportion of the

SOME HOUSES OF THE SOMEWHAT IMPROVED TYPE, AT TUMBES.

world the mass of the people is not yet ready for democracy, even for the simulacrum of democracy which prevails in this country and in England. Yet in such lands, and especially in countries like Peru, a certain small minority—the enlightened upper, or dominant, class—is already fit to receive and to employ rightly real democracy, the democracy which recognizes the ineradicable inequalities existent in mankind and provides suitable social machinery to enable a gifted individual to reach the highest place in society to which his qualities entitle him. The problem which faces such countries is that of making the mass of their people as fit to receive true democracy as the minority now is. Only one social force, benevolent and progressive paternalism, is capable of carrying out this task. Ob-

A View Westward over the Chira Valley from the Verandah of Sojo.

viously some forms of paternalism, the stultifying and oppressive paternalism of early Etruria, of ancient Egypt and so on, are indeed anti-democratic. But the sort of paternalism which is already making its appearance in Peru and elsewhere in Latin America, a paternalism which seeks diligently to fortify the bodies and strengthen the minds and invigorate the souls of the masses, is far, far remote from any tinge of anti-democracy. On the coast of Peru to-day, I am convinced that selfish exploitation of the Indian and other laborers by the upper class (the *hacendados*) is the exception, not the rule. On the other hand, I also believe that *hacendados* like Don Victor Larco y Herrera (of Trujillo) and Don Antonio Graña y Reyes (of Huacho) and a few others, all of them systematically seeking to make every sort of condition on their estates as good as

UNIMPROVED HOUSES AT TUMBES. Built on piles because of floods.

it can be made, are likewise the exception and not the rule. In short, I believe that the *will* to be benevolent is by no means wanting, though the information as to *how* to be benevolent and the realization of the importance of being actively benevolent undoubtedly are wanting.

For the purpose of illustrating my point, I will say something of what this sort of paternalism might accomplish in the Piura-Tumbes region.

A *hacendado* who decides to devote himself whole-heartedly to the task of building up the physique and mentality of the dwellers on his *haciendas* should study intensively the temperament and the abilities of those whom he seeks to benefit. It will be found that the inhabitants of one village on an estate will have a peculiar aptitude for weaving, those in another, perhaps only half a mile away, will be especially adept at making objects out of wood, leather, straw or other materials. Again, the men of one village will be much better and more conscientious tillers of the soil than those of another, although the latter may have a special ability in making adobe or in carpentry. All these variations must be studied, and the special abilities must be taken advantage of, though wisely, not arbitrarily.

When he thoroughly understands his people, and knows all their little tricks of mind and all their prejudices, the *hacendado* will know how best to set about his task, and how to avoid outraging old usages or established habits of mind. He should especially refrain from drawing undue attention to his activities, for if he does, some one will be sure to start acting against him and undoing all his work. He should be patient, and should make up his mind that, for a long time, he will have to go very slowly. Gradually and unobtrusively he should persuade the people to tear down their present unsuitable and insanitary dwellings and he should see to it that the materials for erecting new ones of good adobe, or, better yet, of concrete, are readily accessible. When several new houses are thus built, he should announce that in view of the fact that a spirit of progressiveness seems to be abroad he will do what he can to aid those who are not sufficiently well-to-do to provide for themselves good houses of the new type. This would spur on the laggards, and, after a time, the whole village will be composed of neat, sanitary and pretty houses of adobe or concrete. The next step should be that of developing the love of beauty which is latent in the people. Flower-beds and shrubs should be planted along the streets, and in the plazas (in many places this is already done). To counteract the glare of the bright sunshine, the people should be shown the beneficial results of eschewing whitewash, and of painting their houses dark gray, or brown or other subdued colors. The ceramic ability of the people should be directed toward tile-making, so that good material for roofs (now usually made of poor thatch) may be easily available. Finally, but perhaps most important of all, there should be provided suitable sanitary arrangements, baths and so on. Many travelers in Peru have declared that the peasantry is averse to bathing. This is not so. Whenever a village is near a river the people wash themselves with great care. It is only lack of facilities for washing that makes many of them go without it. In the

A Scene in the Desert near Tambo Grande, Piura Valley.

The large tree is a zapote.

A View in the Piura Valley near Catacaos.

mountains the excessive cold and the lack of means for heating appreciable quantities of water are the chief causes of the general unwashedness of the mountaineers. All this can be remedied, and it should be—by the *hacendados*.

These reforms having been instituted, the scarcely less important ones of introducing better utensils for household work and of encouraging the use of better clothes should be effected. In connection with clothing, the people should be urged not to give up their wonderful hand-woven woolen and cotton textiles in favor of the poor quality and rather dear foreign-manufactured calicos and ginghams which are being extensively in-

The Plaza at Sechura, near the Mouth of the Piura River.

troduced. Personally, I am convinced that the Piura-Tumbes region could be made not only one of the greatest textile fiber-producing regions in the world, but also one of the greatest textile manufacturing regions. Excellent cotton and wool are already produced there. With proper scientific study and preparation, the two other great textile fibers, silk and flax, could also be grown in large quantities. I would strongly urge that the ordinary factory and mechanical methods of manufacture be not introduced, at least not in totality. The people of the Peruvian coast have, for many centuries, manifested a genius for hand weaving. It is a pity that this genius should be stultified by the ordinary super-efficient but entirely unimaginative manufacturing methods of other countries. Instead, I think

The Church at Sechura. Built about 1750, to replace the older one which was destroyed by the earthquake of 1746.

that the people of the Piura-Tumbes region and other parts of the coast should be provided with hand-looms sufficiently improved to ensure commercial profit, but yet of a sort which will allow play to the imaginative and technical abilities of the Indian weavers. Such a combination of qualities would not be unduly difficult to arrive at. In my opinion these people, given cotton, wool, silk and flax linen to work with, and given just the right type of loom, would very quickly show the world new sorts of cloth, and new combinations of material and pattern which would profoundly stimulate the jaded esthetic faculties of the world's dressmakers, tailors and upholsterers. Quality, not quantity, should be the aim. The fact that Piura linen, Piura cotton, Piura silk, or Piura linen-and-silk, or Piura linen-and-cotton or other Piura fabrics were excessively fine and beau-

A VIEW OVER THE TOWN OF MORROPÓN, PIURA VALLEY. Note the two bodies of insect-breeding stagnant water. There is much malaria at Morropón.

tiful, even though proportionately dear, would not in the least impair the demand for them, any more than it does the demand for any other choice article of luxury.

I mention the matter of weaving simply as an example of the sort of commercial activity, based upon the most fundamental traits and abilities of the people, which might be created by the exercise, on the part of the *hacendados*, of the correct sort of paternalism. Commercialism of this description, far from being baleful, would give depth and meaning to the bet-

THE VILLAGE OF YAPATERA, ON THE HACIENDA OF SOL-SOL, PIURA VALLEY. This is a typical unimproved Indian village. There is no provision here for any sort of diversion for the people, nor is there even a church and a priest, the nearest being at Chulucanas, some miles away.

tered conditions of life. It would be very powerful in creating a sane and self-respecting peasantry, half commercial and half agrarian, from whom the material for real democracy would ultimately be derived.

To aid in the work, attention must be given to such matters as sports, both individual sports like boxing, wrestling, fencing and foot-racing, and team-sports, preferably football, lacrosse and basketball. The beneficial influence of these games in creating a spirit of generosity, self-reliance and general virility is well recognized in this country and in England; it is beginning to be realized in the Latin countries, and sports of all kinds are already common among the upper class in Peru. But the task of making the *hacendado* perceive the necessity of providing sports for the Indians is as yet only just begun. Of diversions of a more mental and intellectual type the cinema can be made one of the most beneficial. Films that show life as it really is, especially those in which humor (real humor) is important, and films of all kinds provided that they are free from indecencies and brutalities, should be shown in every village of appreciable size at least two or three times a month.

I have reserved mention of the importance in all this of the priest and the school teacher till the last, for the reason that it is obvious. These two individuals can do things that the *hacendado* can not. It is for them to give point and authority to his efforts, and to supervise the actual carrying out of his carefully planned reforms.

To many, especially to the hawk-eyed and sour-visaged type of predatory European or North American commercial traveler (one is often tempted to term him a peripatetic despoiler of the unsophisticated), all that I have said will seem distinctly utopian. But that opinion will be caused by the fact that they look upon the Indian and *mestizo* with a view to discovering what they can *get out* of him rather than what they can *put into* him. I have studied this matter very closely in a number of representative regions in Peru and Bolivia, and I know that, even where the present conditions are seemingly most hopeless, there is *some* hope. In regions like that which I have called the Piura-Tumbes region, where even to-day conditions might be much worse than they are, and yet be better than those prevalent in the remote mountain districts, the human material which offers itself to the manipulations of benevolent and constructive paternalism is full of latent possibilities of a most cheering sort. Whether or not these possibilities become actualities depends on the *hacendados*, and on the upper class as a whole.

THE RATIONALE OF TESTING INTELLIGENCE, WITH SPECIAL REFERENCE TO TESTING IN THE ARMY

By DANIEL W. LA RUE
CAPTAIN, SANITARY CORPS, U. S. A.

A BRIGHT young man went to the Harvard Graduate School to investigate the freedom of the will. After two or three years of investigating, he concluded that there is no such thing!

For some decades, we psychologists have been measuring general intelligence. Are we sure there is any such thing? Investigation has been steadily deleting the definite article out of psychology: "the" memory, "the" imagination, "the" intellect —to use these terms with serious face is a confession that you have been reading the antique books on "mental philosophy" and neglecting the modern ones on differential psychology.

But is not *general* intelligence "the" intelligence? Can it fare any better? And to test it—is not that like testing the pulling strength, not of horses, but of "the" horse, a logical concept which stands in nobody's stable?

There are certainly two sides to the question, unless we can make out definitely the meaning of the phrase. It appears that general intelligence can be defined in terms of (1) mind, or of (2) brain, or of (3) environment.

1. The word "intelligence" throws back by contrast that which we are *not* measuring, namely, the feelings, and (if there is any such thing apart from intelligence and feeling) the will. Sensation and the sense-complexes, perception, memory, imagination and thought, these constitute intelligence. General intelligence is efficiency in the formation of sense-complexes as a means of dealing with the outside—yes, and the inside, world.

2. Speaking in terms of the brain, we know that it has two general levels: the lower level, like the entire brain of such an animal as a dog or a cat, is composed of centers which respond, more or less independently of each other, to such outer subjects as can excite them. The visual tracts see, the auditory neurons hear, and so on. The intelligence of a dog, or a horse, or of a one-story-brained *homo*, is the net result produced by these centers, unguided as they are, by any superior neurons. And such, too, roughly, is the intelligence of even a bright child, whose higher, reflective nerve cells have not yet come to command.

But these nether neurons of the brain are like the privates of an army, taking the direct shock and beat of the aggressive world about. The superior cells are the headquarters of another kind of general intelligence, a kind of commanding general intelligence. It has a dual duty: it deals with concepts, symbols and abstractions instead of material things; and it issues general orders to all subordinate centers.

Here is the home of "the" faculties, "the" attention, for example, which gives the command, "Attention," to all the lesser faculties, visual, tactual, auditory, and the rest, and reminds them to "make it snappy"! Here, too, lies the reason why it is so much easier to test the intelligence of a high, than of a low, subject: it is the difference between getting a single report from the head of a unified command, and collecting the muster rolls of all the scattered detachments of a Russian or a Mexican army. Also, here is one explanation of why testers are so prone to use numbers, words, symbols, concepts, abstractions, in their measuring schemes: they commit the psychological fallacy of assuming that others are like themselves, double-decker intelligences, and that in so far as one can deal with these higher things, certainly all the lower must have been added unto him.

"General" intelligence, from this point of view, is the unified, supervisory intelligence of the superior centers of the brain.

Finally, intelligence is (intellectual) power of adaptation to environment. This involves (*a*) sensing the situation, perceiving it, (*b*) comprehending, elaborating, perhaps analyzing or synthesizing it, and (*c*) responding (mentally) to it. "What would you do if you missed your train?" To ask this question of a subject is next best to seeing him in such a situation. He must exercise his "sense of reality" on it, size it up, plan his reaction. Testing seems simple enough.

But this world is made of situations. And if they are new enough to require much adaptation, we may not be able, with words merely, to create in the test room a replica of them that will be *real*. It is useless to ask a savage what he would do if he missed his train, or an old bachelor what he would do when the baby cried, or a green soldier how he will behave when a shell bursts near him. Further, just which of many millions of situations are so important, or so typical, or so closely correlated with a web of others, similar or dissimilar, that they should be admitted among the select few that form a test? The answer is coming as a slow deposit from the stream of experience and experiment.

If we are clear as to the more obvious outlines of what we are testing, the next question is, what are we testing *for?* It would be interesting, and perhaps instructive, to collect from common life many varied instances of the application of test processes.

Teasing, teasing,
Just to see what you would do;
Teasing, teasing,
To find out if your love was true.

Here is a thrilling test, with a fairly well-defined object. So Abraham undergoes a kind of divine teasing, to find out if his love for God is true enough to compel the sacrifice of his son; Elijah sets up a test to find which Lord really is God enough to make the fire fall; the farmer tests his seed by planting a sample; a small metal column is cast beside a great pillar, and of the same stuff, to find its breaking strength, and so on.

What is all this for? Not for classification merely, but for *action*. It is not a mere museum arrangement of individuals that we are working for, to put them in place and gaze at them: we want to know what some person or persons can or will do in our common environment, or in some special situation. That is the best test, and he is the best tester, that can most definitely predict and control how the subject will turn out. This is the test of a test, designed to lower any prematurely lifted brow that may be found among us.

Let us suppose a complex machine, consisting of many parts, such as an automobile, or the brain of a soldier, which must perform under new and trying conditions: the soldier is going to France; the automobile is to leave the paved and level streets of the city for country mud, hills, ruts and rocks. How, here in the garage, can we find whether our machine will stand the new strain? That test will tell best which is most like the new conditions that must be met. A certain automobile company, wishing to test out tires, exhausted all its laboratory ingenuity in vain, and finally fell back on an actual run of the road, through thousands of miles, as the only test conclusive.

But war will not wait for soldiers to be selected on this plan. They must be tried out in the tent, so to speak, and quickly, by our best means of predicting what they will do in the fighting field.

Let us have a symbol or two: Let T stand for the great and ultimate trial and test, which is life itself; t shall be our petty laboratory test, by means of which we predict how the subject will turn out in T, the life situation. Then we can safely lay down the general principle that *t should be as much like T as possible*. It is the old laboratory game right over: construct a miniature of your big problem, keeping the same principles at work. So the electric spark in the physical laboratory is a small sample of lightning, and the first wireless waves we know of traveled half way across a room instead of half way around the world.

There are at least two special reasons why *t* should be like T in much human testing. The first is that only so can we be sure of inducing the *attitude* necessary for success in T, and that is half the battle. "The will to win is half the victory." The animal psychologist meets this demand by setting his task, perhaps the threading of a maze, between the animal and some strong natural satisfaction, as that of hunger. Trivial as it may sound, there are few American soldiers who would not work hard at an intelligence test that permitted them, in some symbolic way, to can the Kaiser! On the other hand, if there is something about *t* that rouses the subject to supreme effort, whereas T proves so dull as to leave him apathetic, he will be rated too high. Perhaps the constant attitude of "You're in the army now," which means among other things, that you will put through what you are told to do whether you like it or not, makes this warning less necessary in military testing. But we know how much *morale* counts in execution—and *morale* is simply mental attitude.

The second reason why *t* should resemble T is that *t* may be so specialized and limited as to miss some of the important action features of T altogether. In case of the automobile, for instance, we might test its valves, radiator, carburetor, transmission, and so on—do not advertisers thrust some one of these things into our attention as if it were the whole car?—only to find that a bad spring or differential or axle made proper performance impossible. It is the total run that counts.

To put it in terms of neurons, or, as Thorndike would say, connections: T is bound to bring into play certain nervous connections between stimuli and responses. In any such complex situation as soldiering, there is sure to be a wonderful web of them, some old and well worn, some thoroughly new. Through *t* we must find out whether our subject actually or potentially has these connections. Testing them all, in a limited time, is often out of the question. We can (1) test a certain few of these connections which seem to be typical and fundamental, or (2) test other connections whose functioning is highly correlated with that of the T-neurons, or (3) test those connections, relatively rather low-lying in the brain perhaps, which are involved in the exercise of "common-sense," assuming that one who has a good sub-structure of common-sense connections can probably build up a superstructure of special-purpose connections, or (4) test the high-level neurons with symbols, thought processes, etc., taking it for granted that any brain which is equal to these lofty tasks can certainly perform all lesser. Actually, in the army, we are doing all four.

If we are testing old achievement, which will not require much variation to fit it to new conditions, *t* can almost become T, as in the trade tests in the Personnel Department of the army, where a man actually drives a truck as a test of his truck-driving intelligence. But as a rule, some adaptation to the new is required in T; and if we merely bring well-established connections into play in *t*, such adaptation is but doubtfully tested. But if *t* is *absolutely new*, as when we ask a savage what he would do if he missed his train, or if we use strange language, or require really new reasoning processes, it is too difficult. The solution lies in a *new combination* of *old mental materials*. So it is not surprising to find that we can distinguish the feeble-minded from the normal much less well by having them count forward, or tell their age, or go through some other practised activity, than by having them count backward, or answer problem-questions. The adaptable mind distinguishes itself, not so much by the wealth of its information, but by its ability to organize its facts and processes in new ways to meet new demands, to set its neurons to work in new systems, involving new connections.

Now, *t* is like a small stereopticon slide by means of which we project our picture of what the subject's larger future performance will be. For this reason, we must take care that *t* is not marred or distorted by anything which is not likely to enter into T. For example, objection is sometimes made to certain tests used in the army, on the ground that they require reaction within a fixed time limit, and a limit so brief that no subject ever completes the full test. But the military game is a fast one: wherever the soldier is placed, he is likely to find fast intelligence at a premium as compared with slow. To some extent, this principle would even justify the examining of recruits who are undergoing the effects of fatigue or inoculation, since the military T demands a clear head in spite of a suffering body. But in *t*, it is difficult to make the suffering uniform, and so make it fair.

It may help us further in determining what our scheme of intelligence testing should be if we consider what a complete inventory of intelligence would require. There are here, as everywhere, two great questions to be answered, What kind? and How much? To find a way to the answering of these questions, we must revert to the nature of intelligence and analyze it a bit further.

"Intelligence is intelligence," it is sometimes said, "whether in the skull of a Negro, white man or Chinaman. There are no *kinds*." I believe the bio-psychological concept of *traits* will help us here. To put it briefly: the cerebrum is not a single, simple, homogeneous organ, but rather a collection of organs. Doubtless there are separate determiners in the germ plasm for its separate parts, so that these parts are "independently heritable and independently variable." These parts—call them centers, or better, tracts—are the cerebral counterparts of those various objects or aspects of the environment which it has proven most important, evolutionally, for man to respond to. Each of these tracts is the seat of a trait. And each trait should be defined, not in purely mental terms, but as a reaction to something environmental, as the trait of acute color perception, or the ability to remember words well. A person is the sum of his traits.

Here, then, is the basis of the question, What kind? To test one set of traits with *t*, and then use another T, may prove as useless as to test one man and then use another. Tracts may be wanting in this brain or that, and hence the corresponding abilities wanting in the personality.

Now for the question of How much? Intelligence is not a unit power plant, a single motor which can be belted to anything indifferently, with equal prospect of running it. The *ensemble* of mental traits which make up a personality is more like a collection of separate motors of varying size, which, though they may influence each other's running, nevertheless operate ordinarily with considerable independence. In measuring completely the efficiency of a machine, say an automobile, we must find (1) what kind of parts it has and (2) how strong each part is. To measure a mind completely, we must find (1) what kind of traits it has, and (2) to what level of effectiveness each trait rises.

Now, what possible levels are there? Suppose several people have the trait of reacting strongly to color. One may perceive and act, as certain of the lower animals are said to react to red; the second will perceive-remember-act, will admire the rainbow and try to reproduce it when he gets home; the third will perceive-remember-imagine-act, will juxtapose remembered colors in fanciful combination; the fourth will perceive-remember-imagine-think-act, will work out the laws of color contrast, harmony and balance, and so set forth results by rule. The levels of a trait, then, are those of perception, memory, imagination, and thought. The last two are likely to involve pretty prominently the processes of discrimination, comparison, analysis, synthesis.

Here appears the reason for avoiding the alternative test, the yes-or-no test: it leaves no leeway for trait-power to rise by degrees until it reaches its true test-level, but simply shows presence or absence of some more or less indefinite degree of the trait,—and this not very certainly, since there is always a fifty per cent. chance of a correct guess.

Here, too, we can see clearly the value of special tests for special purposes. We are sometimes asked whether the intelligence test, as used in the army, does not discover special ability of this kind or that, special fitness for some special military position. In a limited way it may do so, and in half-accidental cases; but we can not substantiate any broad claim of this kind. For it is characteristic of the general intelligence test, so far as its *what kind,* its range of traits tested, is concerned, to deal almost wholly with the materials of the everyday environment only—how else could it be fair to all?—and with regard to its *how much,* the height, or degree of the traits, to rise to the level of the thought processes, but to require the most common of them only, and not to run through their whole catalogue. Our test for literates (Alpha) accomplishes these two things by means of *abstract symbols;* and leaves much, in the case of these favored subjects, to *individual initiative;* whereas the test for illiterates (Beta) makes the paper work more concrete, putting in pictures and diagrams, and leads the subject on by the attraction of *imitation,* to do about what he has just seen done on a blackboard.

The general intelligence test, then, tries out simply the central core of consciousness, so to speak, and that in a general way only. Its t is very small as compared with the T, the life situation, for which it tests. Since the ratio t : T is so small, we must be careful how we translate minute and perhaps accidental variations of t into the large and serious terms of T. A few points up or down on the testing scale, in any individual case, may not mean much with regard to pragmatic intelligence, exercised over a long span of time.

Because the general intelligence test leaves unexplored so many traits, and certain ranges of all traits, there are necessary as many special tests as there are special situations into which ability is to be fitted. And they have the advantage that T is smaller, just because it *is* a special, and not a general situation, and hence t can be made proportionately larger. In many cases, t practically becomes T—the ideal situation.

Take a case of this. An Indian captain has told me of an Indian soldier who is blessed with a wonderful "bump of locality." His friends tested this out by taking him to Washington, D. C., pointing out Potomac Park, and then whirling him from point to point of the city in the endeavor to confuse him as to direction. But in no case did he fail, after scanning the horizon a bit, to point straight toward Potomac Park whenever and wherever challenged to do so. It seems certain, after such a try-out as this, that he has at least one invaluable qualification for scouting. In the army, such discovery of a special talent for a particular purpose falls in the Personnel Department.

Let us look next at some of the obvious dangers of intelligence testing. In the first place, we must beware how we use a high-level test to measure low-level intelligence. If our scales are set to weigh nothing less than a hundred pounds or upward, we can not tell accurately the weight of an eighty-pound man. In particular, since devisers of tests are usually expert in the use of literary symbols, and since ordinary test conditions limit seriously the possible variety of responses open to the subject, we slide easily into the belief that a dextrous manipulation of symbols is the prime display of intelligence. No doubt it is true that in an ideally developed brain, the language centers (tracts) are well webbed up with every other trait-tract. Ideally, to experience anything is to be able to utter it. But the stammering lover is matched by the stammering thinker, and there certainly may be intelligent action without the power to put it adequately into words. Probably Cæsar is the only great general who could describe a battle as finely as he could plan it or fight it. Words without deeds, deeds without words: we must be prepared for both. Our old test question, "Why should we judge a person by what he does rather than by what he says," applies to the test itself.

The bulk, and sometimes one hundred per cent., of those who fail in our army test for literates (Alpha) raise their grades when they take the test for illiterates (Beta). This suggests (though it does not prove) that the intelligence is "there," all right, but whereas it can not "come through" in literary terms, it does break out successfully in the more concrete form.

A further danger lies in the use of a general test for special vocational fitness. To a limited extent, this is justifiable: for gumption is valuable in all vocations, and a good intelligence test does test gumption. But the general test tries out, chiefly, what I have called the core of consciousness, and special vocational ability often lies in traits outside that core. So we hardly expect the general test to determine whether one is, or can be, a good typist, musician, farmer, blacksmith, or social worker. But the general intelligence test should yield us two results even here. (1) Other things being equal, he will be best in any vocation who has the highest general intelligence. It is worth while—and the effort is being made—to have intelligence scales carefully worked out for each vocation, to accompany and supplement the special tests for special abilities. (2) General intelligence, among novices in any vocation, should be, on the whole, a good index of rapidity of improvement and final limit of development.

It may be objected that testing in the army has tumbled into the very pitfall here pointed out, of applying a general test to find out the fitness of a man for the special vocation of soldiering. But soldiering is not mere gun-pointing and trigger-pulling: it is a multiplex and all-inclusive vocation, involving nearly every kind of activity found in civilian life and some besides. Soldiering is full of general situations that require general intelligence.

There is a third danger which is just the opposite of the second. It lies in passing from a specific test to a general conclusion. Strangely enough, even some who deny the efficiency of formal discipline, seem to accept the efficiency of formal testing. For example, they assume that they have tested "memory" when immediate memory span for *numbers* has been tested, or that they have tested "attention" or "perception" by having the subject cancel all the A's out of a page of pi. A fourteen-year-old girl whom I once taught never did remember the multiplication table, yet she could easily catch complex pieces of music, retain them, and play them from memory.

We test what we test; but just how much more we measure, in the *mass* of subjects, we must find out by calculating correlations. And in the *individual*, nothing but complete, exhaustive probing is adequate. Here is further justification for the employment of several sub-tests as components of a complete general-intelligence test.

Finally, we must guard against giving a test, standardized by extensive mass methods, too close an intensive, individual application. Whenever we apply a standardized general test to any assemblage of complex parts, such as an automobile, or a horse, or a brain, we are sure that we can divide any collection of such units into grade groups, ranging from high grade to low. But any particular machine or animal or brain may hold up or break down contrary to our prognostication, based on the test. For this reason, we should make haste slowly (to avoid making progress backward) in establishing dividing lines that cut sharply. It is taking too much responsibility to say that positively no one who can not make a certain average-to-high numerical grade in an army intelligence test is fit to be an officer —or a president. If Hughes had tested out higher than Wilson —why not give all candidates for office an intelligence test?— would it, and should it, have changed any votes?

With regard to testing in the army, two large questions arise:

1. Can we measure the intelligence of army men?
2. What military value has such a measure?

When a man enters the army, he is tested in practically every part: there is a board to look after his bones, muscles and joints, a heart board, a lung board, and so on. At length appeared a brain board, so to speak, the Neuro-psychiatric Board. Certainly there should be a board to pass upon the nervous system, for it is the controlling system of the body. Though all other organs be sound, they will be ineffective without a good governing system.

But all these various boards give, in general, a yes-or-no judgment, "good enough for service," or "not fit for service." They do not measure *degree* of fitness. Their attention is not so much on the normal as on the abnormal, and their chief effort is to keep that abnormal out of the army (or, if possible, to improve it sufficiently to serve). The neuro-psychiatrists aim to eliminate the neuro-mentally abnormal.

But now appears a new board, the psychological board, more accurately, the psychometric board, whose fundamental propositions are (1) that intelligence can be measured and graded; and (2) that grade of intelligence is so important that placement in the army should be made accordingly. An interesting innovation, surely; for nowhere else are all recruits measured and graded, beyond the yes-or-no, accepted-or-rejected plan, except in the Personnel Department, and not even there by such exact, objective standards. If the two propositions above are true, they fully justify the use of the increased space and personnel which the Psychological Board uses as compared with other boards which do not attempt such measurement, and fully justify also the total expense of psychological examining as the price of effective classification and placement.

With regard to the possibility of measuring intelligence, two extreme views are found. The first is, that it can be read off so readily from the subject's face, walk, etc., that there is no need of further measurement. The second is, that it can not be measured at all! Those who take the first view can usually be convinced out of it by actual trial—if they are game enough to make one under controlled conditions. They succeed about as well as did the three teachers who were asked by Binet to estimate, off-hand and independently, the intelligence of each of a group of children. It is recorded that the three sets of results showed hardly any agreement.

Intelligence can certainly be measured. The only question is, How accurately? Here, it is only possible to mention a few of the lines of evidence which give the psychometrist faith in his results. (1) Certain tests have already enabled us, in civilian life, to predict educability, school progress. (2) The psychometric rating agrees fairly well—and too close correlation would arouse suspicion—with the rating of intelligence as given by officers who know their men thoroughly by long contact. (3) Officers, "non-coms" and privates show three very different averages, in the order mentioned, and three distinct, characteristic curves. (4) Racial difference stands out as previous investigations would lead us to expect. (5) The lowly-educated, who have had limited opportunity, sometimes surpass the more highly educated, which indicates that we are measuring innate ability rather than conventional education. (6) Repeated, independent measurements, give harmonious results.

By setting men at various tasks which test the heart, lungs, muscles, and so on, we can get a gauge on their general physical efficiency. By setting them tasks which tax perception, memory, understanding and the like, we measure their mental (intelligential) efficacy, can try out the running gears of their intellects.

Now for the second big proposition, which I think we can state, in extreme form, in this way: Granted a passingly good physique, intelligence is thereafter the most important factor in military efficiency.

It appears to me that neither the yes nor the no of this can be proven at present. The practical importance of intelligence in every-day situations is brought out by the much-repeated injunction to "Use your head!" On the other hand, our tests do not go far in measuring response to *social* environment. There are many cases in daily life where one is impressed with the truth of the adage that "Good nature is worth more than good sense." Line officers sometimes place on intelligence a lower value than we would expect, emphasizing rather such qualities as loyalty, obedience, adaptability and dependability. If you insist that a regiment should be balanced on the basis of intelligence, placing the same amount of it in each company, the line officer might reply that he wants it balanced according to discipline, or courage, or initiative. That the superior intelligence of man has been the decisive factor in placing him at the head of the evolutionary race seems extremely likely. And Terman states that "with the exception of moral character, there is nothing as significant for a child's future as his grade of intelligence." Yet intelligence lies largely in the upper, most recently evolved, most delicate portions of the brain. It may be a very significant fact that, although the ratio of officers to men at the front is about 1:30, and among the wounded 1:24, yet among the patients admitted to special hospitals for war neuroses in England during the year ending April 30, 1917, the ratio of officers to men was 1:6. This may be due to the greater mental strain which falls on the officer, or to the fact that his more intelligent, and probably more sensitive, delicate nervous system, suffers shock more easily. If the latter, it is a question as to whether highest intelligence means greatest military efficiency under the most trying conditions. The answer to this question lies in France.

However, there is an interesting and closely related problem which the military psychologist should undertake to work out on this side of the ocean: To what extent is intelligence correlated with general military efficiency as displayed in our military life? To test this, we measured at Camp Meade, the intelligence of 765 men of the 17th Infantry (Regulars), all of whom had been at least several months in the service, and under the same officers. These officers were then asked, without seeing our grades, to rate their men, not as to intelligence primarily, but as to "*military efficiency,* which means *practical soldier value* to the army, all things considered." In estimating military efficiency, the officers were told to "keep in mind such points as dependability, judgment, discipline, comradeship and initiative." Five grades of rating were used, both by the psychological examiners in measuring intelligence and by the officers in grading military efficiency.

The results show that in 49.5 per cent. of the total number of cases, the intelligence rating and rating for military efficiency were the same; in 38.9 per cent., there was a difference of one grade only between the two; in 11.0 per cent., a difference of two grades; and in 0.7 per cent., a difference of three or four grades. If we leave out the last five companies, which reported tardily, and whose commanders, we suspect, took the experiment less seriously, we find the two ratings in perfect agreement in 52.7 per cent. of the cases, within one grade of each other in 36.5 per cent. more, and agreeing within two grades in 10.2 per cent., or practically all remaining cases.

Such experiments should be repeated to find whether they prove the implication of the present one, namely, that if we place a man according to his intelligence rating alone, we shall have placed him, in the great majority of cases, substantially according to his military efficiency, his general camp value. It appears reasonable to suppose, until facts from the front prove the contrary, that camp value and trench value, enemy-killing value, are closely coincident.

At this point, we pass the question of placement on to our military and social leaders, to generals and statesmen. It is our work to discover the intelligence of the division, to point to the heads that hold it: the commanding general must determine where, in his organization, it shall be placed, whether it shall be concentrated in machine gun companies chiefly, or in the ambulance train, or whether it shall be distributed uniformly throughout. Further, our statesmen and other social leaders, taking counsel with the eugenists, must decide to what extent the winning of the war demands the exposing of the most intelligent portion of our general population to the highest mortality.

General intelligence, then, while it is not the only quality that makes a man valuable, is not only highly important for its own sake, but is, in the mass, bound up with other qualities which make for military efficiency. In individual cases, the intelligence rating may prove to be an inexact index of a soldier's general value; it may even go agog as an accurate measure of his intelligence itself, owing to his peculiar condition when tested, or to the too particular application of a general method. But that psychometric methods and measures have a high value for army purposes there is no doubt.

Officers are to be chosen for training camps; a corps of quartermaster's clerks or personnel assistants must be selected; in our haste, we must sometimes choose "non-coms" overnight; the feeble-minded must be eliminated; the Depot Brigade holds several hundred illiterates who are to be divided between an infantry regiment and a labor battalion, according to their native ability to respond to training; the commanding general has a company of uneducated thrust into his division shortly before its departure and wishes to know whether their intelligence warrants taking them to France; the development battalion is swarming: who of the swarm can be successfully developed and sent back to the line, and who should be rejected? Companies, regiments, whole armies are to be balanced, for the saving of time in training, for the just rating of the officers responsible for them, and, most important of all, for effects in the field.

Wherever appear the problems of mental classification and placement, there the psychometrist can be of service.

THIS GENERATION CAN NOT ESCAPE PAYING THE COST OF WAR

By Professor C. C. ARBUTHNOT

WESTERN RESERVE UNIVERSITY

WHAT are the "costs of war"? The answers to this question will depend upon the angles from which the great problem is attacked. The wastes of fighting impress different observers according to their individual outlooks and bulk large within each particular range of view. Perhaps the chief matters of concern in such an inquiry lie in the fields indicated by three topics: (*a*) The human costs, (*b*) The cost in materials, (*c*) The cost in money. The subdivision of the subject should not convey the impression that the parts are unconnected or sharply marked off one from the other, but rather that the whole theme will be easier of comprehension if the parts are considered one at a time.

1. The Human Costs of War

The pen halts at the thought of recording the human costs of war. The broken bodies and the shattered minds, the pains and anxiety, the horrors and despair, the wrecked relationships and the accumulations of hate, the benumbed hearts and the seared souls, all that the soldier endures at the front, and carries through life with him if he returns, all that his friends and relatives bear while he is away and bend under if he does not come back: all these costs are too many and great to be numbered. Of this, the greatest cost, only the least may be said. The words are too few and the expressions are not strong enough to tell the story of human sacrifice forced upon the people of this generation by the raging conflict. This burden can not be passed on to future generations. Whatever human losses are transmitted as an inheritance to the people of to-morrow do not lessen the burden of to-day. They add to the unreckoned human costs of war.

2. The Cost of War in Materials

The materials consumed in warfare are the product of toil and sacrifice and may not be too independently considered as distinct from the human elements of the problem. Men and women have changed the current of their lives and undergone risk and strain second only to those of the soldier in order that the latter might be properly equipped for the direct conflict with the foe.

The materials now devoted to the purposes of war are largely the product of current efforts. Not a great amount of goods and equipment have been carried over from the stocks of past years. Little can be obtained at the expense of the future. What men are to fight with in the immediate struggle must be turned out here and now.

Upon their entrance into the war the different nations were possessed of varying amounts of military and naval equipment. But much of this original outfit has been destroyed and must be replaced by current products. Germany has turned some past products to present account as in the cases where copper roofs and church bells have been made into instruments of destruction. But the accumulations from earlier years can do little for the fighters of to-day. These stocks and stores have been quickly dissipated, with the increasing needs ever demanding more and more.

In a sense the future can be drawn upon for material help, but again the amount, compared with what must be secured, is not of great significance. During the war the wear and tear on machinery, factories, railways, buildings and other durable goods may be allowed to go on to an amount unusual in time of peace, though not to a degree that would interfere with operating efficiency. By allowing this permissible amount of depreciation to take place, the labor and material that otherwise would be used for repairs and replacement could be turned to the production of munitions of war. As a result this war material would be produced at the expense of the future to which would be handed on an equipment in capital and durable consumption goods of less effective character than otherwise would have been the case.

After all possible allowance has been made it is only too clear that the materials of war must be made as the struggle goes on and that the people of to-day must pay this cost by increased labor and saving. This burden of providing the enormous quantities of munitions and supplies is as imperative a daily, current duty as is the service of the soldier in the trenches. It can not be put off nor escaped. The soldiers of to-day fight with the products of civilian laborers of to-day. The costs of war in materials must be paid by this generation, it can not be passed on to the future. This fact is so simple, clear and plain that multitudes of people do not realize its significance. The the real economic direct cost of war. It must be met here and now. No methods of combining note issues, bond sales, and production of the material equipment for the fighting force in taxation can alter the situation. While the fighting is on and not after it is over, must the civilians work and save to make the needed goods. The economic costs of reconstruction when peace comes will be additions to the costs of war, not payments for it nor reductions in the expense.

The call to work and save is as immediate and pressing as the call to fight. Neither can be escaped nor postponed.

Saving is important because it releases labor and material from civilians' uses and turns them to the public service. The spender in essence asks people to work for him or furnish material for his own satisfaction. On the other hand, if he saves and turns his funds over to the government he gives to his country the power to secure this labor and material for public defence while he foregoes its private enjoyment. Saving thus increases the materials available for the army and navy. Saving and increased production both will have to be pushed farther than ever in our past experience if through this war we are to win a durable peace. Greater saving and greater exertion in making equipment must precede the fighting not follow it. The cost of war in terms of goods must be met to-day. It can not be passed on to succeeding generations.

3. The Cost of War in Terms of Money

In earlier times when wars were fought with little money and no credit paper the basic costs in human pains and in materials were outstanding. The fighters and their generation paid these costs with little chance of misunderstanding in respect to who were the real bearers of the burden due to the struggle. In later days when governments issue paper money, sell bonds and collect taxes the situation has become complex and a great deal of confusion has arisen concerning the ultimate effects of the different methods by which the costs of the war in terms of money may be paid. Some of the difficulties seem to be due to an inability to examine the matter from the same point of view or to hold to a given angle throughout the discussion. The effect of a given policy on individuals, on economic classes, and on successive generations is not likely to be clear unless one keeps in mind the specific part of the problem that is being considered.

The principal methods through which money for war purposes may be obtained are six in number:

1. Requisitions in occupied territory. Germany's practise in Belgium serving as an example.

2. Indemnity from a conquered enemy. Germany's policy at the end of the Franco-Prussian War and at the beginning of this war.

3. The profits of state-owned industries, as the German railways or the mines of England as suggested by the Fabian socialists.

4. Issue of paper money, as the greenbacks in our Civil War and Germany's present issue, disguised though they are as issues of banking institutions.

5. The sale of bonds to be paid for by taxes after the war.

6. Taxation during the war.

The following discussion will concern itself with the consideration of the effects of the second three methods of raising the money needed for war purposes.

The issue of paper money and sale of bonds are alike in that they are both loans, though very different in that the note issue is a forced loan that inflates the currency, while the bond purchase is a voluntary transaction that does not necessarily produce inflation. All three are alike in that the taxpayers have to foot the bills, though collection is postponed in the case of the first two. Bonds and taxes are alike in that the bond buyer and the taxpayer must turn over the money to the government at once, though what is received for the money, a bond in one case and a tax receipt in the other, differ widely. Furnishing the money, like furnishing the men and the materials for war can not be passed on to later generations. All three must be provided now by the people of to-day. Whatever may come back in the future does not alter the fact that all three, the money, the men and the materials must be given up by the people of the present if there is to be any future worth looking forward to. An examination of the differential financial expedients for putting the government in funds will indicate the characteristic features of each one and the economic consequences of its employment.

A. *The Issue of Paper Money.*—This is the easiest way, but the suggestion of its adoption is the counsel of folly or despair. Our experience in the Civil War and the bitter lessons from other times and countries ought to keep us from repeating the monumental blunder of financial incompetence. Just now the thing seems improbable, but if the war is drawn out to great length and the financial load grows steadily greater, some belated financier will probably arise and tell us of a burdenless way of paying war expenses by running the printing presses.

When a government issues paper money and compels its citizens to accept its notes in payment for goods and services, its action amounts to a forced loan without interest. But this forced loan differs from an ordinary loan in that the citizens' purchasing power is not diminished as it is when money is handed over to the government in exchange for bonds. In the latter case the lenders turn over part of their power of buying to the nation and to that degree take themselves out of the market. The demand for goods is transferred from private to public hands, but it is not increased by the funds derived from this type of loan as such. To the existing supply of goods the usual demand is presented, except that it is made by the government instead of by private individuals. The result is that there is a minimum disturbance of the price level and the general business situation.

When a government issues paper money and goes into the market with it to buy supplies a very different result obtains. The government's new purchasing power is added to that of its citizens and the greatly increased demand presented to the ordinary supply of commodities drives prices upward at a rapid rate. The tendency toward higher prices, inseparable from the imperative needs of war, is greatly exaggerated and the whole business of the country is disturbed by an abnormal change in the level of prices. Ordinarily the citizens' increase in purchasing power is due to an increase in their productive efforts in making goods and the greater demand is matched by a greater supply of commodities, so that the exchange ratio is not altered and the price level is more or less constant. Not so with the increase in buying power acquired by a government through the issue of paper money. No simultaneous increase in output meets the enlarged demand and the existing stocks of goods are subjected to the pressure of normal private buying plus this abnormally created public purchasing power. The consequent rise in price favors a few and upsets the calculations of the great mass of citizens, with the hardship falling usually on those least able to bear it.

A second influence works in the same direction. A resort to paper issues is a confession of weakness and an evidence of incompetence. The first step is quickly followed by the second and the government is soon unable to redeem its notes in standard money. The country suspends specie payment and the paper dollar itself then becomes the standard money in which values are expressed. The paper standard fluctuates in value as compared with the specie standard according to the probability that eventually it will be redeemed in coin. The volume of the issues, the prospects of success in the war, and the changing policies of the changing officers in charge of the administration will affect the public's faith in ultimate redemption and hence in the value of the paper standard. The result of this fall in value and these fluctuations in the standard are rises and alterations in the prices of commodities due to no influence in the field of production or consumption but to unpredictable changes in the paper standard whose gyrations reflect an unhappy combination of the fortunes of war with the compromises and second choices of political and often partisan policy.

The unproduced purchasing power put in the hands of the government and the erratic paper standard in terms of which the prices of commodities are quoted lead to the type of experience described by Louis Blanc when he wrote of a French situation, "Business was dead; betting took its place." Rising costs of living lead to labor disturbances that cut down production. People with fixed incomes suffer hardship. The government pays the inflated prices for its war supplies, and the soldiers find what they can buy with their meagre pay marked by low visibility. The increased cost of the war falls upon the taxpayers when the bills are eventually passed to them and they have their perennial privilige of paying for blunders that should have been avoided. The country ought to set itself like flint against any suggestion of issues of paper money, directly or indirectly, that would lead to a departure from a specie basis. The war can be fought without inflation of the currency by the government or banks, just as the navy can fight without a ration of rum.

With this discussion of paper issues for the purpose of eliminating them as a practical policy we can turn to a consideration of borrowing by bond sales as a method of raising money in time of war.

B. *Borrowing by Selling Bonds.*—No nation is ever likely to put into operation an adequate taxing system upon the outbreak of war. A militant oligarchy hopes to pay the expenses of its adventures out of indemnities collected from the defeated enemy, while democracies will never be so prepared for war that they will have at hand a system of war taxes devised in advance and ready for immediate enactment when the crisis comes. But money must be secured at once. Resort is therefore had to the sale of bonds as the effective method for obtaining the required funds, usually preceded by issues of short-time certificates of indebtedness in anticipation of the proceeds from the bonds. Bonds have this very great advantage of the superior quickness with which they yield the required funds.

A second significant feature of bond sales arises out of the fact that their purchase is a voluntary action. Joined with this is the convenience in denomination and terms of payment. As a result citizens can adjust the amount purchased to their respective abilities in a fashion that will allow persons of modest means to turn over their savings to the government, as well as offer the opportunity to every other group in the country to advance the needed money in such measure as their resources will permit. By tapping each store in accordance with its contents the bond shows itself a flexible instrument by means of which the hidden wealth and unsuspected financial resources of the great body of citizens are made available for the public service. People voluntarily turn over to the government in exchange for bonds great sums of money that otherwise would lie beyond the ken of the tax-gatherer or that could be reached only by the most inquisitorial methods, which would tend to defeat themselves by arraying the ingenuity of the owners against the inadequate knowledge of the officers of the law.

The fruitful resource of bond sales is so effective because it unites the two powerful appeals of patriotism and personal profit. Citizens are urged to put their funds at the disposal of the government because the safety of the country and all they hold dear depends upon the expenditure of money in the public defence. They are shown that others are going into battle for the security of the citizens at home and that the soldiers' hardships are not even poorly matched by the pecuniary sacrifices that must be made by the civilians if the fighters are to be given the support with equipment, food, weapons and ammunition that they must have in order to discharge the duties to which they have consecrated their lives.

To this call upon patriotic feeling is added the prospect of economic advantage due to the safety of the principal and the payment of pure interest on the loan; that is, interest from which nothing need be deducted as insurance against risk or for care and skill in management. The probable premium on the bonds after the war is also an inducement. A much greater advantage is promised by the probable fall in prices after the war. If we assume that present prices are about fifty per cent. higher on the average than pre-war prices, then a dollar to-day will buy no more than 65 cents bought in 1914. If prices after the war fall to the pre-war level a dollar then will buy as much as a dollar and fifty cents will purchase to-day. The saver who chooses to buy a one hundred dollar bond to-day rather than spend $100 for current consumption is in reality choosing between $65 worth of goods now and $100 worth of goods after the war, measured on a peace-price basis. In other words $100 invested in a bond now will command when the bond is paid as many commodities as $150 will buy to-day. This is a real premium and a large one, overlooked usually because people think too much in terms of money and not enough in terms of goods.

Added to this gain after the war is another advantage that comes from saving now. Refraining from unnecessary buying for private use during the war reduces the demand for commodities and thus lessens the tendency of prices to move in an upward direction. People by continuing their usual buying compete with each other and the government in the purchase of goods. By this persistent bidding among private individuals and against the government the level of prices is raised all around and money spent does not go as far as before. On the other hand, turning part of one's outlay into bonds reduces this competitive demand, checks the rise in prices, and makes what one does spend for consumable goods able to get more goods in the market. Saving thus makes more saving easier by moderating the rising cost of living.

When it is evident that buying bonds combines these economic advantages of (1) safety of principal with (2) pure interest, (3) a probable premium on the bonds after the war, (4) an even more probable advantage of greater amount through a fall in prices when peace comes, with a consequent increase in the purchasing power of their savings, and (5) a tendency to mitigate the rise in prices during the war: when it is seen that these individual advantages are joined with the opportunity to be of public service, the combination of patriotism and profit places at the government's disposal great sums of money with remarkable speed, a result that is vital at the outbreak of war.

C. *Taxation in War Time.*—It has long been suggested that part of the prudent preparedness for war should be an outline scheme of taxation, drawn up in advance, ready to be filled in and enacted promptly upon mobilization. But for reasons indicated above this has never been done.

The process of enacting tax legislation is slow, considering the emergency to be met, and the result is likely to be a statute satisfactory to no one, oppressive to many, and unworkable in some of its parts unless supplemented or modified by administrative rulings. The crudities have to be hammered out on the anvil of experience.

With these disadvantages to be met, the returns from taxes come into the public treasure slowly, too slowly to furnish funds for the great emergency, without the assistance to be had from bonds.

Along with this defect, taxation has the great merit of compulsion that is lacking in the case of bonds except so far as it is provided by the pressure of group or public opinion. Taxation forces many persons who are able to pay to do their patriotic duty whether they are willing or not. Much money that would not come to the help of the public voluntarily is reached by the strong arm of the law and drafted into the service of the country. There are so many varieties of citizens that no one method of reaching all of them is adequate. The government must go equipped with every possible collecting agency in order to get, by both persuasion and compulsion in their varied forms, all of the enormous sums that must be raised to meet the pecuniary outlays of modern warfare.

The rigid rules of the taxing machinery have an important rôle to play, though they have limitations in their effectiveness in raising funds. These rules must be general, broad in application, and inelastic in execution, applying to groups rather than to individual and special cases. They get with considerable effect whatever comes within their scope, but much of the country's resources escape beyond the limits of these laws. To reach the resources of some would require such rigor in the law that the burdens upon others would be intolerable, and the harsh rules would so interfere with the free play of business enterprise that the productive efficiency of the country would be reduced. While the limits to the amounts that can be raised by taxation can be greatly widened by education and experience, the policy takes time and can never hope to attain the bond's ability to reach individual capacity.

The tax-gatherer's task is made easier in war-time by the patriotic enthusiasm for the support of the fighting men. Citizens who are unable to go to the front find an outlet for their devotion to their country through tax-paying and the exchequer is enriched by the willing payments of many who find relief in the consciousness that their money is representing them in the raging contest. This war-time tax-paying impulse dies down when peace arrives and paying taxes for the discharge of war obligations takes on the character of paying for a dead horse. It behooves the finance officers, therefore, to collect while the collecting is easy and the taxes are fruitful.

There are some types of earnings that are war-bred in character, such as excess or war profits and incomes swollen through the increased business activity due to military operations and the by-products of such enterprises. These temporary, increased incomes should be reached at once, because they will not be available if time is allowed to pass. Moreover, if they are reached quickly before the recipients have had them long enough to develop a feeling of possession in them, a larger fraction of such incomes can be taken, with less mental anguish on the part of the taxpayers, than would be possible if the process of sharing the new gains with the nation were longer delayed and time given for a vested interest to develop in this type of unearned increment. Prompt, vigorous taxation of war profits or excess profits due to war business, direct or indirect, will make it clear that these gains are due to the general situation and not to exceptional industry or management on the part of the recipients, and that they are not in origin or character to be regarded as private property.

Considerable difficulty is encountered in those cases where businesses must be extended in order to produce supplies necessary for the conduct of the war. No ordinary profit would justify the construction of plants whose product would be without a market should peace suddenly come. Here it would be better not to make the extension on the basis of a speculative, private enterprise but to have the government underwrite the risk involved in the additional investment as a public expense.

The excess-profits tax bristles with difficulties, but these must be met in order that the rich revenue it will produce may be secured in this time of exceptional need.

The Relation of Bonds and Taxes in Distributing the Cost of War

From what has been said it is evident that as a matter of practical, sound finance both bond sales and taxation must be employed in order to get quickly and in adequate amount the money needed to pay the cost of war. The debatable question is the proportion of the income that should be raised by each method.

One of the curious and widespread illusions respecting the advantage of raising funds by borrowing instead of by taxation is to the effect that through the later payment of the loan part of the money cost of the war will be passed on to future generations. It is evident, as indicated above, that this generation furnishes the money required for war expenses, whether it is raised by taxation or by bond sales. The taxpayer gets back a tax receipt while the man who lends to the government receives a bond, but both have handed over money to the public treasury.

This generation has put up the hard cash. When the bonds come due and future taxpayers furnish the money to pay the obligations, to whom is the money paid? To this generation which gave the government money for the bonds? Assuredly not. This generation will have gone to its reward by that time and the taxpayers of the next generation will pay the bondholders of the next generation, not the bond buyers of this generation. As long as the problem is considered from the point of view of the mass of the people described as "this generation" as contrasted with future generations, there is no doubt that "this generation" must furnish the men, materials and money needed to win the war and that it will be impossible for the people of to-day to collect anything in return from the people of to-morrow. It is when the problem is approached from the angle of the interests of individuals or economic classes that the difference between taxes and bond sales becomes of significance. In these relations it is possible to pass the burden to others in case of bond issues when it would not be possible should the money needed be collected by taxation. The significant facts from these angles may be made to appear in a few simple suppositions.

For the purpose of illustration let us suppose that (1) the entire cost of the war were met by selling bonds and (2) that all citizens were able to buy the same number of bonds and (3) that the bonds were eventually to be paid for by a poll tax of so much a head, assuming "that all other things remain the same." If each citizen bought a $1,000 bond and later paid $1,400 in poll taxes to cover the interest and principal of the bonds, the effect would be essentially the same, apart from the cost of administration, as if the burden had been met by taxes during the war. Each citizen would have given up at once $1,000 in either case, receiving a bond in one instance and a tax receipt in the other. Were the bond method chosen the government later would reach into the bondholder's right-hand pocket for taxes and pay into his left-hand this same money as interest and principal. If the bonds ran for a long time the same relation between taxpayers and bondholders would continue, paying and receiving would balance each other. There would be no choice between bonds and taxes as methods of raising money.

If the bonds were unpaid for fifty years and the generation of buyers passed away and a new generation inherited the bonds and the obligation to pay taxes, the case would not be altered. This earlier generation would have turned over the money to the government and passed on the bonds to its heirs, who would pay off the bonds with taxes, but this earlier generation would get none of the money. The future taxpayers would pay the future bondholders and in this supposed case no one would be ahead or behind, seeing that bondholding and taxpaying are assumed to be equal for every citizen. The original bondbuyers might as well have paid taxes as bought bonds. It is of no particular advantage to pass to one's heirs an asset like a bond if it is accompanied by the equal liability to pay taxes.

This supposition of equal power to buy bonds and pay taxes is too far removed from reality to serve for more than an illustrative point of departure. Imagine that the citizens are classed in groups according to their ability to buy bonds, *e. g.*, in the relation of 1, 5, 10, 15, 25, etc., and that they are assessed for taxes in a similar ratio. This might be nearer the real situation, but it is still evident that they would have to give up the price of the bonds at once upon buying them, and that later they would be taking out of one pocket to pay taxes the money would be returned to the other as interest and principal on the bonds, leaving them neither richer nor poorer.

These suppositions are intended to illustrate what is perhaps evident upon mere statement, that there is no advantage to the individual in the policy of public borrowing rather than in pay-as-you-go taxation if his purchase of bonds as an investment is matched by an obligation to pay taxes later in proportion to his holdings of bonds. He might as well accept a tax receipt at once for his money as to get a bond that he must later pay off himself by turning over money for tax receipts. He gives up cash at once in both cases and his later income from coupons and final payment when the bond system is adopted are matched by his payments of taxes. When later taxation is proportioned to bond purchases it is an illusion to think of the bond as worth more than a tax receipt. All of this is based on the assumption that the purchaser of the bond holds it until maturity or passes it on to his heirs.

But it may be objected that the bondholders can sell their bonds, whereas there is no market for tax receipts. If the money were reinvested the new income would be reached by our supposed system of taxation according to ability. If the price received from the sold bonds were used in untaxed consumption the seller would be in the group indicated later who would find advantage in the system of public borrowing rather than in taxation.

There is no escape from the conclusion that if the people generally buy bonds according to their ability and are taxed according to their ability to pay the interest and principal of the bonds, there is no advantage to any one in the purchase of bonds rather than the payment of taxes during the war.

If one should turn an abnormally large proportion of his property into bonds would the situation be changed? Not at all, because he would lose the higher income that might have been gained in other fields as an offset to the income from the bonds. On the other hand, buying no bonds or relatively few would not give any one an advantage. His investments in other fields might yield a larger gross return but if the taxes, as we are supposing throughout these illustrations, were actually adjusted according to ability to pay, these higher returns would be reached by the tax-gatherer and no advantage left to the holder of individual or corporate investments as contrasted with the owner of government bonds. The taxes paid by the former would be paid to the latter until the national debt were paid.

In all three of the supposed cases, whether one buys bonds according to his ability or more than the normal amount or less than could have been expected, there is no gain to individuals in the bond system as compared with taxation during the war, provided the taxes after the war are collected according to the citizens' ability to pay and the individuals and their heirs continue in the same classes as far as taxpaying ability is concerned. If every individual retained the same relative economic rank and were obliged to pay taxes according to his ability after the war he might as well pay taxes during the war. When either of these conditions does not exist there enters the possibility of individual advantage when the government raises money by selling bonds rather than by collecting taxes at once.

The persons who would gain directly by the bond system would be chiefly the ones for whom postponed taxation would mean escaped taxation: the recipients of war profits or enlarged incomes during the war, the citizens who would be saved from consumption taxes during war and thus be able to buy commodities cheaper, those who would be able to escape their proportional burden through the character of the tax system adopted after the war. The essence of the matter is to be found in its effect upon the ultimate resting place of the burden of taxation. Bonds make it possible to redistribute the cost of war among the different economic classes through modifications of the tax system or the opportunities to avoid its pressure that might give results after the war of a kind which would not be possible during the conflict. A statement of some of the possible combinations of bondholding and taxpaying will suggest the possibilities of thus shifting the burden of the money cost of the war among the different groups of which the nation is composed.

It would make a significant difference in determining who would pay the cost of the war if in constructing the revenue system a strong preference were shown either for taxes upon articles of common use or for direct taxes such as income, inheritance and excess porfits taxes. If the money to pay interest and principal of the bonds were raised by taxes on sugar, coffee, tea and other staple consumption goods, either through internal taxes or tariff duties, the cost would fall upon the ordinary citizen with a weight exceeding his relative ability to pay. If the bonds were widely held the mass of the people would go through the experience of paying higher prices for the necessaries of life in order to get back the money they had advanced in war-time. An increase in the cost of living would be required to pay the war debt, one offsetting the other, but the mass of the people would be out the original purchase price of the bonds.

On the other hand, if the tax system were one largely of direct taxes and the bonds widely held, the burden would be thrown upon the well-to-do groups while the redistribution of the receipts from taxes as interest and principal of the bonds would increase the income of the mass of the people at the expense of the richer taxpayers. It would amount to this: that whatever money people of modest circumstances advanced during the war would be repaid to them with interest by their wealthier fellow citizens and the general tendency would be to reduce the inequality of the economic classes in the nation.

A very different situation would result if the bonds were held by the relatively few people of large fortune and the taxes were collected by tariffs and excises on staples. The mass of people of lesser fortune would pay the bulk of the taxes and the money would flow to the stronger economic groups as interest and principal, with the consequent increase in the inequality of possessions.

To suggest another possibility, the bond system might be combined with post-war taxation in a way that would keep down the burden of taxation for the mass of the citizens during the war by making it possible to forego general consumption taxes on staple goods. Taxes on incomes, inheritances and excess profits might be supplemented by bond issues during the war and later the war taxes be continued in peace-time until the bonds were paid off. By such a plan bond issues would aid in placing the money cost of the war upon the shoulders of the recipients of the larger incomes regardless of who bought the bonds originally. If this group bought them they would have advanced the money during the war and paid themselves off after the conflict. If the people of modest means purchased the bonds from the government they would have advanced the money during the war and would be reimbursed out of the receipts of taxes paid by the stronger group.

Without exhausting the possible combinations of bonds and taxes doubtless it is plain from these perhaps over-sharply contrasted comparisons that the effect of bond issues is largely determined by the type of taxation finally resorted to in order to pay off the obligations. The issue of bonds postpones the resort to taxation, an advantage in some cases, but its chief ultimate result lies in the possibility of redistributing the money cost of the war among the economic classes of the nation, not in passing it to future generations.

Looking at the matter from the limit of unpatriotic meanness, it may be said that to the degree to which one may hope to escape paying the taxes that will have to be laid after the war to cover principal and interest of the bonds, to that degree he may logically favor bond issues that will enable him to escape taxation during the war. As long as there is the chance that the post-war taxing system will bear less heavily upon some citizens than upon others, as long as there is the expectation that individuals not now able to pay much in taxes will later grow into the heavy tax-paying group; as long as individuals through losses may need to turn bonds into money for current expenses and through reverses decline in tax-paying power, so long will it seem more advantageous to individuals to give their money during the war for bonds rather than tax receipts. The key to the situation is not that this generation is not able to pay the money required to carry on the war (it must do that), but that the purchase of bonds may permit the burden of finally paying the tax to be shifted to other individuals or to the heirs of others. An illustration may be found in the possible effect of immigration after the war upon the number and composition of the tax-paying body of the United States. If peace brings a flood of people from Europe they will divide the burden of taxation with the taxpayers now here and their descendants. In such case bond issues now would be effective in lessening the cost of the war to the latter group and their heirs, and in that degree be more advantageous than taxes during the war. On the other hand, if peace should send a wave of emigrants from our shores to Europe the loss of these potential tax-payers and the probable industrial dislocation following the war would make tax-paying then to meet interest and principal of the bonds more difficult and borrowing would be the more burdensome policy in the long run. To strike a balance between these possibilities would require the peculiar foresight so glibly revealed by passing social soothsayers.

Bonds are an investment to all those who do not later have to pay taxes or a proportionate share of taxes to meet the interest and principal. To all others they are the means through which patriots may contribute to the support of the war and later wipe the slate clean by putting money into the government's vaults in paying taxes and drawing it out again by cashing coupons and eventually receiving the face of the bonds.

Lest there be misunderstanding it ought to be said that failure to buy bonds does not enable one to escape the burden of later taxation, whereas the thrift practised in saving to buy bonds will enable one later to carry the burden of taxation with greater ease.

If the bulk of the bonds are bought by that portion of the people whose incomes are above two thousand dollars and if the bulk of the taxes are paid by such persons in the form of income, inheritance, excess profits and corporation taxes, the burden of the war debt will be wiped out in the process of paying themselves with taxes that come from their own pockets. The real sacrifice in such case is made in buying the bond, not in paying it off. If the country can stand the burden in war-time, it need not worry about the load of debt in years of peace. The claims of the citizens against the government can be offset by the government's claims for taxes against the citizens and the obligations will cancel each other. The nation need not break down under the economic strain. Excluding the cost of collection, every dollar that is taken from the citizens after the war to pay the debt will be returned to the citizens. There will be no drain upon the country's resources of a wasting sort such as is experienced during the war. When the war is over its cost in money to the country as a whole will have been paid. Clearing off the debt involves a redistribution of a portion of the community's wealth among the bondholders and taxpayers, not a reduction of the country's assets.

Political sagacity and balanced economic judgment in distributing the burden of taxation will be the prime essential in the debt-paying period. The system of taxes then especially should be constructed with keen attention to those sound principles of finance that will least interfere with the fruitful development of the nation's economic strength and most nearly meet the demands of equity and justice.

Looking at the question from another point of view, a comparison of the interests of the soldier and the civilian makes the choice between the policies of borrowing or taxation a matter of importance. The soldier has left his business and prospects of economic advancement to defend his country. The civilian at home enjoying in many cases increased opportunities ought to bear the money cost of the war. It is the least that he can do.

While it is true as indicated above that ultimately the difference between bonds and taxes is not as great as is commonly supposed, nevertheless the bond method carries the possibility of disadvantage to the soldier. When he leaves the ranks of fighting men he may find himself conscripted into the army of taxpayers who will be obliged to pay off these bonds at a later date. Every claim of fairness, decency and patriotism demands that the civilians shoulder the financial load now by taxing themselves to cover the largest practicable portion of the war expense, willingly yielding their money as others are offering what is of infinitely greater value. No one should think of admitting to himself that he would prefer a bond to a tax receipt if the bond meant that in later years some one-armed hero would have to pay more for his taxed tobacco in order to pay interest on the bond. Cutting the coupons from such a bond would blister the owner's fingers.

Admitting, as has been done, that bonds are an indispensable adjunct to war finance under existing conditions, nevertheless the soldier has the right to call upon the civilian to pay taxes to the utmost while the war is on so that broken men will not come back to share in paying the money cost of that for which they have already paid in pain and sacrifice while they reflect with bitterness upon the ingratitude of civilian slackers.

In their effect upon the saving that turns men and materials from individual to national service bonds and taxes will differ with individuals. Persons who could not well be reached by taxes will find the appeal of the bondseller convincing, while others need the compulsion of taxation to make them change their habits of consumption and release for the public good what they have usually consumed in private enjoyment. The feeling that the bond is an investment leaves many owners with the idea that they have provided for their future and may therefore spend freely in the present. They forget that bonds are but the evidence of postponed taxation. On the other hand, the taxpayer is subject to no illusion. He knows what has happened and, finding himself deprived of his money, is in a mood to restore his depleted assets by saving. He is more open to the appeal for patriotic thrift than is the complacent bondbuyer who has parted with anything like the same amount of money. It is altogether probable that the pressure of taxation is more likely to bring home to the thick-skinned the need for private economy than is the opportunity for the purchase of bonds.

The relative effect of the two methods of finance upon the level of prices is closely connected with their effect upon saving. If bond buyers paid for their securities by cutting down their expenditures and investments, and taxpayers met their tax bills in the same way, the purchasing power of both would be transferred to the government and, so far as demand is concerned, there would be no inflation of prices from either source. Demand that was formerly private would now become public, but its total would not be increased. Its direction would be changed and prices of commodities needed in relation to national defence would be raised while other goods would fall off in sales. Such changes are not to be called inflation. They are part of the process of turning the forces of production from non-war to war industries and are necessary as long as the government does not resort to a policy of industrial conscription and the civilians hang back in the readjustment of their lives, while they cheer on the boys who are offering theirs to the country; the civilians who keep the home fires burning under the flesh-pots of their old desires.

While it is conceivable that neither bond issues nor taxation necessarily leads to inflation, it is probable that in practise bonds lend themselves more readily to produce such a condition than do taxes.

What is inflation? Ordinarily an increase in purchasing power comes from an increase in the production of different types of goods. These can be sold and the money received used to buy other goods. That is to say the increased demand for goods arises simultaneously with an increased supply, the two offset each other and the price-level is kept about as before. When a good harvest enables the farmers to send agricultural products to the cities as demand for factory-made goods and the enlarged supply of factory products makes an increased demand for the farmers' output, brisk business may be transacted with no particular change in the price level and with an increase in general well being. The food sent in by farmers as "demand" for implements helps to create the supply of implements, while the implements sent out to the country as "demand" for food aid in the production of the supply of food. On the other hand, the essence of inflation is the creation of purchasing power or "demand" without the creation at the same time of goods or "supply." Enlarged "demand" arising outside the current productive processes is not balanced by greater "supply" and the pressure of an increased buying power upon the ordinary stock of goods drives the general price-level upward to an inflated stage.

The agency through which purchasing power may be thus abnormally swollen is credit, either in the form of paper money issued by a government or loans by commercial banks on securities based on something else than saleable commodities already in the channels of trade.

When a government issues its paper money it goes into the market and uses its notes to buy in competition with and in addition to the buying power of its citizens without increasing the amount of goods to be sold. Thereupon prices move upward. The issue of paper money is an indication of weakness and is in fact a stride toward suspension of specie payment. The metal standard money is supplanted by the new paper. From then on prices are expressed in the paper standard. The value of this money changes with the prospect of its redemption in coin so that the new high level of prices moves up when the prospect of redemption is lessened and down as the outlook improves, as has been pointed out earlier.

In the second case when the inflation comes as a result of extensions of bank credit it may be brought about by the issue of bank notes or by the granting of deposit accounts against which checks may be drawn. The current level of prices in normal times is adjusted to conditions in which bank loans are made freely on credit paper arising out of commercial transactions that have but a short time to run. Increasing the volume of loans of this character does not inflate prices because the increase in purchasing power made available merely meets need for it due to the greater supply of saleable goods. When, however, commercial banks, that can safely lend their credit only to facilitate commerce in the form of short-time loans, begin to lend on securities that do not arise out of current buying and selling such as government bonds or other types of investment such as constantly renewed notes of governments or investors, the danger of inflation is at hand. The purchasing power that is thus created abnormally increases the power to demand goods with no accompanying increase in the supply of saleable commodities and the price level rises. The process amounts to coin-ing capital into money. It acts as would a huge addition of gold to the existing stock of money if it could be made without an expenditure other than the stroke of a pen. It lowers the value of the standard and hence raises the price level.

These extensions of credit do not cause higher prices; rather they permit the powerful war demand to express itself in more compelling terms in attempting to call for quicker and greater production of essential articles. More dollars are offered as a premium for speed and volume of output. The value of dollars thus falls in relation to goods and the new relation is expressed by the inflation to a higher level of prices that spreads over the whole field of buying and selling with all the painful adjustments that are involved. The evil is an unnecessary one and adds to the cost of the war by raising still more the prices that the government must pay for supplies; prices that are high enough for unavoidable reasons of increased cost of production without adding inflated credit to the list, and these higher prices mean heavier issues of bonds or more taxes. Eventually the taxpayers have to foot the bills when the bonds are redeemed after the inflation has subsided in time of peace, and the prices of labor and commodities are lower. It has been authoritatively estimated that the inflation of prices due to the greenbacks of the Civil War made the war cost the taxpayers $600,000,000 more than it would have cost had the country kept itself on a specie basis. The inflation due to bank credit is similar in its consequence.

Because bonds lend themselves to this type of extension of credit, their existence in large amounts tends to inflate prices. They have even been used directly in the purchase of commodities when business houses in a mistaken spirit of patriotism have offered to accept them in exchange for goods.

While as stated before it is to be conceded that bond issues do not necessarily lead to inflation and a higher level of prices, it is so easy to tread this primrose path to torment that the prospect is sufficient to make a restraint upon unnecessary bond issues of real importance.

Another problem of some complexity is emerging with each additional issue of bonds and is certain to become more serious if borrowing is given too large a place in our war finance. The threatening trouble arises from the fact that the rate of interest offered on bonds is below the market value of loanable funds to many investors, on the one hand, while, on the other, it is not possible to increase the rate without creating a form of investment that would lead to serious and disturbing competition with savings-banks deposits and investment securities, to say nothing about the great increase in the eventual burden upon taxpayers. There are indeed many persons to whom the bonds at the present rate are attractive as investments and many others whose patriotism can be counted upon to make the financial sacrifice involved in buying the government securities whatever the rate of interest. If the rate of interest is to be kept down the bond issues should be held within the limits of the purchasing power of these classes and taxes be relied upon to make this possible. Taxes laid upon business would tend to lessen the excess gains of industry and hence act somewhat as a restraint upon the rate offered for loanable funds for industrial and commercial purposes. If there were less opportunity for huge war profits borrowers for business extensions would not offer such high rates of interest on capital, with the consequence that the government and business generally would not be compelled to borrow upon such unusual terms in competition with abnormally stimulated types of industry and trade. Increasing the proportion of war revenue from taxes and lessening the amount raised by bond issues will thus make it easier to sell bonds at a moderate rate of interest and enable us to avoid an injurious disturbance of values in the field of savings and investment that would add to the burdens of the war.

The outstanding conclusion in this consideration of some of the principles of war finance is that the costs of war in men, material and money are present costs that cannot be saddled on the future.

Pay-as-you-go taxation is the logical way to carry the present money cost, but it is impracticable as the sole method because it does not yield fast enough and has never been sufficiently developed to reach fully individual capacity to pay. It must be combined with bond sales to get at once the desired results. The latter yield large sums because of their appeal to patriotism and personal profit. The latter idea of an investment with a net return is true for the individual when the bondholder is not obliged to pay proportionate taxes later for the redemption of the bond. In case he must do so the bond is not in reality superior to a tax receipt gotten at once, though it does rank with any other investment whose returns are destined to pay taxes, and all investments now being made are likely subjects for future taxation. However, the future is so uncertain and the general run of citizens so little given to looking forward that most people regard the bond as an investment. As a result the psychological strain of raising huge sums is greatly reduced.

The bond method in addition allows more latitude in the adjustment of taxation in and after the war than would be possible in case all expenses were paid by taxation during the conflict. This possibility of redistributing the financial cost of the war among different persons by the particular system of taxes adopted makes it important to give attention to the types of taxation chosen both during hostilities and when peace comes, in order to make the whole scheme meet the demands of equity and justice.

The presumption in favor of vigorous taxation in war-time is strengthened by the patriotic willingness to pay taxes while the struggle is on, by the increased ability to pay of many with enlarged incomes, by the temporary character of some of these larger incomes that makes it desirable that they be reached at once, by the fact that returning soldiers should not be compelled to face heavy taxation to pay interest and principal of bonds owned by civilians, by the probability that in many cases taxation is more effective than bonds in leading people to save, and finally that bonds are likely to be the basis of inflated credit which will raise prices, while their excessive issue with the necessary higher rate of interest will introduce a disturbing factor in the field of savings and investment.

The sum of these considerations of war finance is this: the largest practicable portion of war expenses should be carried by taxation while the war is being fought, and the issue of bonds be kept within the limits set by necessity.

THE ETHICAL VALUE OF SCIENCE

By Professor E. P. LEWIS
UNIVERSITY OF CALIFORNIA

THE object of scientific study is to learn all that we can concerning ourselves and the universe in which we live, with the aid of the senses and reasoning faculties which were presumably given us to use. Such studies can only enhance our devout admiration and respect for the works of the Creator, yet from the earliest times we find that the devotees of religion and of philosophy, whether pagan or Christian, have looked askance upon the scientist and have challenged his conclusions. Plato in his "Republic" voices contempt for scientific studies in the remark: "If any one undertakes to learn anything of sensible objects, whether he gape upwards or bellow downwards, never at all shall I say that he learns, for I aver that he has no real knowledge of these things, nor shall I say that his soul looks upwards, but downwards, even though he learn lying on his back, either at land or at sea." Throughout the Christian era theological dogma has fought a losing fight against the development of science. To-day the force of this attack is almost spent, but there lingers still in many orthodox minds the hazy belief that the scientist is a materialist who ignores all spiritual values, who is oblivious to beauty in nature, poetry, and art, and whose labors are devoted to devising means for securing material wealth and selfish gratification. Those whose training has been confined to the humanities seem inclined to the view that there was once a golden age when all men were just and generous, enlightened and happy, when religion was pure and undefiled, and that science has destroyed this happy state. Man has eaten of the fruit of the tree of knowledge,

> The fruit of that forbidden tree whose mortal taste
> Brought death into the world and all our woe.

A recent writer in *The Atlantic Monthly* holds science largely responsible for the extirpation of culture, and claims that it has challenged the supereminence of religion, has turned philosophy out of doors, has thrown contempt on all learning not dependent on it, and has purchased support by the bribe of material comforts. Some have attributed the great war to the suppression of spiritual values by the influence of science, and its horrors to malignant investigators who spend their lives in devising agencies of death and destruction. Usually this is suggested by innuendo rather than by specific allegations. As an example, consider the following statement of Stephen Coleridge in the *Saturday Review* for April 7, 1917: "Science never elevated conduct nor aggravated virtue; it never bade any one sacrifice his life for another nor to lead a forlorn hope; it never illumined charity nor condemned cruelty; its one positive perfected concrete human production in the modern world is the German." To the unthinking this rhetorical sophistry produces the effect of a convincing condemnation, whereas all that it really charges is that science has not done certain good things, without specifying any particular evils that it has wrought—except the German by-product. We must remember, however, that the Prussian is not a modern product—that morally he is to-day, in all international relations at least, what he was in the time of Frederick the Great, when there was little science in Prussia. Science has not made him what he is, but it is he who has perverted it to base uses. And what shall we say of the theologians, the clergymen, and the philosophers who have made the Hohenzollern ethics their own? Shall we therefore condemn all philosophy and religion?

Coleridge's statement would be quite as true if we should substitute for the word science the word art or food, neither of which is regarded as antagonistic to the better impulses of human nature. The statement would be quite as true—but how different the implications—if it were worded thus: "Science never degraded conduct nor diminished virtue; it never forbade any one to sacrifice his life for another nor to lead a forlorn hope; it never rebuked intelligent charity nor fostered cruelty." Further, it may be said with truth that science has never burned martyrs at the stake; it has never forbidden the use of the reason given by God to man, nor attempted to throttle human liberty; it has never bribed its disciples with power and wealth; it has never maintained that the end justifies the means nor claimed divine sanction for its evil deeds; it has done none of those things which have made religious dogma so feared and mistrusted that some highly civilized nations do not permit religious instruction in their public schools. We may see all around us the evidence that every implication of Coleridge's statement is untrue; that science does elevate conduct; that it does cultivate the spirit which causes men to lead forlorn hopes and to sacrifice their lives for others; that its whole influence is to foster the clean, the wholesome, and the good in our social life; that it leads inevitably to the condemnation of cruelty and injustice; and the scientific study of history, with overwhelming evidence gathered from the experimental laboratory of human experience, gives the lie to the doctrine that any individual or state can with impunity violate the ethical laws upon which the safety and happiness of mankind depend. This doctrine has often been defended and put into practice by philosophers, theologians, statesmen and those who claim to rule by divine right. It would be impossible to find many scientists of repute throughout human history who inculcated or defended unethical conduct—with one recent exception, when a group of scientists surrendered their reason to a false philosophy of state and appended their names to a famous manifesto likewise signed by theologians, philosophers and lawyers. Many scientists, such as Galileo, have led forlorn hopes in defence of truth. In our own day and own country there have been men who have laid down their lives in the effort to discover through science the way to save their fellow men from suffering and disease; and science is seeking to salvage what it can of life, property and civilization from the holocaust which it had no hand in kindling.

I do not wish to cast opprobrium upon true religion, the religion of the Sermon on the Mount, which certainly gives no sanction to persecution or to the doctrine that might makes right. We must make every allowance for the spirit of the times, for ignorant religious zeal, for blind devotion to authority; but the fact remains that in all the celebrated cases, such as that of Galileo *vs.* Urban VIII., or those of Huxley *vs.* Gladstone and Huxley *vs.* Bishop Wilberforce, the balance not only of intellectual honesty, but of the Christian spirit of fairness, was overwhelmingly on the side of the scientists. I believe, moreover, that sober scientific judgment will ultimately convince mankind that the religion of the Sermon on the Mount, not that of the Hebrew God or of the Prussian God, is the necessary basis of an enduring civilization. This conviction certainly will never come from wrangling over creeds, rituals or articles of faith, nor by keeping such matters as Sunday observance and divorce in the ethical foreground.

It has sometimes been suggested—in fact, that was what Coleridge evidently intended to imply in the words quoted—that science is responsible in large measure for the great war and all its horrors. The claim that it contributed in any way to bring about the war is too fantastic to consider, for science has nothing to do with conquest, with commercial exploitation or with upholding the divine rights of dynasties. So far as the horrors of war are concerned, it is quite true that many of the results of scientific investigation have been applied to the work of destruction, but they have been so applied, not by scientists themselves, but by those whose position and power rest upon the traditions and the superstitions which science has always challenged. We must remember, moreover, that the same principles have been used to combat the perverted uses which have been made of them. Nothing can be more unfair than to attribute to science the unworthy uses of it that have been made for selfish purposes.

It seems sufficiently evident that science is not antagonistic to righteousness, and there is abundant reason to believe that it has a positive ethical value—that it is, indeed, the greatest ethical force of our time. The end of scientific investigation is to discover the truth about all things, so far as man is able to grasp it—the truth concerning not only the material things and phenomena of the universe, but also the truth concerning man's instincts and impulses and all the relations of human society, and the truth concerning the consequences to mankind of the conduct of men and of states. Religion may and should inculcate righteous zeal, but this impulse alone, no matter how intense and sincere it may be, does not necessarily enable us to distinguish between right and wrong, and may even make us all the more zealous in wrong-doing. To make an ethical decision we must see all the relations of the subject to ourselves and our fellow men, and see them disinterestedly, without prejudice and without regard to authority and tradition. This is a mental attitude which is essentially scientific, and which is consistently developed by scientific studies alone. As an illustration, let me mention my own early experience. In the southern states slavery was regarded as having divine sanction. Any teacher or preacher who taught otherwise was ostracized or banished. For years after the civil war this tradition survived, and I was taught and believed that the abolitionists had thwarted the purposes of God. While still a boy various scientific books fell into my hands. Not one of them mentioned slavery or considered any ethical questions, but they quickly brought about a change in my mental attitude which caused me to see that slavery was wholly bad—a wrong to the enslaved and evil in all its effects upon the slave holders—not bad from any *a priori* consideration, but because human experience had proved it to be so. Blindly its defenders had taken their stand on the ground of moral principle, when a searching self-analysis would surely have convinced them that the only consideration which determined their attitude was that of material self-interest; and a very short-sighted self-interest, overlooking the ultimate decadence of their civilization. John C. Calhoun, who received his early teaching from a Presbyterian minister, and who later received a classical and legal education, wrote: "We regard slavery as the most stable basis for free institutions in the world," and Judge Harper's legal training led him to the conclusion that "Nothing is more evident than that the institution of slavery is the cause of civilization." It would be impossible to imagine a man of scientific training making such palpably absurd statements as these. The fact is that no civilization tolerating slavery has ever endured; and that, in the words of John Stuart Mill, "slavery is incompatible with any high state of the arts of life and with any great efficiency of labor." Science did not flourish in the south—it is impossible to imagine that science and slavery could continue to coexist in the same community—but orthodox religions and classical scholarship have found nothing uncongenial in such association. It is well for us to ponder over such historical facts. There probably exist to-day among us evils as great as that of slavery. Our religious scruples are too easily overcome by self-interest; but science may open our eyes to the dangers that confront us.

Notwithstanding the lamentations of many that this is a degenerate age, when faced with the facts every one must admit that during the past thirty years there has been an immense improvement in the ethical standards of society. The political spellbinder has lost his grip; politics has in some measure been purified; official corruption has diminished; the standards of efficiency of our public officials have been raised; for the first time in our history the application of ethical principles to business affairs has made a little headway; we are beginning to question the perfection of our legal procedure; a new sense of civic responsibility and of our duty to our fellow men has been created, and we are acquiring new and higher ideals of patriotism and of international relations. This can hardly be the result of religious training, for this is generally acknowledged to have lost much of its efficacy; and furthermore, on the whole the influence of religious organizations has been conservative in all social and economic matters. They seem to consider that the antiquity of an institution or belief endows it with a vested ethical right to continued existence. It is probably more than a mere coincidence that the awakening from our moral stagnation began with the sudden increase of opportunities for education in high schools and colleges and the general introduction of scientific studies into these institutions. None of the formal sciences undertakes the consideration of ethical questions, but the common aim of all the sciences is to discover the truth, regardless of tradition, authority, prejudice or personal interest. The habit of mind thus acquired can hardly fail to influence conduct in all social relations. I believe that Huxley's words are profoundly true: "It is becoming less and less possible for the man who puts his faith in scientific methods of ascertaining truth, and is accustomed to have that faith justified by daily experience, to be consciously false to his principles in any matter." To illustrate, scientists are rarely political partisans. Probably none could be found who would approve the giving of public office as a reward for political service, and this not because of any special virtue, but because their mental habits cause them to see clearly the evils of such a system. It is the rule rather than the exception that politicians of the highest Christian professions, or with predominantly classical and legal training, defend or tolerate this practise. No doubt prescribed courses in science would do much to purify the political atmosphere.

It would surely promote the administration of justice to give every lawyer a sound scientific training. Can any one doubt that scientific methods of obtaining evidence would be more effective than those followed by the courts? Would it not be better for society if the prosecuting attorney and the attorney for the defence should have the common aim of ascertaining the exact facts in each case, with a view to obtaining a just application of the law, rather than to have the former determined to convict, and admitting only those facts which will help to convict, while the latter is even more determined to make use of every possible technicality or perversion of the facts in order that his client may escape merited punishment? How strange and wholly unscientific the logic by which the opposing lawyers can from identical premises deduce precisely opposite conclusions!

Economics is called a science, but it would seem that it might employ scientific methods more extensively with profit. There is probably some ground for the suspicion that this generation is fettered with economic dogmas as past generations were fettered with religious dogmas. It seems to me that the accepted laws of economics are fundamentally unscientific in so far as they give only partial recognition to the feelings which determine human conduct and to the influence of the conduct of individuals or of classes upon the general welfare of society. Political economy does not sufficiently take into account the qualities which differentiate men from the lower animals, and which should be recognized in any scientific study of the economic relations of men to each other—or rather, it makes a differentiation wholly in favor of the lower animals by assuming that man is dominated solely by a selfishness rarely found among brutes and a greed for material possessions which they wholly lack. As a result men of naturally good impulses are sometimes swayed from their better impulses under the compulsion of what they are told are inexorable laws of nature. To justify this impression, let me quote an early definition by John Stuart Mill:

> Political economy is concerned with man only as a being who desires to possess wealth. . . . It makes abstraction of every other human passion or motive. . . . It considers mankind as occupied solely in acquiring and consuming wealth.

Walker summarizes the attitude of the English school of economists in these words:

> The end of wealth man never fails to desire with a steady, uniform, constant passion. Of every other human passion or motive political economy makes entire abstraction. Love of country, love of honor, love of friends, love of learning, love of art, pity, shame, religion, charity, will never, so far as political economy cares to take into account, withstand the efforts of the economic man to amass wealth.

It would seem that the economic man is not a very desirable citizen. Mill later in his life rose to a higher level in his "Principles of Political Economy," which is a social philosophy giving some weight to the considerations which affect the highest welfare of society. There is probably a wide diversity of opinion among economists of the present day, but I am under the impression that teachers and leaders in business and law-making usually adhere to the principles set forth in Walker's summary. If these are indeed the principles which have governed the economic life of civilized countries, we need not wonder at the industrial and economic ills which seem to grow more acute as the years go by and the crowding of population makes the individual more and more dependent upon his fellows for opportunities of existence, development and happiness. Perhaps a more comprehensive scientific view—one which this war has already done much to advance—may some day give us a political economy which has for its end the welfare of society at large rather than that of the limited class of individuals who control the means of production and can at will increase their wealth at the expense of the majority of mankind. This new political economy may convince us that the principle of *laissez faire* leads to anarchy, that the law of supply and demand may be controlled to man's uses as we control the law of gravitation, and that only those are worthy of liberty who are ready to make a free-will offering of it on the altar of social welfare.

In less enlightened times science was attacked because it contradicted what was regarded as divine revelation. The most orthodox will now admit that science was right in regard to these questions, but many still maintain that it is antagonistic to spirituality and beauty. If this is true, it must be because spirituality and beauty are attributes of supernaturalism, not of naturalism—because nature is ugly and sordid, so that only violations of natural law can make a legitimate appeal to man's nobler feelings. It is true that scientists study material things, but they are a part of the universe. Does God repent having made this universe? If so, why does he not destroy it as an unclean thing? If mind and soul are not degraded by their residence in the material body, why should it be considered degrading to study that body? Of late much scandal among the godly has been created by the speculations of some scientists as to the possibility that mental processes are direct consequences of physical and chemical changes. This is still an open question, but it is difficult to see why it has any more religious bearing than the Copernican theory, to which the churches have become reconciled. Behind these physical and chemical changes there is a first cause—call it God if you will—which no human mind can fathom or explain. It seems rather rash to assume that the powers of this God are so limited that he could not make a self-directing universe in which thoughts and emotions are determined by the interplay of atoms, as our bodily movements are directed by muscular contractions. Surely such a creator would deserve more admiration than would one who had bunglingly constructed a universe to which he must constantly lend a hand to keep it going. Although the scientist studies material things, there is perhaps no other class of men so unworldly, so little diverted from their life work by the temptations of wealth or power, idle pleasures or bodily comfort. No man is more impatient than he with narrow views concerning practicality or with the notion that the chief end of science is the invention of machines or industrial processes for man's material comfort and aggrandizement.

The boundaries of science will always be enlarged by specialists who will in many cases be so engrossed in their work that they may be justly criticized for narrowness—but we often find specialists in art, literature and religion who are likewise deficient in Greek symmetry. Nevertheless, the scientists will always receive more censure, because his narrowness is not so like the narrowness of the average man as that of the workers in other fields, who are concerned with things more specifically human. But the good to humanity at large, which is our chief concern, comes not from the training of the specialist, but from the residual effects of various subjects upon the minds and conduct of those who study them. Certainly we must grant that the humane studies, which touch most closely upon man's intercourse with his fellows and with his esthetic enjoyments, are the indispensable basis of a sound education, but much of man's capacity for using his reason in the problems affecting his own life, including ethical problems, will surely be lost without some acquaintance, not so much with the facts of science, as with the method by which science attains demonstrated truth. Many of the opinions and institutions which society has inherited must be taken with a grain of salt. Science is the saving salt; but it does not follow, because a little salt is a good thing, that a diet exclusively of salt will be better.

In this discussion it has been necessary to refer to some of the limitations of formal religion, which claims the custodianship of ethics, and of the humane studies which make spirituality and beauty their aim, for the purpose of showing that science may be of help to both in realizing their ideals of the true, the beautiful, and the good. There has been no intention to decry genuine religion or to deny the fundamental importance of humane studies. The necessary basis of the most effective education must be the studies concerned with immediate human relations, the rules of conduct, the languages, the literatures, the arts, which spiritualize and beautify our lives and enable us to share them richly with others. But we can not exclude science with impunity, for if we do we shall surely lose much of the significance of the humane studies, and we shall fail to establish the highest criterions of conduct unless we see clearly the truths and understand the relationships which it directly or indirectly puts us into the attitude to perceive. The past has bequeathed to us a precious heritage of thought and of beauty, and among those long dead are many whose intellectual and spiritual authority will live for all time; but we have also inherited traditions which fetter our minds and souls, and institutions which weigh heavily upon us. Each generation must challenge the validity of the beliefs and institutions which the past would impose upon it, and they must justify their claims to continued existence. The humane studies make us familiar with the treasures of the past, but they also sometimes render us unduly subservient to authority and tradition. Science inculcates the questioning and discriminating spirit; it respects no tradition that does not justify itself to reason, and listens to no authority which can not demonstrate its validity. It cultivates the open mind which is ready to accept new truths and the discriminating mind which presents their too hasty acceptance. Most people who have had some scientific training will quickly forget the details of the sciences they have studied, but the effect of the scientific method upon their minds will rarely be completely effaced. This method is simple and direct, and makes no use of the dialectic subtleties with which lawyers, theologians and philosophers have so often deluded themselves and their disciples.

Many great humanists have recognized the important part played by science in the ethical development of civilization. In "The Hope of the Great Community" Royce writes:

> Some motives which tend to render the genuine Pauline charity, the genuine love of the unity of the great community to which all civilized men may, when enlightened, consciously belong—such motives, I say, have been furthered by the arts, the industries, the sciences and the social developments of the nineteenth and twentieth centuries as thousands of years of previous activity have never furthered them. . . . How far reaching the abundant phases of human life are tending to become under the influence of those humane arts and sciences which of late have so successfully combated disease and brought together nations and men who once could not in the least feel their brotherhood.

Matthew Arnold was not over-partial to science, and rendered great service in criticizing the over-zealous claims of some of its adherents, but he clearly saw its place in liberal culture. He wrote:

> Hard unintelligence must be supplied and reduced by culture, by a growth in the variety, freshness, and sweetness of our spiritual life; and this end can only be reached by studying things that lie outside ourselves, and by studying them disinterestedly. Let us unite ourselves with our better mind and with the world through science.

Religion and philosophy, literature and art, history and science, each in due proportion plays its part in the intellectual and moral development by which alone we can understand and express the best that is ourselves and in the world. Each helps to show the path of wisdom, righteousness and fruitful living to him who seeks it, but none of them can help him who lacks the desire or the will to do right. Granted this inclination, I believe that the habit of mind which is developed by scientific studies is at least as important an ethical agency as the others, and I am inclined to think that in the present stage of civilization it is the most important. The scientist has the same human failings as other people; he may have no better intentions nor be no more righteous-minded than they; but he can sometimes act more intelligently in carrying out his good intentions. Science teaches us to seek the truth without prejudice; it develops the habit of disinterestedness; it leads us to consider all known elements in making ethical judgments; it prompts us to seek the amelioration of the health, the well-being, the happiness, of our fellow men; it diverts our vision from the fruitless contemplation of a past in which we can play no part to the present wherein lies our task; and it bids us to consider the future and the welfare of generations still unborn. The humanist seeks to perpetuate the wisdom and beauty of the past, and in doing this he renders no mean service; but he is apt to depreciate the present and to despair of the future, to forget that it is the task of each new generation to winnow the chaff from the gathered harvest and to plant the seed for new harvests. With the mutual sympathy and united efforts of humanism and science, civilization, firmly rooted in the past, may grow unhampered to its full fruition.

When this war is over it will be in a large measure the mission of science to rebuild a shattered civilization. It will restore the industries of nations; it will house the homeless, feed the hungry and cure the sick. But it will be even more potent in healing the deep-seated ills of society which are the consequences of past social misconduct, whether innocent or malicious. Good intentions and religious training, unaided by understanding, will not carry us far. Whatever good may come from prayer, intelligent men prefer to have their ailments treated by a physician who seeks the causes and cures of disease in a scientific manner, or the firm-handed surgeon whose knowledge of anatomy enables him to remove cancerous growths without killing the patient. It will be the task of men of scientific training or of scientific spirit to heal the wounds which have been wrought by the duplicities of statesmanship, by the selfishness of privileged classes, and by false philosophies and religions, and to remove malignant economic growths by radical operations. It is, I believe, the highest mission of science to contribute its part to the training of such men. The objective by-products of science, such as the telephone and the automobile, seem to me to be of relatively little importance; but its subjective influence on man's intellect and conduct is of the highest consequence. In universal scientific training in this larger sense lies the hope of democracy.

Science has much to contribute to the happiness of the world in a material way, and it is right that it should be encouraged in this work. No doubt the lessons of the war will convince our government, our educational institutions, and our industrial organizations that too much can not be done to stimulate the material applications of science. But there is a real danger that too much stress may be laid on these material aspects of research, which are not science, but only its by-products. Competent investigators should not only be provided with facilities for their work, but they should be absolutely unhampered by any demand that their researches should be of immediate practical utility; and it is equally important for the interests of society that teachers of science should lay more emphasis upon its intellectual and ethical significance. Much of the ineffectiveness of scientific teaching in this country, its failure to inspire interest and to win respect, is undoubtedly due to laying too much stress on its practical, vocational, or narrowly scientific aspects, rather than on its humanistic side.

There is a materialism which in every age, especially during times of great prosperity, has insidiously weakened the mental and moral fiber of mankind—a materialism of wealth, of self-indulgence, of inordinate luxury. This materialism thrives on modern industrialism, but it has an economic rather than a scientific basis, although science is often held responsible for its defects, because scientific discoveries have had such a wide industrial application. The primary object of applied science is not to create wealth for individuals, but to lessen the hardships, cure the bodily ills, and increase the legitimate comfort and happiness of mankind at large. If this is materialism the good Samaritan was a materialist. An unscientific political economy has made it possible for individuals to prevent the general diffusion of these benefits, to acquire fortunes which have in no sense been really earned by bodily or mental effort, and to bring about a condition of industrial servitude which can only result in a social upheaval unless it is corrected. It would be well if religion, humanism and science, with a sympathetic mutual understanding, would join in a united and unceasing attack upon this materialism, which is their common enemy.

Wealth has its worthy uses, but selfish greed for riches and power blinds man's spiritual eyes and causes him to strive for sordid and ignoble ends. Some scientists, in common with other human beings, have limited vision; but at the worst this vision is not directed to ignoble things and their aims are not selfish. They do not deny the existence or depreciate the value of the human attributes and aspirations which defy analysis in their laboratories. The aim of the scientist is to see clearly that which is, even though he cannot explain it; and he sees that the wages of sin is death for the individual or the state; that in mankind there is an instinct for the good, a reverence for self-sacrifice and moral heroism, for mercy and magnanimity, which is rarely completely suppressed in the worst of men; that men will die for immaterial ideals, and that the mysterious thing called beauty exercises a potent and wholesome influence over mankind. How these things came about and whither they tend he can not tell, but he knows that they are as real as the laws of mechanics, and that he, like other men, is swayed by them.

Intent upon his daily task, the individual scientist is hardly conscious that he has a creed, and could with difficulty define the forces which drive him. But there is a strong impelling force behind his activity. It is not a conscious ethical force, but neither is it a desire for wealth, popularity or power, nor for any wider recognition than that accorded by his fellow workers. This force is surely something more than idle curiosity; there is in it an element of devotion and of self-sacrifice, an impelling desire to contribute to the ultimate good of humanity in more than a material sense. Were he driven to make his aspirations articulate, he might formulate them in words not very different from those of St. Augustine:

> Let us not leave thee alone to make in the secret of thy knowledge, as thou didst before the creation of the firmament, the division of light from darkness; let the children of thy spirit, placed in their firmament, make their light shine upon the earth, mark the division of night and day, and announce the revolution of the times. The old order is passed, the new arises; the night is spent, the day is come forth; and thou shalt crown the year with thy blessing, when thou shalt send forth laborers into thy harvest sown by other hands than theirs, when thou shalt send forth new laborers to new seed times, whereof the harvest shalt be not yet.

THE PRINCIPLES OF EDUCATION

By Dr. P. G. NUTTING

EDUCATION covers the span of life from the cradle to the grave. Impressions are received in bits and blocks in an endless stream. Some of these pass almost at once into oblivion, leaving the merest trace in our minds. Other impressions, stimulating more or less interest through partial or anticipated connection with something already in our minds, are seized upon, inspected and then, if found true and worthy, tagged and pigeon-holed with other associated impressions. An occasional new impression of unusual strength will dominate a whole group of old impressions.

The mind then makes abstracts (ideas) of groups of impressions to connect with abstracts of other groups. The best measure of mentality is probably this tendency to interconnect and abstract the essential ideas in a wide variety of other ideas and groups of impressions. And mentality in this sense is a measure of the degree of education in an individual.

The impressions of an infant are limited to those received from its immediate surroundings. During school days, the mind receives and assimilates ideas from farther afield not associated with desire or discomfort. Later on, in high school and college days, the mind likes and readily assimilates groups of abstract related ideas and even probes the infinite and unknowable. In middle life, the dominant interest lies in the practical problems of everyday life. The field of our activities is our school and the newspaper and magazine our text-books. The mind demands fresh facts and new ideas. In later life, after the details of most minor problems have become familiar, interest turns once more to general principles and larger problems, details are reduced to routine when possible.

In short, education is as long and as broad as our lives. National welfare requires that it be recognized and treated as such. What we now call education is a mere generalization of parental instruction covering the period of most active interest in the most abstract ideas. Real education in the interest of the nation should be such as to develop and bring into action all the latent possibilities in every individual. Whatever our useful activities at any period of our lives, we should be continually receiving and assimilating new ideas with both bodies and minds fresh and active, with a code of ethics firmly established and a philosophy of life equal to any emergency.

In our present system of education, the responsibility of the nation to the individual is recognized for that part of the individual's mental education which he ordinarily receives from text-books. No attempt is made to instruct him or even to supervise his instruction in later life. He obtains by experience and the experience of others gleaned from chance conversation, from newspapers, magazines and from books such information and ideas as may better fit him or unfit him for his work and his share in the government. The value of knowledge gained in this manner is not to be decried, but it might be made much less casual than it is; the nation might at least see to it that false information and false doctrines are not disseminated and that no inquiring mind goes unsatisfied.

The *physical education* of its citizens has been left almost entirely to chance by nearly all nations, although physical strength and fitness are very important factors in the work of every one. The play and work of their daily lives, together with a casual indulgence in sports on the part of a few, make up the physical training of the masses. Considering its great value to the nation, it would appear advisable to encourage athletic sports, to provide numerous leaders for the specific purpose of encouraging athletic contests and getting all, even the modest, into the fields, golf links and tennis courts. The great value of universal military drill in strengthening the physique of the young adult is beyond question.

For the *moral education* of its citizens, the nation assumes no responsibility whatever. The code of ethics of the average individual is partly instinctive, but largely the product of home influence supplemented by that of one's associates. Various churches and Sunday schools essay the great task of looking after the morals of the public, but reach comparatively few in any vital manner. It must be admitted that their appeal to the public is not very general, partly on account of the nature of the material taught and partly on account of the methods used. The thought of possible punishment or reward in a future life are neither necessary nor sufficient to direct the activities of the average individual.

As a matter of fact, the strongest force influencing behavior is the instinctive desire to attain the respect and esteem of our associates. We know that in an hour we may, by improper conduct, lose the respect which required months or even years to build up and are careful accordingly. By hard experience we obtain knowledge of the safe limits of conduct and by generalization build up codes of morals, ethics and etiquette to govern our actions on future occasions much as a professional man builds up a knowledge of the fundamental principles used in his profession.

The individual who does his best and lives up to his best is sure of the respect of his associates, and since that respect is a criterion for correct behavior it is necessary and sufficient that we strive to attain and retain that respect. Having pleasure and attaining happiness and contentment are by some considered proper and sufficient objectives in behavior, but such motives and criteria are neither necessary nor sufficient in all cases.

Correct education in morals, ethics and manners consists in the formation of codes which, if followed, will lead to the continued and increasing respect of one's fellows. The great school of such education must ever be the complex activities of daily life. The lessons drawn from such activities, the fundamental principles involved, are the vital part of such education. What those lessons and deductions shall be is determined largely by the nature of previous mental reactions to somewhat similar conditions, hence results are strongly cumulative, correct or incorrect deductions are rapidly built into the structure and are difficult to modify later.

As stated, our codes of behavior are chiefly the result of our reactions to conditions of daily life. These are supplemented by lessons drawn from history, from fiction and at the present time, to a considerable extent, from motion-picture drama. Fiction and drama are nominally at least under state and national supervision. It is conceivable to even conservative minds that the nation might well exercise such control as would safeguard the general welfare or might even take steps to promulgate proper ideas and ideals. Possibly teachers of morals and ethics could be provided to conduct schools of morality and ethics for immature minds. The greatest teacher of morals of all times taught largely by parables and this method is second to none. In essence, it is instruction by the study of practical moral problems.

Tendencies in education at the present time are decidedly toward the objectives outlined above. High-school and college curricula are being pruned and modified to eliminate the less desirable in favor of the more useful studies. Those past school age and those whose duties do not permit school attendance are being reached by university extension courses and by correspondence schools. Certain colleges and universities are in favor with certain prospective students on account of the superior opportunities offered in athletics, that is physical education as such is in demand. Technical schools are multiplying in numbers and improving in quality. Universal military training is being seriously considered. However, there has yet been no attempt at systematic general moral education nor any connected effort to instill the principles of industry or morality in our schools. Taking it for granted that such instruction is in the interest of the general welfare, fundamental principles should be worked out and taught by example and the study of practical problems.

The interrelations between mental, physical and moral education and general well being are well known, but rarely taken cognizance of and never made use of for definite ends. An active, healthy, well-trained body is no inconsiderable asset to the intellectual worker and an important factor in good morals. Athletic training and contests make for fair mindedness, patience and the faculty of concentrated effort. The height attained by Greek civilization is in no small measure attributed to the out-of-door life and fondness for athletic sports of the average Greek citizen. The value of sound morals and a sound philosophy of life on the general welfare of individuals and of a nation needs no argument. On the other hand, the value of the average college education to the average citizen is frankly questioned by many and not without reason. The defect in a poor academic education lies in its being a mere accumulation of knowledge; it fails to give that command of fundamental principles that comes only through research and the solution of numerous practical problems. Even the average college education, however, generally leads to a considerably enhanced ability and national tendency to "see straight and think straight," that is it tends to eliminate delusions of all kinds.

A good education results in increased *knowledge, training* and *activity;* along mental, physical and moral lines in its broadest aspect or in some limited field at its narrowest. Many of our great and useful citizens, by unstinted activity and through wide experience in practical problems, have made good in every sense of the word without any academic training. Mere breadth and depth of knowledge is of least avail, teachers and clerks generally are well supplied with it, but without first-hand knowledge of first principles and strong incentives to apply them, never make much progress. However, the gap between academic and industrial life, formerly so wide and deep, is now rapidly narrowing. In many industries college men are preferred as factory superintendents on account of their clearer vision and lack of bias, while on the other hand our universities and scientific societies are coming into closer and closer touch with industry. Many of our best teachers of professional subjects are men who have become experts by practical work. With education at its best, every field of instruction in every institution of higher learning should be dominated by an expert having a thorough command of fundamental principles gained by research or practical work or both.

The Education of the Expert.—The interests of the public and of the nation will be served if all important problems, public as well as private, are in the hands of experts for solution. In administration, legislation, the public health service, agriculture, all branches of engineering, commerce and education, practical problems are continually arising and upon the correct solution of these problems depends the welfare of many individuals and even of the nation itself. The engineer applies fundamental principles to practical problems and to insure progress by the elimination of rule-of-thumb methods requires good engineering practise all along the line. In some fields present practise closely approaches all that it might be, in others almost barbaric incompetence is the rule. Our supply of possible experts is ample, our methods of training them produce good results, although open to much criticism, but our methods of getting the right men into the right places are woefully inadequate and costly.

The older economics recognized two chief factors in industrial welfare, labor and capital. It is now coming to be recognized that there are not two, but three, of these important factors—capital, the trained expert and labor. Without the expert neither capital nor labor can exist to-day for very long in any of the greater industries. He is neither a capitalist nor a mere laborer, but a solver of problems to clear away obstructions and open up new fields of activity. Industries to-day must progress or perish and advances can be made only by the application of organized administrators, engineers, chemists or other professional men. It behooves us therefore to use every effort to improve the quality and increase the number of our trained experts.

Statistics show that genius knows no caste. Men of great achievements originate in all classes in about equal percentages —they can not be bred. If eugenics plays a part, its influence is greatly overshadowed by other factors. Getting the right start and then giving full play to one's bent are the vital factors in developing capacity for great achievement. The right kind of education helps all along the line, in the proper choice of life work, in the preparation for that work and in the development of special ability for advanced work. There are doubtless plenty of individuals capable of very much greater achievement had they but sufficient incentive to overcome their natural modesty, indolence or caution and the proper educational facilities for obtaining the knowledge required and technical skill in its use.

In early youth, before he begins to specialize, probably the best *mental* education for the future expert is not very different from that now generally received in this country, namely, an accumulation of abstract knowledge with training in the three R's. His *physical* education also is probably not subject to much improvement beyond a more universal indulgence in more out-of-door sports and games. But his moral, ethical and *psychical* education falls far short of what it might be. Between the ages of about ten and seventeen he reasons out what is worth striving for in life, forms his code of conduct, and sets up a scale of relative values in possible achievement. At this stage he is very sensitive to external influences, since such influences are strongly cumulative. And for the average youth such influences are of the most casual nature!

A tutor of Peter the Great is said to have formed and crystallized in his youth his purpose to raise Russia from semi-barbarism to civilization, and this he accomplished in the most energetic and single-minded manner in spite of his being deliberately surrounded with pleasures and temptations to wreck his career. It would appear advisable to tell to the young the stories of individuals of great achievement; of Peter of Russia, of Pasteur, of Joan of Arc, Columbus, Franklin and Lincoln, emphasizing the elements of their greatness; their mastering of first principles, their singleness and soundness of purpose, their readiness to attempt the difficult and well-nigh impossible, and their continual hammering away along their chosen lines of activity. In such lessons the moral, ethical and psychic are closely interwoven and the treatment should bring out all three. Nowhere in our schools do we have such teaching, but it is everywhere of vital importance to the general welfare in the education of the future expert. While we are discussing the teaching of the Bible in our public schools we overlook the opportunity of instruction in a field full of the greatest possibilities for national progress.

It is doubtful whether any selection or segregation of specially fit students is advisable before or during the high-school period. No psychologist can select at sixteen just the individuals who will at forty be the most useful citizens in various fields of activity. Some mature early and achieve great results early in life, while others mature slowly and go further. Too early selection and specialization are likely to cost more than they are worth. Up to and through the high-school course the aim should be to give a broad and thorough grounding in the more important branches of academic training, together with a sound physique and a correct, efficient code of behavior.

Following the high school probably the best results are obtained by two years' work at a small college, followed by two years of partly specialized work at a good university with finally two to five years' work in a high-grade graduate or professional school. In all this work the first aim should be to secure a thorough grounding in the fundamental principles of the subject covered. Any profession first attains high standing when the fundamental principles upon which it is based are worked out and formulated. Any professional man can attain high standing in his profession only through a thorough knowledge of the fundamental principles of his profession and the ability to apply those principles.

In the interest of national welfare, mental qualifications alone should be the deciding factor in selection for advanced training. The best of college, university and technical education should be available to students in the humblest circumstances, with free tuition and opportunity for earning living expenses. It is the general impression that students who earn their own way are better represented in proportion among those of great achievement than those supported by their parents. Certainly no one should be excluded or subjected to a heavy handicap because of poverty.

The best of our graduate and technical schools, professional schools, industrial research laboratories and the government departments at Washington offer very nearly ideal training for the future expert in many fields of activity. There is a judicious combination of instruction and practical work under the supervision of capable experts to give the combination of knowledge and technical skill in solving problems required by the specialist. Those contemplating research as a profession should possess a thorough knowledge of the fundamentals in their chosen field, together with demonstrated skill in research. These are attained by well-directed study and research work. The lesser teaching positions in our universities offer excellent facilities for training the future expert; the teaching organizes and hardens his command of fundamentals while graduate study and research advance his knowledge and skill in solving problems.

To provide more and better training for experts, we need (1) more high-grade technical and professional schools, (2) closer relations between the pure research of our universities and industrial research, (3) a broadening of the curricula of our graduate and technical schools to cover fields (such as city administration, illuminating engineering, glass technology, etc.) at present neglected and (4) a central national university of the highest grade to centralize and lead activity in the various fields of professional education and research. It is a hopeful sign that present tendencies are toward all these research ends.

Present methods of training the future expert are open to considerable criticism. The story is told of one of our leading experts in the geology and metallurgy of gold that when the ambition to become such first stirred him he went to Agassiz for instruction. Agassiz gave him a turtle and told him to study it. After several weeks of patient effort he took his results to Agassiz with the statement that he knew all that was to be found out about that turtle and was ready to start the study of gold. He was, however, sent back again and again to his turtle until he knew every detail of its markings, its habits, its appetite, its rate of growth and every movement. Finally, after months of work on the turtle, he was told to go and study gold. The critical period in his career of achievement was that during which he learned how to observe and study. Our higher education is not sufficiently intensive. It is too hurried and lacks definiteness of purpose. Fundamental principles are not emphasized by the teacher nor mastered by the student. Side issues are allowed to divert the attention and break the chain of concentrated effort to completely solve definite problems. These defects are due partly to a national trait of mind, but the proper influence from leaders would do much to correct it.

Although national welfare demands that education should be provided for all and the aim of every individual may properly be that of becoming an expert in some one line of activity, it is by no means to be expected that the yield of specialists will be 100 per cent. There will always be a percentage of partial defectives of all degrees of efficiency. These will always supply the unskilled and the less skilled labor for the rule-of-thumb trades. If universal military service were adopted, not all would be found physically capable of full training, but only cripples would be unfit for some sort of physical training and service. In any case equal opportunities should be provided for all and actual fitness should be the sole deciding factor in determining whether education of any given grade is to be provided for any individual.

Education in middle and later life is chiefly through two channels: increased technical skill through practical work, increased knowledge of fundamental principles through the technical journals. Education in its broader aspect, fitting the individual for his broader duties as a citizen, comes through similar channels, daily intercourse with one's fellows and through reading the newspapers and magazines. It is probably because the human mind has for ages been developed by this dual form of education that similar methods give best results during the student period.

The proper kinds of magazines, scientific journals and newspapers are powerful tools for educating the general public in their various fields of activity. Instead of the present laissez-faire policy of our government, ignoring the fact that such channels of information are powerful factors in general education, it would seem to be in line with general welfare to exercise some supervision over their conduct. Newspaper charlatanism, in which the interest of the individual or of a party has been placed above that of the nation, has worked untold mischief in this country. Inane editorials are the rule rather than the exception. It would doubtless be in the interest of national welfare if editorials were written only by those familiar with the basic principles of national welfare. The nation could well spare all papers run in the interest of individuals, of political machines or any organization that puts its own interests, even in times of peace, above those of the nation.

In the conduct of our scientific and technical journals there is much room for improvement. The best of these are models of their kind, others are run in the interest of the society whose organ they are, regardless of future value as works of reference. At least one journal prints articles in fields as diverse as archaeology, pure mathematics and physiological chemistry. No one reader is interested in perhaps more than a fifth of the matter printed, yet the whole is bound together. There is a great deal of overlapping in some fields while other fields are without any good reference journal. In practically all cases, the individual members of scientific societies are under heavy burdens of expense to maintain their journals. It would seem advisable to see that all fields of science and technology were properly cared for in the interest of general welfare, to the extent of regulation and subsidy if necessary.

MINERALS AND POWER

By Professor F. E. WILLIAMS
UNIVERSITY OF WISCONSIN

THE importance of minerals in warfare is attracting the consideration of nations as never before. In time of peace the value of a nation's mineral deposits is easily underestimated. The higher the stage of development, the more essential become its mineral supplies. We have used the terms stone age, copper age, bronze age, iron age and coal age to designate different periods in the evolution of progress. Now, not only are we using far more coal per capita than ever before, but also vastly greater quantities of the materials that characterized former periods, namely, iron, copper and stone.

The development of the United States in industries, other than agriculture, is illustrated in the increased use of its mineral resources. Agricultural exports have increased greatly, but not in proportion to the mineral exports and the manufactured articles which have resulted from their utilization. In the period since 1880, foodstuffs (though showing an actual increase) have fallen from 55 per cent. to 21 per cent. of the total exports, while the export of manufactures has increased from 24 per cent. to 58 per cent. Exports of mineral products and manufactures thereof have increased from less than 4 per cent. in 1880, to 42 per cent. of the total exports in 1913 (the latest year unaffected by war conditions), an increase in value of more than one and one half billion dollars.

It is even more surprising if we compare the output per capita of the more important minerals for the last one third of a century. While the population has but doubled, the production and consumption of coal per capita has increased from less than 1½ tons to nearly 6 tons—an increase of 357 per cent. The United States took first rank in the production of coal in 1899 when Great Britain was surpassed and this lead has been maintained ever since. The production of iron ore increased 337 per cent.; petroleum 391 per cent.; copper 1,200 per cent.; cement 2,087 per cent.; gold, 23 per cent.; silver, 22 per cent.; lead, 125 per cent., and zinc 638 per cent. At the same time, the increase in agricultural products has but little more than kept pace with the growth of population, with the exception of cotton and sugar, which show advances of 130 per cent. and 394 per cent., respectively. Especially has the south increased its mineral production. In 1882 the Southern States produced but 8 per cent. of the mineral output of the United States; in 1890, 14 per cent.; in 1900, 16 per cent.; in 1910, 19 per cent.; and in 1914, 22 per cent.

The future of the mineral industry is assured, because of the increasing diversity of products and the known reserves of many minerals. In 1880 the statistics of mineral production in the United States covered about fifty articles, while the accompanying table shows over 75 items of considerable importance, and the report of the United States Geological Survey (1915) mentions about 90 additional products. Before 1880 the base metals and nonmetals were of subordinate importance, but now the former have come to the front and the latter have exceeded the total value of all the metals. The accompanying table shows that gold and silver have increased but a comparatively small percentage. Part of the output of these two metals, especially the silver, is from the by-products of copper and lead mines. Sulphuric acid, another by-product, has been in the past an embarrassment to operators of smelters, but is now a commodity of great price. Much of the platinum produced in this country is won from the refining of gold bullion and copper matte.

During this period of marked growth in mineral production, there has been a change in the character of the deposits worked —a passing from the exploitation of bonanzas to the working of low-grade deposits. This has led to the establishment of larger and more permanent communities and hence to a safer foundation for progress.

The relation of mining to other industries is obvious, and, for the last few decades, especially in western and northwestern America, the miner has been the pioneer of civilization. Since there has been such an enormous production from lean ores it follows that estimates of our reserves are constantly being raised. This increase in estimated reserves has also been brought about by further exploration. A few years ago it was estimated that the visible reserves of copper ore for four districts in three states was about 160,000,000 tons. Now these four districts are known to have 600,000,000 tons of reserve in spite of the fact that 60 million tons have already been mined. In like manner there has been an added estimate of phosphate rock and coal reserves. The field work done by the United States Geological Survey has increased the estimates of reserves of phosphate rock from a few hundred million tons to more than five billion tons. The quantity of easily accessible anthracite and bituminous coal exceeds the estimated tonnage in 1909 by 440 billion tons, an increase of nearly 30 per cent., and the day of opportunity for both exploration and investigation of the mineral resources of this country is not by any means past.

The accompanying table shows the enormous growth of mineral production in the United States in the last thirty-seven years. Some of the statistics are a little misleading, as is always the case where values are given instead of amounts. Prices change from time to time and often enormously. Amounts for the earlier years are hard to obtain, and it was thought best to keep the values as a basis for comparison throughout. It can be seen that most of the outputs have increased much more rapidly relatively than the population. In some cases there has been a steady growth in the utilization of some particular product; in others there are sudden rises due to new discoveries or inventions or to abnormal conditions in trade or manufacture, for example, the exigencies brought about by the present war. The effect of the war is easily seen if we consider our exports since 1914. The exports of the articles considered in the accompanying table show an increase of about 300 per cent., or from $515,000,000 in 1914 to $2,043,000,000, in 1917. The value of the exports of coal and coke rose from $62,700,000 in 1914 to $89,400,000 in 1917; copper and copper manufactures from $149,400,000 to $323,900,000; iron and steel, including manufactures but excluding machinery, from $135,800,000 to $867,100,000; lead and lead manufactures, from $3,100,000 to $16,500,000; zinc and zinc manufactures, from $1,000,000 to $67,100,000; brass and brass manufactures, from $7,400,000 to $383,200,000; cartridges from $3,500,000 to $65,100,000, and petroleum, from $152,100,000 to $230,900,000.

With the anomalous conditions brought about by the war there has been a great development of many of the rare minerals. Many others, formerly of but little industrial value, have been used for substitutes for those which are practically indispensable. Whenever other factors do not interfere the industries of any nation are generally more stable when it contains within its borders the basic raw materials for the maintainance of its industries, but with the great diversity of modern manufactures many nations demand a variety of substances all of which are rarely available on one continent. The cheap water transportation between continents permits the competition of foreign and domestic resources. This is especially true if there is no tariff. The tendency has been, therefore, for the richest deposits to supply the markets of the world. This condition has been changed by the location of many resources with respect to warring countries and by the great scarcity of ships, hence, the development of the substitutes and rare minerals of the United States.

Titanium, which had declined in use because of the open-hearth method of making steel, having supplanted the Bessemer process, is again in demand as a substitute for manganese in some processes, and also for aluminum in deoxidizing steel.

Much manganese dioxide was used before the war in neutralizing the greenish color of untreated glass. Much of this had come from the Turkish empire, and the available ore from other sources furnished the material at too high a price. It was found that selenium, which had been but little more than a curiosity, could be substituted. As a result there were about 50,000 to 60,000 pounds of selenium used in 1917. Selenium is a by-product of copper refining, and made only in the United States. Its success in connection with glass seems to assure its permanent use in the future.

Uranium and vanadium have also been used much more extensively since the war began; the former in ferro-alloys in connection with tungsten to reduce the quantity of the tungsten and the latter in ferro-alloys which have great shock-resisting qualities, as for heavy frameworks for locomotives.

Molybdenum is in great demand, having doubled in the world's production in the last two years. It has many important uses where resiliency and shock-resisting steel is needed. One of the important uses at present is in the lining of cannon and gun barrels which greatly lengthens the usefulness of each.

Cadmium is a mineral whose output was hardly worthy of mention in 1913; in 1916 there were produced 135,212 pounds, valued at $205,433. Before the war the chief output came from Silesia and hence was shut off from world trade. Some has been recovered in various processes in which zinc compounds are involved. It is used as a pigment and at present is important in some secret war use.

Chromium gives hardness to an alloy and prevents rust, consequently there has been a great demand for chrome steel for war purposes. Hence a great increase in production of cromic iron ore has been brought about since 1914. Another important use of chromium is in the tanning of chrome leather. In 1913 the United States produced 255 long tons, valued at $2,854; in 1916, 47,035 long tons valued at $726,243; and in 1917 there was a slight increase over the latter figure. The principal sources of production were Rhodesia and New Caledonia, with lesser amounts from Russia and India.

Prior to the war, from 90 per cent. to 95 per cent. of the world's platinum came from Russia. The only other important source was Colombia. The normal world's production is about 250,000 troy ounces. In 1913 the United States produced 1,034 troy ounces of platinum (and allied metals), valued at $46,530; in 1916, 28,088 troy ounces, valued at $2,301.762. It is used in jewelry, chemistry, dentistry and electrical contact points. Paladium may be substituted for platinum in dentistry where great strength is not needed. At present there is a strong demand for platinum for use in the manufacture of sulphuric acid.

Because of the enhanced price quicksilver has increased in production very rapidly in the last few years. The chief producers are Spain, Italy, Austria-Hungary and the United States. In 1913 the United States produced 20,213 flasks (75 pounds net), valued at $813,171; in 1916, 29,932 flasks, valued at $2,576,547; in 1917, 36,351 flasks, valued at $3.857,000. It is used mainly in the manufacture of fulminate for explosive caps, of drugs, of paint, of electrical appliances, and scientific apparatus, and in the recovery of precious metals by amalgamation. The first use mentioned above caused the great demand and high price, with consequent increased production.

Ten years ago, tungsten was only of moderate use in the steel industry. Now the world's production is about 10,000 tons and the United States is the largest producer of tungsten ore in the world. Before the war, Germany controlled the output from ore supplies, largely from British possessions, but it is manifestly the intention of England to control most of the minerals of the Empire in the future. Tungsten is the most important of the metals used in high-speed steel. About 90 per cent. of the tungsten output is used in alloys, mostly in steel.

In the case of manganese ore which has become so necessary to modern industries and which for a period of years was supplied by many deposits in several countries, there has been a steady decline in the production from minor deposits relatively near markets and a corresponding increase in production from a few rich, even though remote, deposits. None of the industrially important nations produce more than a very small part of the manganese ore that they need; all of them have procured most of this in normal times from the three important sources in the world—Russia, India and Brazil. Manganese and manganiferous ores (the two chief sources of manganese) were produced in the United States in 1913 to the amount of 4,048 and

NON-METALS

	1880	1900	1913	1916	1917
Arsenious oxide	....	....	159,000	555,000	1,300,000
Asbestos	4,312	16,000	11,000	448,000	
Asphalt	4,400	416,000	5,282,000	7,102,000	
Barytes (crude)	80,000	188,000	156,000	1,011,000	
Borax (crude)	277,000	1,018,000	1,492,000	2,409,000	
Bromine	115,000	141,000	115,000	922,000	
Calcium chloride	....	....	130,000	217,000	
Cement	1,853,000	13,284,000	89,551,000	104,689,000	Slight increase
Clay	200,000 (potter's)				
Products	....	96,212,000	181,289,000	207,260,000	
Raw	....	1,840,000	4,180,000	5,752,000	
Coal					
Bituminous	53,444,000	220,930,000	565,235,000	665,116,000	Increase, 8.3 per cent.
Pennsylvania anthracite	42,197,000	85,758,000	195,181,000	202,010,000	Increase, about 20 per cent.
Cobalt oxide	24,000	12,000	....	....	
Coke	6,631,000	47,443,000	128,922,000	170,841,000	
Diatomaceous or infusorial earth and tripoli	45,600	24,000	286,000	242,000	
Emery	29,000	103,000	4,800	124,000	
Feldspar	60,000	181,000	777,000	702,000	
Fluorspar	16,000	95,000	736,000	923,000	
Fuller's earth	....	68,000	370,000	707,000	
Garnet (abrasive purposes)	....	123,000	183,000	209,000	
Gems and precious stones	100,000	233,000	319,000	218,000	
Graphite	50,000	....	....		
Amorphous	....	198,000	39,000	21,000	
Crystalline	....		254,000	915,000	Increase, 24 per cent.
Grindstone and pulp stone	500,000	710,000	856,000	766,000	
Gypsum	400,000	1,627,000	6,775,000	7,959,000	
Lime	19,000,000	6,797,000	14,648,000	18,619,000	Decrease, 10 per cent.
Magnesite (crude)	....	19,000	77,000	1,394,000	Increase, 100 per cent.
Marls	500,000	30,000	....	....	
Mica					
Scrap	....	55,000	83,000	70,000	
Sheet	128,000	93,000	354,000	524,000	
Millstone	200,000	33,000	56,000	45,000	
Mineral paint					
Natural pigments	146,000	644,000	512,000	Value given under unspecified	
Zinc and lead pigments	764,000	3,667,000	9,021,000	23,516,000	24,614,000
Mineral waters	500,000	6,245,000	5,631,000	5,735,000	
Natural gas	....	23,699,000	87,817,000	120,227,000	
Oilstones	8,000	174,000	207,000	155,000	
Peat	....	....	197,000	369,000	
Petroleum	24,601,000	75,989,000	237,121,000	330,900,000	Increase, 14 per cent.
Phosphate rock	1,124,000	5,359,000	11,796,000	5,897,000	
Potash	....	....	....	4,243,000	
Pumice	....	....	55,000	82,000	
Pyrite	5,000	750,000	1,286,000	1,966,000	
Salt	4,830,000	6,945,000	10,123,000	13,646,000	Increase, 9 per cent.

NON-METALS

	1880	1900	1913	1916	1917
Sand					
Glass	....	....	1,896,000	1,958,000	
Molding, building and gravel	....	....	22,322,000	27,852,000	
Sand, lime brick	....	....	1,238,000	1,474,000	
Silica (quartz)	80,000	127,000	201,000	243,000	
Slate	1,530,000	4,240,000	6,175,000	5,339,000	
Stone	20,626,000	36,971,000	83,733,000	79,042,000	
Sulphur	21,000	88,000	5,480,000	Under unspecified	
Sulphuric acid	....	....	4,346,000	14,100,000	Increase, over 50 per cent.
Talc and soap stone	67,000	384,000	1,120,000	1,292,000	
Talc (fibrous)	55,000	500,000	789,000	962,000	
Thorium minerals (monazite)	....	49,000	....	3,400	
Zircon	....	49,000	....	....	
Unspecified	6,000,000	1,000,000	420,000	15,000,000	

Figures for the year 1917 must be regarded as approximate, rather than final. "Increase" or "decrease" applies to amount, not values.

METALS

	1880	1900	1913	1916	1917
Aluminum (consumption)	....	$1,920,000	$13,845,000	$33,900,000	
Antimonial lead	240,000	995,000	1,592,000	4,464,000	
Antimony	10,000	838,000	429,000	Figures not available	
Bauxite	....	90,000	998,000	2,296,000	
Cadmium	....	....	....	[1]205,000	
Chromic iron ore	28,000	1,400	2,854	726,000	Slight increase
Copper (value at New York city)	12,943,000	100,615,000	189,795,000	474,288,000	510,000,000
Ferro-alloys	....	....	13,015,000	50,282,000	
Gold	36,000,000	79,171,000	88,884,000	92,590,000	84,457,000
Iron ore	23,157,000	66,590,000	130,906,000	181,902,000	236,178,000
Pig iron	89,316,000	259,944,000	458,342,000	663,478,000	Slight decrease
Lead (refined value at New York city)	9,573,000	22,961,000	36,245,000	76,207,000	78,816,000
Manganese ore	86,000	100,000	40,000	627,000	Increase 300%
Manganiferous ore	Included under iron ore		25,000	2,005,000	
Nickel (value at New York city)	257,000	3,886	79,000	671,000	Decrease, about 20 %
Platinum	400	2,500	47,000	2,302,000	
Quicksilver (value at San Francisco)	1,858,000	1,273,000	813,000	2,577,000	3,857,000
Silver	34,717,000	35,741,000	40,348,000	48,953,000	About same
Tin (metallic equivalent)	....	....	47,000	no figures	
Titanium ore (rutile)	400	1,300	49,000	no figures	
Tungsten ore (60 per cent. concentrate)	....	11,000	672,000	....	Increase 800T (16%)
Uranium and vanadium minerals	....	....	609,000	no figures	
Zinc, sales values	2,833,000	10,902,000	37,772,000	151,005,000	102,350,000

59,403 long tons, respectively, and valued at $40,080 and $25,-124; in 1916, 26,997 and 548,803 long tons, valued at $627,417 and $2,005,491. In 1917 there was an increase over the 1916 production of manganese ore of about 300 per cent. The use of ferromanganese and spiegeleisen in manganese steel is a well established industry. Manganese is used to remove oxygen and sulphur from steel and thus render it very hard, but still ductile, therefore, such steel is used for a number of purposes requiring a hard, tough steel. Manganese ore is also used in dry batteries and in the flint-glass industry.

Magnesite has increased in production many fold. It is used for refractory bricks in open-hearth furnaces, composition flooring, fire-resistant paint, sulphite process in wood pulp manufacture, heat insulators or covering for steam pipes, and in magnesia cement. Magnesia cement is used for making decks of ships, floors of hospitals and railroad cars, and has been employed successfully in the European war for making gun emplacements, as it sets quickly and has some resilience.

There are many other substances that have increased abnormally in the last three years. Of these may be named, asbestos, barytes, potash, sulphur, iron pyrite and sulphuric acid.

In a report to the President a few years ago, the Secretary of the Interior, in speaking of the resources of the country, gave minerals a high rank and referred to them as "The Foundations of Power." "A nation that produces under normal conditions 40 per cent. of the world's coal and 66 per cent. of its petroleum surely has its share of the two great fuels; add the fact that our mines, furnaces and smelters yield 40 per cent. of the world's iron, 60 per cent. of its copper, and 32 per cent. of its lead and zinc, and the reason is patent for America's industrial greatness."[1]

References

Engineering and Mining Journal, January 12, 1918.

Macfarlane, John J., "The Foundations of Power," *Commercial America*, January, 1918, pp. 15–21.

Smith, George Otis, "The Public Interest in Mineral Resources," Mineral Resources of the United States for 1915, pt. I., pp. 1a–9a.

"The Americas," vol. 4, February, 1918, pp. 26–30.

"Mineral Resources of the United States for 1914," pts. I. and II.; *ibid.*, for 1915, pts. I. and II.

Preliminary Mines Reports of Mineral Resources of the United States for 1916.

United States Geological Survey Press Bulletins from December, 1917, to March, 1918, inclusive.

[1] Smith, George Otis, "The Public Interest in Mineral Resources," Mineral Resources of the United States for 1915, Pt. I., pp. 1a, 2a.

MEDICAL LABORATORIES

By ELLIS KELLERT, M.D.

DIRECTOR OF THE BENDER HYGIENIC LABORATORY, ALBANY, N. Y.

THE utilization of laboratory methods in the diagnosis of infectious diseases probably dates back to the time when the *Bacillus anthracis* was found to be the microbe causing anthrax in sheep and when Pasteur discovered the organism producing "pebrine" in the silkworm. In 1880, the protozoan causing malarial fever was identified in the blood and thereafter in rapid succession the bacteria inducing many other diseases were described. Methods for the isolation and study of the various disease-producing germs were developed to such an extent that the new science of bacteriology became established and subsequently expanded so greatly that few bacteriologists claim expert knowledge in the entire subject. As a result of the study of the action of pathogenic bacteria on the animal body, it was found that many organisms induce the formation of specific substances, the presence of which may be readily found in the blood. Two common illustrations of this phenomenon are typhoid fever and syphilis.

In all departments of science, what are primarily toys or curiosities soon become useful and necessary appliances in everyday life. This constitutes progress. The science of medicine in particular leaps forward with each new discovery or new method of procedure. Witness the germ theory of disease and its subsequent elaboration and proof; the far-reaching effects of the observation by Theobald Smith and Kilbourne that insects may act as the intermediate hosts in the transmission of disease; the value of prophylaxis, the perfection of the microscope, the invention of the stethoscope and the use of the aniline dyes in bacteriology and pathology. The story of the marvelous progress of medical science during the past fifty years is more interesting than anything hitherto published and yet the tale is but begun. The narration of medical progress is of extreme interest to the lay public and this is testified to by the avidity with which magazines and newspapers publish medical news in all detail. This interest should be encouraged and stimulated, for only with the active cooperation of the public can medicine accomplish its greatest triumph—the elimination of disease by preventive measures.

The hot-house of medical progress is the laboratory. Destroy the laboratory and we revert to the medical practice of the fifteenth century. The physician would again take up his individual method of guessing in which he is frequently justified by a kind nature which has limited the progress of most diseases. In the absence of animal experimentation the old "shotgun" prescription would again come into vogue, and the unscientific and irrational use of a multitude of drugs would be the prevailing fashion. Since laboratory methods are often precise in the information which they yield and in many other instances give highly suggestive findings, it is logical to conclude that they should not be neglected even in apparently trivial cases. Experience may be extensive, knowledge deep and the special senses highly developed, but instruments and exact methods should be employed for confirmation if not for purposes of actual diagnosis. Information thus obtained is a source of great satisfaction because a permanent record is established, and the subsequent treatment justified.

Diagnosis of the disease present is essential because upon it depends not only the character of the treatment, but also the prognosis which frequently is of great importance and invariably most earnestly inquired about by the patient. While he may feel interested in knowing the name of his affliction, the sick person is more concerned regarding the ultimate outcome of his case. The value of prognosis is well illustrated by typhoid fever. This disease is caused by the *Bacillus typhosis* and the diagnosis may be established by finding the microbes in the blood during the first three or four days of the illness, or by subsequent examination of the blood by the Widal method and by counting the leucocytes. Typhoid fever is a "self-limited" disease and the mortality is usually 5–20 per cent., varying somewhat in different epidemics. Closely related to the typhoid bacillus is the paratyphoid bacillus, of which there are two strains. Infection by these organisms produces a train of symptoms similar to typhoid fever but more mild. Fatal cases are extremely rare and in paratyphoid fever the physician would have no hesitancy in predicting a favorable termination of the illness. The diagnosis between these conditions can only be established by laboratory methods.

In medical practise the physician finds many diseases the manifestations of which are so typical as to leave no doubt regarding the diagnosis. Thus scarlet fever, measles and smallpox are detected without great difficulty. There are many others, however, with variable signs and symptoms in different individuals and it is in these cases that the laboratory plays so important a part. As a matter of interest, let us group the various diseases commonly found in this country according to their dependency for diagnosis on laboratory methods.

Group A

Diseases diagnosticated with certainty by laboratory methods

Typhoid fever	Leprosy
Syphilis	Tetanus
Diphtheria	Gaseous gangrene
Cholera	Diabetes
Cerebrospinal meningitis	Malaria
Gonorrhea	Intestinal parasites
Tuberculosis	Trichinosis
Actinomycosis	Anemia
Bacillary dysentery	Pernicious anemia
Amebic dysentery	Leukemia
Anthrax	Chlorosis
Pneumonia	Hemophilia
Glanders	Tumors

Group B

Diseases in which the diagnosis is greatly assisted by laboratory methods

Septicemia	Abscess
Nephritis	Appendicitis
Gout	Peritonitis
Lead poisoning	Asthma
Poliomyelitis	Erysipelas
Typhus fever	Influenza
Vincent's angina	Whooping-cough
Pneumonia	Smallpox
Meningitis	Tumors

The above list, although not very long, includes by far the greatest amount of morbidity ordinarily prevalent. Most diseases are due directly or indirectly to bacteria and the demonstration of the presence of the suspected pathogenic organisms usually suffices to establish the diagnosis. The exceptions are the few instances in which individuals normally harbor disease-producing bacteria. Such persons are termed "carriers" and the most frequent examples are those that harbor diphtheria bacilli in the throat or typhoid bacilli in the intestine or gall-bladder. In the army cantonments it has been shown conclusively that normal individuals act as carriers of virulent meningococci and pneumococci.

In recent years laboratory work has received great emphasis in medical education. Medical colleges are usually judged and rated by the quality of their laboratory courses and consequently the young graduate of the present day considers, and rightfully so, that laboratory methods are essential to the successful practise of medicine. He regards the necessary apparatus as part of his armamentarium and, indeed, as important as the stethoscope or thermometer. Laboratory technique, however, is so time consuming that busy practitioners find it impossible to perform any but the simplest examinations and so turn to the nearest well-organized institution for assistance. While recent graduates maintain a proper viewpoint toward the diagnostic laboratory, the older practitioners are too often indifferent and unwilling in many instances to avail themselves of laboratory service. They are content with their clinical diagnosis and, while undoubtedly correct in most instances, yet they should confirm their estimate of the case by an exact method if available. In this way only can they successfully claim to be scientific practitioners of medicine.

When we speak of exact methods in diagnosis we usually mean an accuracy of 90–95 per cent. Because of the multitude of variable factors concerned and the changing conditions of the body, it is scarcely possible to attain greater accuracy. Usually in practice the chief reason for the failure to arrive at a correct diagnosis lies in the lack of thoroughness on the part of the physician or the omission of repeated tests and examinations. When one considers the complex human organism and the frequent variations in the course of disease it is scarcely to be expected that a given set of factors necessary to the diagnosis will remain constant through any great period of time. Thus by way of illustration is leukemia a progressively fatal disease in which, however, "remissions" occur, that is, periods, usually of brief duration, when the patient is practically normal so far as can be determined objectively. Of course, an examination made at such a time will yield negative results and yet a few days later decided and positive changes will occur. Again, in malaria, the blood when examined between chills may be negative, but shortly before the chill will be found to contain myriads of the specific organisms. In diabetes, no sugar or very little, may be found in the urine, but the blood, on examination, will be found to contain a greatly increased amount. Thus it will be seen that the intelligent application of laboratory methods is essential to success. Properly speaking, the medical laboratory should not and can not as a rule make a diagnosis. The laboratory worker reports his findings to the physician, who correlates the results with his clinical observations and thus arrives at the true diagnosis. Medical laboratories are frequently termed diagnostic laboratories, but improperly so, for their function is to obtain additional data for the attending physician who is the only one qualified to make the diagnosis. Laboratories may occasionally be in error in their reports, either because of the natural fluctuations or complications of disease or because of incomplete observations, or more rarely error in technique. That "experience is fallacious and judgment difficult" is just as true to-day as in the time of Hippocrates, but the degree of error in diagnosis is constantly decreasing. The personal equation, however, is still an important factor in the work.

In every community where hospitals are situated, many surgical operations are performed during the year and tissues or organs removed from the body, but not always submitted to the pathologist for examination. All such specimens should be sent to the laboratory for microscopic study. Complete records, including stained sections of the tissue, should be made and kept permanently. Thus in later years, if necessary, it will be possible to examine these records in the light of new illnesses or symptoms that may arise. This is more frequently necessary than is commonly believed, particularly in the case of abdominal operations, where the removal of an appendix or ovary, for instance, is in question. Our best surgeons have such examinations made as a routine for several reasons, chiefly, however, as a matter of scientific interest and to confirm their pre-operative diagnosis.

That many physicians who are indifferent to the advantages offered by laboratory assistance can no longer remain so is becoming more evident with each succeeding year. The public is gradually acquiring a rather extensive knowledge of disease and the application of laboratory methods, and many patients now show a decided interest in the laboratory reports. This attitude should be encouraged because it will lead to greater cooperation on the part of the patient in treatment and preventive measures. During the present Great War the sanitary department of the army has acquired a position second to none in importance and the chief reliance of that organization is upon the laboratory. The increasing activity of state and municipal health departments who insist on laboratory examinations in suspected cases of tuberculosis, typhoid fever, poliomyelitis and meningitis is but one indication of the importance of the medical laboratory. The war has brought about a serious and earnest attempt to control venereal diseases. Registration of infected individuals will undoubtedly soon be required in many states and the basis for the acts of the authorities will depend largely, if not entirely, on the laboratory examinations. When this war is over, millions of men will return to civil life impressed with the value of the laboratory in the diagnosis and prevention of disease. They will know that typhoid fever, pneumonia, meningitis and many other diseases are only properly diagnosed by the finding of the causative organism, that the rational treatment of wounds and other infections depends upon knowing the nature of the bacteria present, that the efficacy of the treatment for syphilis can be best judged by the Wassermann reaction and that the diagnosis of a host of other conditions requires special skill and training on the part of the physician. The doctor can no longer arbitrarily say to his patient that he has such or such ailment, but must in support of his diagnosis cite the laboratory report. This information not only helps the patient, but is also instructive to the physician.

Diagnosis, however, is only part of the work of the medical laboratory. No such institution is properly organized unless ample funds and facilities are available for research. While the efficiency of the laboratory may be kept at a high point in the performance of routine tests, the systematic investigation of new problems should be part of the daily labor. Research may be carried on to elucidate new facts, to confirm previous studies, to record isolated cases of scientific and practical interest, to improve existing methods, or to collect statistics for future study. This special investigation minimizes the dulling effect of routine and acts as a mental stimulus to the laboratory worker. Thus we find the best laboratories continually engaged in research and they who have thus acquired the experimental viewpoint are much more likely to explain an uncommon train of symptoms or determine the nature of a puzzling case.

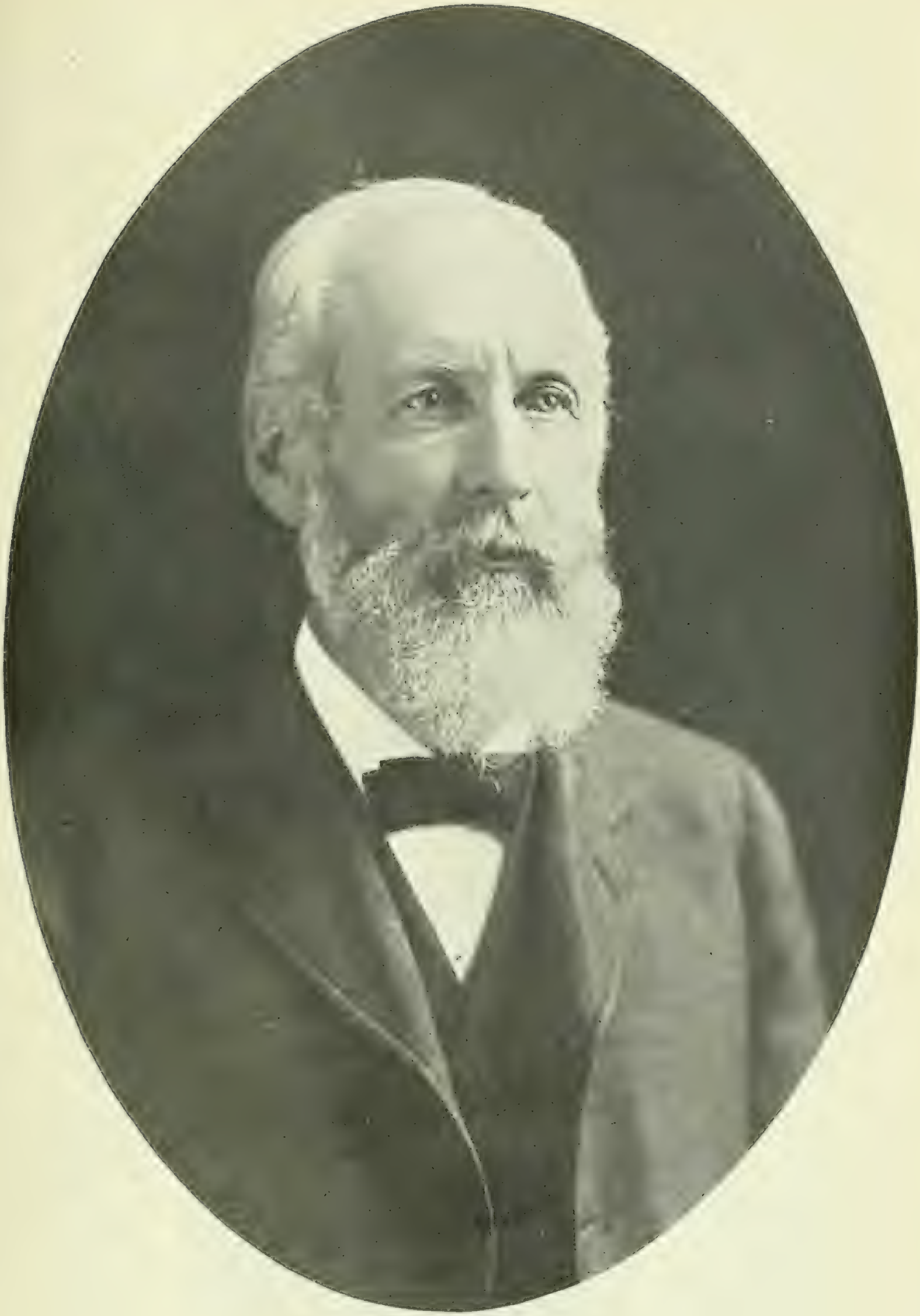
What is the future of the medical laboratory? Although remarkably well developed at the present time, we find that, in view of the many great problems which medical science must yet solve, these institutions have only begun their work. The discovery of disease germs, yet to be made, new methods in the diagnosis and prevention of infections, and even improvement of existing methods, offer fields for many years of labor. Here and there isolated workers have contributed valuable facts and made important discoveries, but innumerable fundamental problems yet remain. Only recently the advent of new methods have led to morphologic studies of great importance, thus again opening a field which at one time was thought closed. The extensive subject of functional diseases is being clarified by the methods of chemical analysis now in use and the new science of colloidal chemistry will further aid greatly in the solution of many perplexing medical problems.

Hand in hand with the discovery of the cause of disease is the problem of therapy. In comparatively few instances can diseases be cured after they have become well established. Chief among these are diphtheria, malaria, hook-worm infection, syphilis and cerebro-spinal meningitis. There are a host of other diseases dependent upon functional derangement of various organs and their alleviation depends largely on hygienic and dietetic measures. Many other abnormalities are relieved usually by the removal of the offending organ and then nature reestablishes the normal state, with or without further assistance. Examples of these are appendicitis, goiter, calculi and tumors. Thus it is seen that the greatest practical progress made in medical science has been along lines of prevention. This has been accomplished primarily by isolation and the elimination of conditions favorable to the growth and transmission of microbes and secondly by preventive inoculation.

Consider for a moment how successfully malaria, yellow fever, plague and smallpox have been controlled. These diseases, in the past, decimated whole populations and at times threatened to destroy entire nations. Who can estimate the value to the world of the control of these four infections alone? The destruction of mosquitoes and rats, the method of vaccination, simple procedures and not at all difficult of application, have already been of immeasurable benefit to mankind. They all represent the work of the medical laboratory, except smallpox vaccination, which was made known to the world by Edward Jenner before the days of medical laboratories. Later day improvements in the production and use of vaccine were made, however, in the laboratory.

The two great objects of medical endeavor in recent years have been to prevent infection, either before or shortly after exposure, and to apply a specific remedy after the onset of symptoms. The success of Pasteur in preventive inoculation against anthrax in sheep led to the adoption of similar methods in many other infectious diseases with varying results. Having apparently exhausted all possibilities along these lines, the laboratory workers turned to chemistry and sought to obtain drugs or chemical products which when injected into the body destroyed the parasites, but without inducing harmful changes in the organs. The most brilliant results obtained have been by the use of atoxyl in sleeping-sickness and salvarsan in syphilis. Thus it is seen that medical investigation has become an exceedingly complex subject and that the united efforts of the physician, the biologist, the chemist and the physicist are necessary in order to obtain favorable results. Physical science is rapidly looming to the front as an aid in the solution of medical problems and has already accomplished much, as in the application of our knowledge concerning the X-ray and radium in the treatment of disease.

The organization of a well-conducted medical laboratory calls for a competent staff and adequate equipment. The primary object is to render immediate and necessary service in the diagnosis and prevention of disease. This means that a certain amount of routine work will be conducted for the physicians and hospitals in the neighborhood. The second important object of the laboratory is to engage in research. This may be along lines to which the institution is committed, or will depend on the interests of those in charge of the laboratory, or upon accidental findings during the routine examinations. Much valuable work has been accomplished as a result of chance observations, but they really are not accidental, because the workers are ever on the lookout for unusual phenomena. Owing to the liberality of wealthy citizens of this country, many buildings have been erected and equipped for diagnostic and research purposes and they are sufficient for years to come. What is needed urgently is endowment for existing institutions and funds for salaries and materials to conduct research. Many laboratories well equipped as to working space and apparatus are unable to carry on investigations because of lack of finances. It is futile to erect buildings for scientific purposes unless funds are also provided for the work. With such support and encouragement the problem of the infectious diseases and tumors will soon be solved and their eradication is certain to follow. The greater portion of the remaining diseases will be cared for by the science of hygiene which is making such rapid progress.



Grove Karl Gilbert

THE PROGRESS OF SCIENCE

GROVE KARL GILBERT

From the time of Benjamin Franklin and Count Rumford, America has produced distinguished men of science; but it is only in recent years that it has rivalled the older nations in research work. The two sciences first to attain this position were astronomy and geology, in which opportunities for research work were opened through the endowment of observatories and through the state and national support of geological surveys.

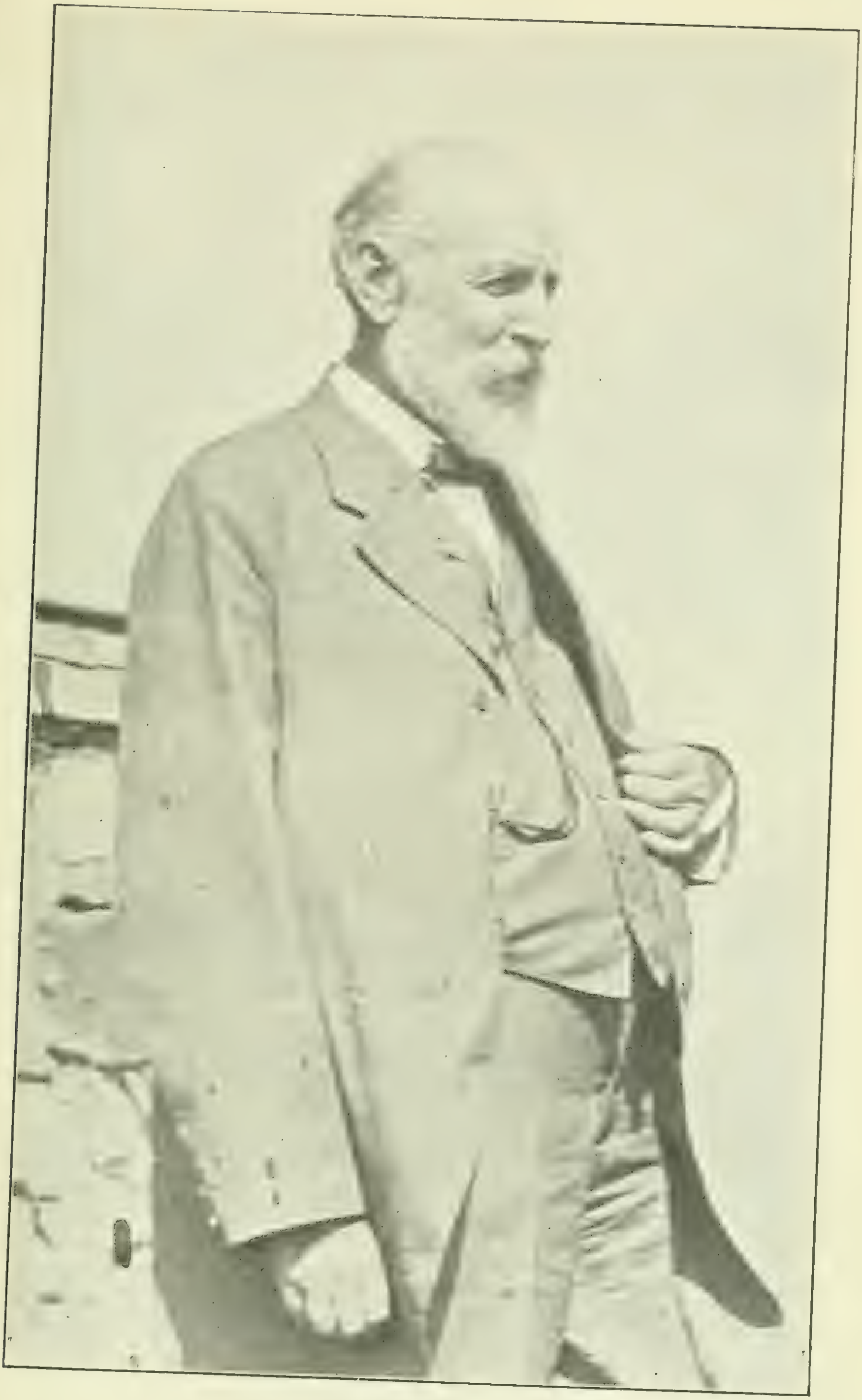
When the United States Geological Survey was organized in 1879, Grove Karl Gilbert had been for eight years engaged in the survey of the western territories under Wheeler and Powell. He was not only a member of the survey from its organization until his death, but shared in the work leading up to its organization, and was in large measure responsible for its admirable methods and results. During this long period Gilbert represented the highest ideals of scientific work, careful observation and sound judgment, philosophical broadness, complete straightforwardness.

Gilbert was born in Rochester in 1843, his father being the portrait painter, Grove Sheldon Gilbert. After graduating from the University of Rochester, he was for some time engaged in Ward's Natural Science Establishment, the training school for a number of distinguished naturalists. In 1869, he began his geological work on the Ohio Geological Survey under Newberry. At that time, when only twenty-eight years of age, he prepared maps showing the ancient glacial waters in the Maumee Valley, the first ever made of ancient lake beaches. His later important work on Lake Bonneville describes the large predecessor of the present Great Salt Lake, which existed in glacial times and overflowed northward to the Columbia River. One of Gilbert's most important early papers was his report on the Henry Mountains published in 1877, describing a new type of mountains, originally areas of sedimentary strata lifted by the injection of lava from beneath, to which the name laccolith is now given. Each of the large number of papers and monographs prepared by Gilbert during his fifty years of scientific activity contains a contribution to the subject.

Professor Herman LeRoy Fairchild, of the University of Rochester, the early home of Gilbert, at a memorial meeting held by the Rochester Academy of Sciences, said:

> Dr. Gilbert's mind was of the reflective, philosophic type. He sought for the explanation and relationship of phenomena. His calm judgment and clear discrimination joined to a spirit of fairness and with gentle manners caused him to be much sought as a critic and helper. He was a sort of father-adviser to the members of the survey. Doubtless much of his thought has found expression in the writings of the younger men who revered and loved him. The writer of this appreciation never heard him say a harsh word of any one.

Gilbert was twice president of the Geological Society of America, no other American geologist having received the honor of a second election. He was president of the American Association for the Advancement of Science and of the American Society of Naturalists. On the approach of the seventy-fifth anniversary of his birth on May 6,



Grove Karl Gilbert

his friends were asked to send to the Geological Survey letters of congratulation to be handed to him on that day, but he died on May 1.

THE UNIVERSITY OF PARIS

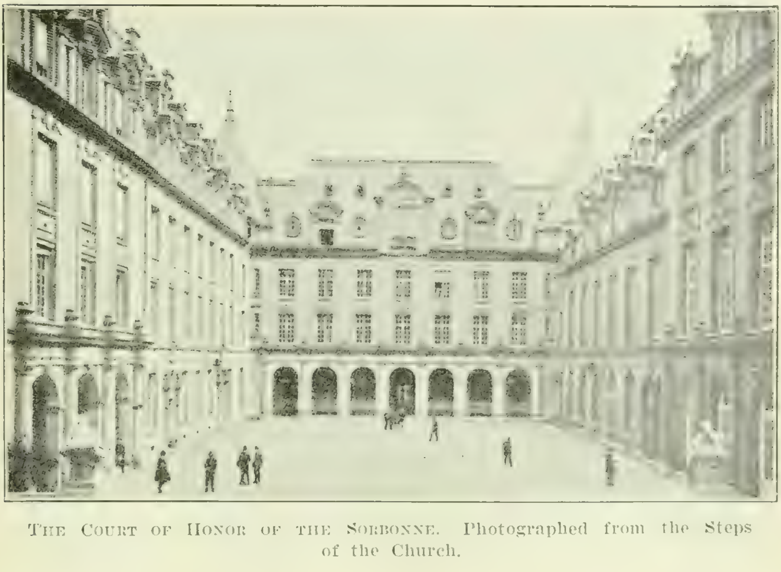
THERE was published last year an appreciation by American scholars of "Science and Learning in France" with a survey of opportunities for American students in French universities. The volume is edited by Professor John H. Wigmore, of Northwestern University, at the time of its preparation president of the American Association of University Professors, and contains articles on French contributions to the several departments of scholarship and science by leading American students with an introduction by Dr. Charles W. Eliot. Appendices give practical details concerning educational advantages for American students in France and the organization and degrees of the institutions of higher learning.

There has now been issued under the auspices of the council of the University of Paris a volume entitled "La Vie Universitaire à Paris" prepared by a number of leading French scholars and to a certain extent addressed to the American student. The publication of such a volume at the present time bears witness to the fine spirit of the French people in maintaining the historic institutions of the country and planning for their future development.

Professor Durkheim, who contributes the chapters on the history and the organization of the university, tells us that Paris is the oldest and largest of the world's universities. It is a position for legitimate pride, even though the margin is not large in either direction. In respect to size, comparisons are difficult, for it depends on which of the educational institutions of a city are included and on how the students are counted. According to *Minerva*, the University of Paris had, before the war, 17,512 students, followed by Berlin with 14,034, Moscow with 9,516 and Petersburg with 8,955. It will now be the United States rather than Russia which will rival Paris in the size of its institutions. Apart from summer school and ex-

THE SORBONNE AS BUILT BY RICHELIEU IN 1642. The Church contains the Tomb of Richelieu. From an engraving by Aveline.

THE CHURCH OF THE SORBONNE AT THE PRESENT TIME. The monument before the Church has been erected in Honor of Auguste Comte.



THE COURT OF HONOR OF THE SORBONNE. Photographed from the Steps of the Church.

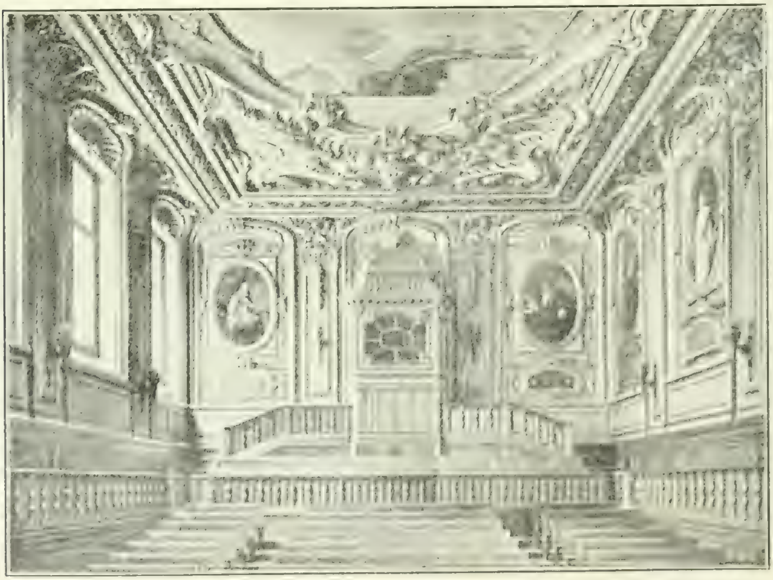
tension courses Columbia had in 1916, 7,327 students, Harvard 5,226, Michigan, 6,276 and California 6,467. But the different institutions for higher learning in Boston or in New York, if their students were combined, would in size rival or surpass Paris and Berlin.

Salerno, a medical school in the ninth century, may claim to have been the earliest of universities, but it was finally closed in 1817. The universities of Paris and Bologna arose in the course of the twelfth century, but Paris claims a slightly earlier organization. Bologna was primarily a law school controlled by the students, Paris a school of theology and philosophy controlled by the masters.

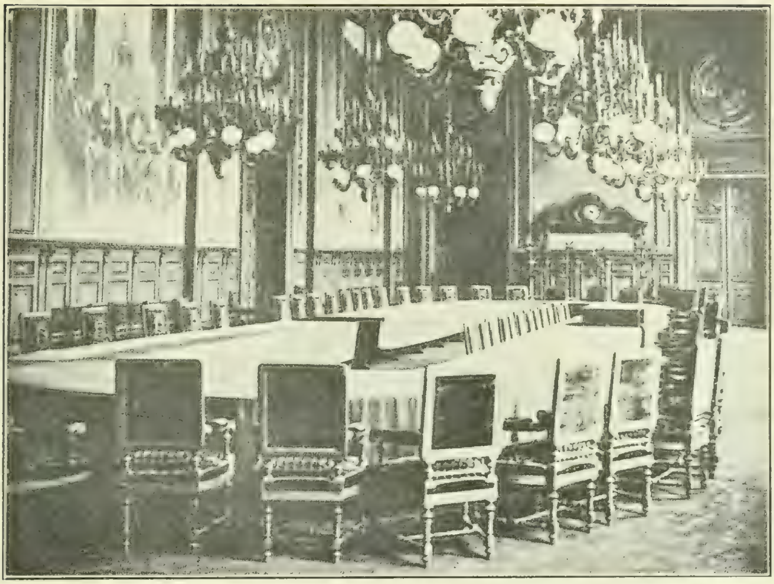
Abelard, teaching first in the cathedral school of Nôtre Dame, attracted crowds of students. He founded other schools and other teachers established schools from which gradually arose the University of Paris. In the thirteenth century and later, colleges or dormitories for poor students were endowed. The Sorbonne was founded in 1303 by Robert de Sorbon for theological students, and was rebuilt by Richelieu in 1627. It survived as a school of theology until the revolution, and in a sense became the university, which for centuries was controlled by the Jesuits, while the forward movement of science and letters proceeded outside, largely under the auspices of the academies.

French education was centralized and made professional and practical by Napoleon, and it was only under the third Republic that Paris once again became a great university and the universities of the provincial cities were recreated.

The Sorbonne has been rebuilt and enlarged threefold, and made the administrative center of the university, whose various buildings are grouped about it. Some pictures are here reproduced from the book which are of interest in relation to the architectural developments of American universities.



Examination Hall of the Faculty of Letters of the University of Paris.



THE COUNCIL ROOM OF THE UNIVERSITY OF PARIS.

THE CHEMICAL WARFARE SERVICE

THE meeting of the American Chemical Society in Cleveland and the National Exposition of Chemical Engineers in New York have brought to general attention the great part played by chemistry in national welfare and in the conduct of the war. Modern warfare is essentially engineering, and there is scarcely any department with which chemistry is not vitally concerned. The part that has been played by our chemists in warfare is well described by Dr. Charles L. Parsons, the secretary of the American Chemical Service, in an address that he gave at Cleveland.

Before the entry of the United States into the war, a census was taken of American chemists, and full information was obtained concerning the qualification of some 15,000. In the early part of February, 1917, the president of the American Chemical Society, Dr. Julius Stieglitz, offered the services of the members to President Wilson in any emergency that might arise and received an appreciative reply.

Active work was begun by the Bureau of Mines and other agencies which culminated in the organization of the Chemical Warfare Service in June, 1918. As Dr. Parsons says it was a real epoch in the history of chemistry in warfare when, as a result of conferences held at the Bureau of Mines with officers from the Medical Corps, War College, General Staff, Navy and civilian chemists, the Chemical Service Section was established as a unit of the National Army.

All newly drafted chemists are assigned to the Chemical Warfare Service to be detailed or transferred or furloughed where needed. It is charged with the "responsibility of providing chemists for all branches of the government and assisting in the procuring of chemists for industries essential to the success of the war and government." It has an authorized personnel of 45,000, of which any portion may be chemists if needed. At present there are approximately 1,400 graduate chemists in the Chemical Warfare Service.

Dr. Parsons concluded his address with the words:

> War, the destroyer, has been on the other hand the incentive to marvelous chemical development with a speed of accomplishment incomprehensible in normal times. Discoveries made in the search for instruments of destruction are already in use for the development of chemical industry. Many others, unpublished as yet, and to remain unpublished until the war is over, will prove of the utmost benefit to mankind. The same agencies that add to the horror of war to-day, the same reactions which are used in the development of explosives and poisonous gases on the one hand, and in counteracting their effect on the other, will find immediate and useful application in the years to come. The war has been prolonged by chemistry. The German chemist, apparently working for years with war in view, has supplied the German armies with the means for their ruthless warfare, but the chemists of America and our Allies have met them fully in chemical development, and when the chemical story of the war is written where all can read, it will be the verdict of history that the chemists of America were not found wanting. The chemical program of the United States Army and Navy has been at all times ahead of our trained man power and the mechanical devices necessary to apply what the chemists of America have produced.

SCIENTIFIC ITEMS

WE record with regret the death of Aaron Nicholas Skinner, formerly professor of mathematics at the U. S. Naval Academy and assistant astronomer of the Naval Observatory; of Charles R. Eastman, of the American Museum of Natural History, the author of important contributions to paleichthyology; of Bertram Hopkins, professor of mechanism and applied mechanics in Cambridge University, Colonel in the British Army, and of O. Henrici, F.R.S., emeritus professor of mechanics and mathematics in the Central Technical College of the City and Guilds of London Institute.

MAJOR GENERAL MERRITTE W. IRELAND, of the Medical Corps, has been appointed Surgeon General of the Army, to succeed Major William C. Gorgas, who was retired on October 5. General Gorgas will remain in Europe as the medical representative of the United States Army at the Interallied War Council.—Dr. Arthur L. Day, director of the Geophysical Laboratory of the Carnegie Institution of Washington since its establishment in 1906, home secretary of the National Academy of Sciences, has resigned to accept a research position with the Corning Glass Works, Corning, N. Y.

THE statutory meeting of the general committee of the British Association for the Advancement of Science was held in London in July, and at this meeting much disappointment was expressed that for the second year in succession it has been found impossible to arrange for an ordinary meeting. A resolution was passed unanimously asking the council to arrange for a meeting in London next year, if it should prove impossible to arrange to meet at Bournemouth. The question as to the type of meeting which it was desirable to hold was left to the council to decide.

THE SCIENTIFIC MONTHLY

DECEMBER, 1918

CAMOUFLAGE

By ABBOTT H. THAYER

MONADNOCK, N. H.

ABORIGINES in general have used camouflage in their war costume.

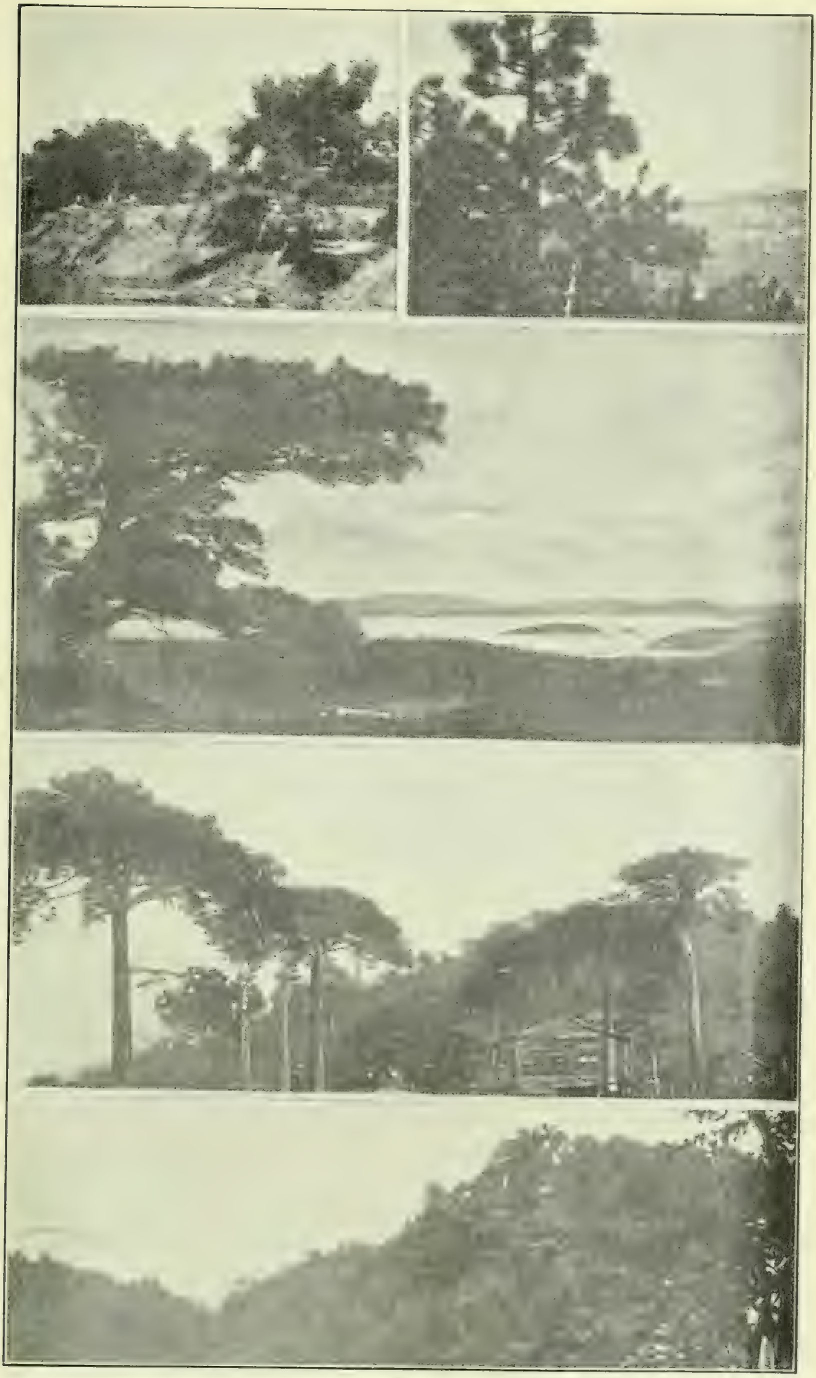
In their superhuman perfection, the concealing coats of animals that hunt or are hunted are now the models for the armies' camouflage corps: models so perfectly adapted to concealment in every conceivable scene, they are the despair of humanity. To study the principles underlying them, and to adapt them to the needs of the army, is now man's job.

The most totally effacing costume can not be counted on to prevent its wearer's being detected when he moves enough; but even in this case it makes him a poorer target when it comes to dodging, whether it be man or beast. The white sky-faking tail feathers of warblers serve to help save these birds when pursued through the woods by hawks, where the swiftness of the chase sets all the background optically into the same motion.

Whatever question there is as to the need of animals to be concealed, as to the evolution of the patterns on them, and the purpose of these patterns, one fact in regard to the costumes of animals is demonstrable, *i. e.*, that these conceal their wearer most of all from the viewpoint of the very eyes that we believe this wearer most needs to avoid: in some the greatest need is to be enabled to catch, in others it is to escape being caught. In the one case, the skunk's or badger's white top, faking the sky, effaces their looming heads from the sight of the field mice and ground insects they are hunting; in the other case, the same black and white scheme saves on the same principle the zebra from the crouching feline.

It is a comment on the use that men make of their eyes, that with all the various uses, utilitarian, scientific and esthetic, a principle, *always in evidence,* the principle that patterns *al-*

Landscapes photographed through Stencils of Skunks to show the Protective Coloration of the White Sky Counterfeits.



The Landscapes photographed through the Stencils of the Skunks.

THROUGH A STENCIL.

ways inevitably tend to conceal, has waited till now to be discovered.

Two main oversights have caused the whole misconception as to the concealing effect of pattern on animals: one, the failing to study an animal's markings *from the viewpoint*, always, as a matter of course, *of the animal whose sight was to be deceived;* the other, the perfectly fatal confounding of *detection* with *identification after detection.*

Any pattern having color notes that are conspicuous from man's point of view insists upon recording itself upon men's minds, and has come to be considered as intrinsically conspicuous. Take, for instance, the part a skunk may play in our minds. We probably detect him oftenest by noticing a white patch going about at twilight in perhaps the neighboring field as we look down on it from our piazza. For this reason this little beast has been set down, without further investigation, as conspicuous; while the case really is that nature has colored him for concealment from the small creatures on which he feeds, and above which he looms against the sky. (One would guess that because this white patch is so easily seen by hawks overhead nature has given him other means for his *own* protection.)

Exactly contrary to the conceptions of Darwin and his followers, pattern conceals its wearer everywhere against all backgrounds in direct ratio to its strength, *i. e.*, the degree of difference between the notes that compose it.

Monochrome, no matter how gray, *reveals* its wearer against all backgrounds whatsoever (and most of all if these are monochrome) except a background which is an absolute repetition of itself. (Of course it is the practically universal countershading of the world's animal life that alone could give it a monochrome aspect, changing the look of solidity to that of a flat surface.) Anybody will see at a glance that a monochrome area in the scene, having the shape of man, horse or bird, will

THROUGH A STENCIL.

catch the eye whenever it does not *absolutely match its background,* whereas, if the countless details of the scene recurred in the form of patterns right across this man-, horse- or bird-form, this form would be buried under this counterfeit of the scene.

On the other hand, the most monochrome of backgrounds opposes no difficulty to the concealing effect of pattern on an object seen against it, because some one of the colors of the pattern is almost sure more nearly to match the background than the other colors of it, and consequently *it* will seem to belong to the *background* rather than to the *object.*

A Brook Scene photographed through a Duck-shaped Stencil.

In cases where the colors of the pattern are all of them characteristic of the region, the deceptive imitation of the background is overwhelming; yet this resultant background-imitation is practically the universal accomplishment of animals' patterns. I have been left alone in the world to point this out; yet this whole fact is simply the ABC of all painter craft. Every painter in the world could have told you all about it the

Copyright by *The National Geographic Magazine.*

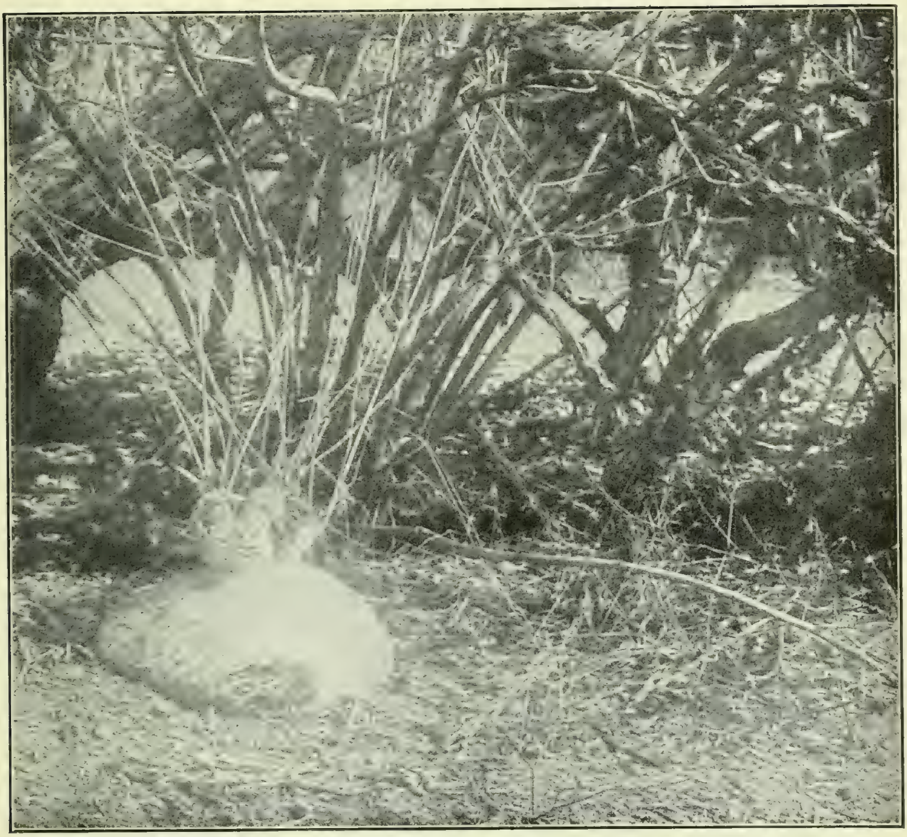
A Kalinga Warrior.

TATTOOED WARRIOR.
Kindness of the University Society.

SCENE PHOTOGRAPHED THROUGH THE STENCIL OF A WARRIOR.

moment you asked him. In short *every* part of the naturalist's belief on this subject has been *antipodally* wrong, and just for want of asking sight-specialists' (*i. e.*, painters') aid about matters of sight.

Here is the whole indisputable fact in a nut-shell. As all painters know, two or more patterns on *one* thing tend to pass for so many separate things. All art schools will tell you that it takes a far-advanced pupil to be able to represent the *patterns* on any decorated object so true in degree of light and darkness as not to "cut to pieces" the object itself, and destroy its reality. Objects show or don't show by silhouetting dark or light or of a different color against a more distant thing—a stick against the ground, a tree against the sky. Among the million details that constitute out-door nature, every smallest detail is only distinguishable by becoming to the spectator a pattern against its background. Consequently when nature paints with marvelous accuracy on some animal a picture of a twig and the ground, the mind inevitably accepts it as twig and



THE SCENE PHOTOGRAPHED THROUGH THE STENCIL OF THE WARRIOR.

ground. Could nature any further conceal an inhabitant of this scene than by painting superhumanly perfect *copies* of these objects on each inhabitant?

All the patterns and brilliant colors on the animal kingdom, instead of making their wearers conspicuous, are, on the contrary, *pure concealing coloration,* being the *actual color notes* of *the scene in which the wearer lives,* so that he really *is* nature's utmost *picture* of his background.

All colors and designs on animals *are pure art,* taking the lead, in the purity of their generalizations, of all human performance. Each bird's or beast's costume is pure scenery.

To discover what scene a bird represents, in cases where one plumage lasts all the year, consider what circumstances cause him the greatest need of protection, and you will commonly discover that he is *colored in representation* of such part of the scene, and such phase of it as the eyes that he most needs to avoid would see him against.

PATTERNED INDIAN AND MONOCHROME FIGURE. The Monochrome Figure may be the more distinguishable.

Artificial Zebra and Ass from Viewpoint of a near-by Stalking Lion, viz., a Lower Level. The Zebra concealed; the Ass revealed.

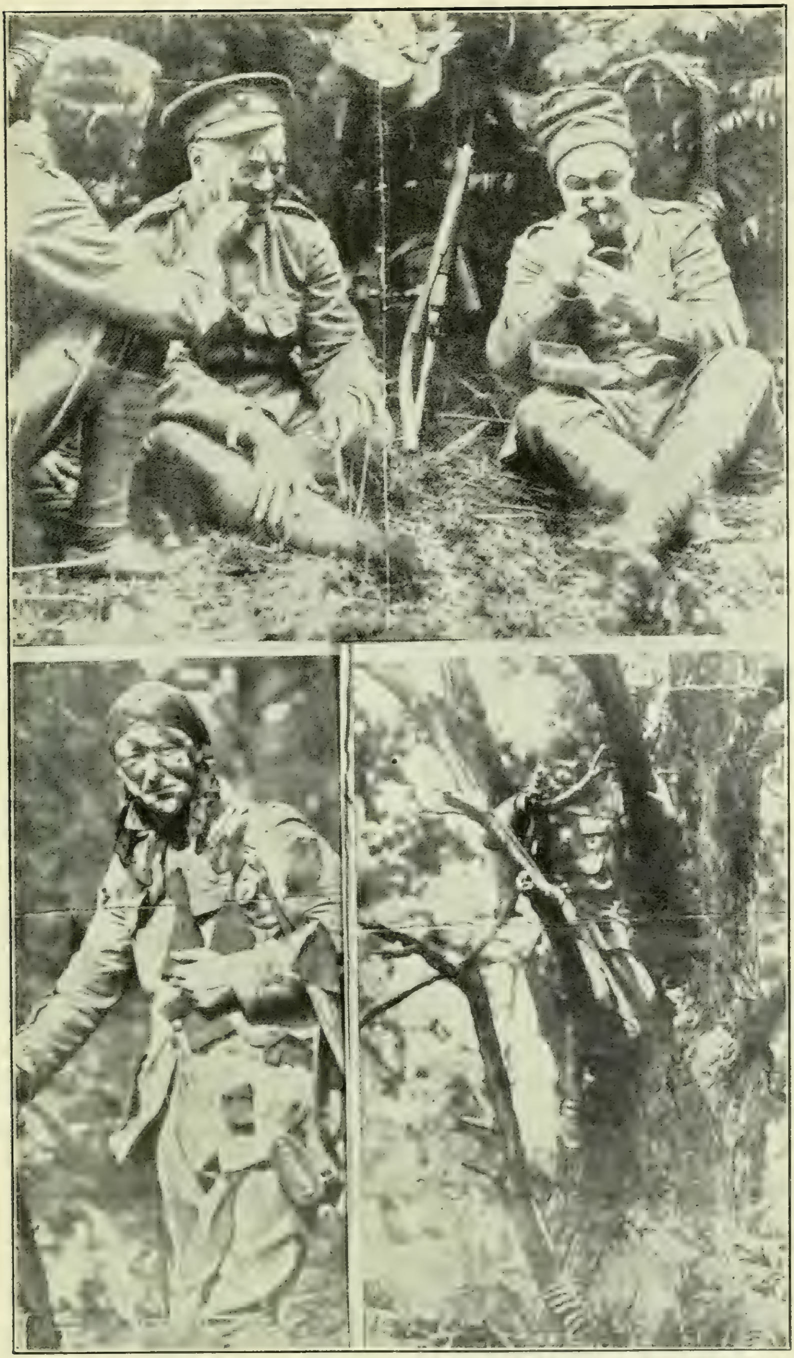
Naturalists will learn to know an animal's haunts and habits by his colors and patterns, which are nature's *utmost concealing coloration,* inasmuch as every color-coalition of any part of an animal with his background, or any presentation of the same color-note as that of any part of his background, inclines the beholder to think that he *sees background,* when he is really seeing a part of the animal. Even the scarlet bodice of the scarlet tanager by being a perfectly unbird-shaped scarlet patch amidst the forest foliage comes essentially into the same general classification because of the sprinkling throughout the forest of single scarlet leaves.

Go to the sedgy border of any water that best represents the type of place (*i. e.,* fairly level country) where antelopes, zebras, etc., would come to drink, and with your eyes a foot from the ground (crouching lions' eyes height) study through an antelope-shaped hole in a card the sky and reed-tops where they meet all about, and which would form these beasts' background to a crouching feline. What you discover is that the antelope's head-patterns example a universal costume-law, viz., those color-notes which are almost always present in the lion's view of the antelope, are fully repeated on the part of him this enemy is surest to see against such color-notes of the background. These head-patterns do the best that can be done to keep the antelopes' heads from silhouetting against the sky. They *fake* branches or reeds against the sky.

Go into the woods and in the comparatively open underwoods examine the realm between you and the sky through a similarly cut-out wood-warbler-shaped hole, and do the same to the bushes that surround your path *below* your level, etc. In this way ask the *ground* how the woodcock needs to look to escape an overhead hawk; ditto, ask how a low bush warbler; ditto, how a high tree warbler seen diagonally *above* the level of the accipiter. Remember that every bird or beast or insect picture thus made by looking at the background through that bird-, beast- or insect-shaped hole constitutes the asking nature what aspect would in that particular case totally efface such a creature in this exact situation when seen from just this viewpoint.

Next, one has only to try this on places enough to satisfy himself that he has the average. Always he will find that the costume of the species in question has every token of being *that average costume.*

An animal thus costumed tends to picture, wherever he is



From the London *Sketch*.

CAMOUFLAGE MAKE-UP. A Camouflage Scout and the same concealed in a tree.

seen from *average positions,* an average and most expectable type of scene. This morsel has very little need to fit very perfectly the surroundings it chances in any particular case to have. It merely says to the beholder, "Here is a bit of the sunny type of scenery that you know so well in this region when you direct your sight at this angle."

Looking through stencils more or less *upward* at the sky and branches will give us herons, jays, nuthatches, chicadees, etc. Looking through them more or less downward at the forest shrubbery over which the forest hawk commonly flies will give you the more or less ground-faking sparrows, etc., and such low bush foliage-faking warblers as lack the white sky counterfeit-patterns, such as the Maryland yellow throat and Canada warblers. Looking through stencils downward at the ground itself will give you ground-faking species, grouse, snipes, whippoorwills, etc.

See if you can make the stencil out-of-doors anywhere represent a flamingo save by looking at the dawn or evening sky over the lagoon, in which they are wading and against which their water enemies inevitably see them, or by looking at the water (reflecting these skies) against which the eagle would see these birds. See if you can make it represent *any* white-top-patterned species by looking at *dry* ground, or by looking in any direction save the one in which the avoided eyes would easiest detect a monochrome creature that did not absolutely match its background.

You can (any one can) look over all scences through stencils, knowing that in every case the result is God's last word as to what costume would *there,* from that viewpoint, efface its wearer.

This being the case, man has only to cut out a stencil of the soldier, ship, cannon or whatever figure he wishes to conceal, and look through this stencil from the viewpoint under consideration, to learn just what costume from that viewpoint would most tend to conceal this figure.

THE FOUNDATIONS OF BELIEF AMONG PRIMITIVE MEN

By Dr. JONATHAN WRIGHT

PLEASANTVILLE, NEW YORK

IN seeking out the origin of error and truth, fact and fancy in the history of the evolution of medicine, it soon became apparent to me that considerable thought must be devoted to a consideration of the foundations of human belief in general. It is quite impossible to follow back along the thread of progress in science with any assurance of not having lost it, unless one inquires very seriously why primitive man, or semi-civilized man, or any other man, thinks as he does. A novice in practical ethnology can view such an obstruction to the study of the origin of medicine only with dismay. He is forced from the vantage ground of original observation by the multiplicity of demands upon his capacity and his energy. He is obliged to study not only ancient primitive man in ancient texts and monuments, but he finds no opportunity, or but little, for the corrective study of prehistoric man in his own observations on modern primitive man. He has to turn to travellers' tales and accept the second-hand study of others whose opportunities are greater and whose territory is more circumscribed. It is then with all humility that I expose here a consideration of a few of the impressions which I have derived from the more original works or others. If I am forced thus to disclaim any pretence of the study of primitive man at first hand, I am also compelled to acknowledge the fragmentary and incomplete nature of the discussion I am offering. The analysis of the vast congeries of motives of human belief which are exhibited gradually to the student of human nature far surpasses the possibilities of an essay much more pretentious than this. I can only put forth those impressions I have received in sifting a certain amount of the evidence I have studied in the pursuit of some comprehension of the ideas of primitive man as to the art of medicine entirely or largely undifferentiated from other activities of a budding mentality. The investigator in the field must begin by choosing some phenomena as this which is at least partly comprehensible to him, and try to ascertain how the primitive mind arrived at such a state. The first requisite in a labor of this kind is to divest oneself as completely as possible of any thought as to the correctness or the error of the fact or theory which forms the substance of the conception. Unless one realizes that this is the product of a human mind, or of a number of them, worthy of careful attention, whatever may be the particular brand of error in which the student himself is immersed; unless one realizes that in a generation or two some future critic will have the same tendency to smile or yawn over the pet beliefs that haunt contemporary thought, little advance in getting at the back of the mind of primeval man will be achieved. The next to consider is the environment in which primitive or ancient man himself was immersed. Then the history of his racial and social evolution. Finally, what is usually less important, racial idiosyncrasy of cerebral function. This is less important because usually as between the races of men the variations in the quantity and quality of cerebral function are slight apart from the effect of environment in its broad sense, inclusive of historical or evolutionary experience. For the vast majority of the races of men, cerebral capacity in its physical or anatomical sense and functional or qualitative sense is the same, while their sensations and emotions are but the reflex responses of their own forgotten acts and thoughts which in time past have been registered by the brain.[1] They have been registered there and they find expression with primitive man in a different way than with us.

Primitive man's participation in the processes of nature has caused him to assimilate into his subconscious mental processes certain moral impulses, if we may so call them, which when revealed to him in dreams influence him in a way inexplicable to the civilized man whose subconscious warehouse has been stored with a different sort of impulse and who does not heed dreams as realities, which he must take into account in shaping his actions. It is not only then that he is guided by dreams, which may indeed be summoned up from the subconscious realm by overeating, but back of the dreams lie the impressions made upon him by happenings in the forest and on the plain, by flood, fire, famine, by the scorching heat and the numbing ice. In this sense then he is indeed the child of nature, though often it is through his theories and his dreams he participates in it. Then back of his impressions are the explanations of why they have taken the form they have. It is a vicious circle. His fears, arising from his pantheistic misinterpretation of nature, guide his theories and his dreams or his theories through the

[1] Leonard, A. G., "The Lower Niger and its Tribes," London, 1906.

medium of his fears guide his actions. Primitive man, a participant with nature in her pitiless moods, "bare of tooth and red of claw," knows naught of humanitarianism, but this altruistic sentiment is merely with us an expression of social evolution which he lacks. To a certain extent this lack of social evolution may be said to be back of narrow-mindedness in a civilization just as a lack of individual evolution is back of personal narrow-mindedness. So in olden Greece there existed perhaps a pardonable arrogance which led them to draw a sharp line between the Hellenic race and barbarians. Modern science and to a large extent modern usage has obliterated this line of cleavage and we discuss the "civilization" of the Aztec, the Babylonian, the Chinese, the Bantu and the Iroquois from more or less the same point of view we do that of the Frenchmen, the Saxon or the Teuton, and, if we are to make progress in the analysis of the evolution of thought, we must not pin ourselves to standards of culture or morals or indeed of knowledge. We must treat with entire objectivity, so far as we can, the cult of the savage. It is not difficult to take an account of his material civilization, but as Lord Avebury[2] says:

> Travellers naturally find it far easier to describe the houses, boats, food, dress, weapons and implements of savages, than to understand their thoughts and feelings. The whole mental condition of a savage is so different from ours, that it is often very difficult to follow what is passing in his mind, or to understand the motives by which he is influenced. Many things appear natural and almost self-evident to him, which produce a very different impression on us. "What!" said a negro to Burton, "Am I to starve, while my sister has children whom she can sell?" When the natives of the Lower Murray first saw pack oxen, some of them were frightened and took them for demons "with spears on their heads," while others thought they were the wives of the settlers, because they carried the baggage.

At each step along the road we have traveled since the Stone Age, our environment has changed and, as the path stretches behind us, we lose sight of the impressions which the road side has furnished. It is not alone a matter of physical change in the environment, but it is also a change in the mental environment. By the side of material evolution marches a social evolution and a mental evolution. It is the latter which forms the environment in the brain of man for the idea entertained by thought or for the fact observed in the material and social evolution around. So when we think of the processes in the brain of primitive man we must, as Frazer[3] says,

[2] Avebury, Lord (Sir John Lubbock), "The Origin of Civilization and the Primitive Condition of Man," London, 1889.

[3] Frazer, J. G., "The Dying God," London, 1912.

divest ourselves of our modern conceptions of the immensity of the universe and of the pettiness and insignificance of man's place in it. We must imagine the infinitude of space shrunk to a few miles, the infinitude of time contracted to a few generations. To the savage the mountains that bound the visible horizon, or the sea that stretches away to meet it, is the world's end. Beyond these narrow limits his feet have never strayed, and even his imagination fails to conceive what lies across the waste of waters or the far blue hills. Of the future he hardly thinks, and of the past he knows only what has been handed down to him by word of mouth from his savage forefathers. To suppose that a world thus circumscribed in space and time was created by the efforts or the fiat of a being like himself imposes no great strain on his credulity; and he may without much difficulty imagine that he himself can annually repeat the work of creation by his charms and incantations.

Fundamentally the human mind, so far as etiology is concerned, is like nature; it abhors a vacuum, and it is human by virtue of this very quality which is said to separate man from the brutes. Man only with reluctance and after long wrestling with the problems before him comes to the agnostic state of mind. He must have a reason for things. "*Felix qui potuit rerum cognoscere causas.*" Savage man and modern man in the face of mystery delude themselves into thinking they have found a reason, by filling what would otherwise be a sort of vacuum, with an incomprehensible agent, vitalistic for modern science—a spirit for the savage. The very fact that he has the mental energy to fill the gap in his knowledge with *any* concept asserts his humanity in differentiation from the brute. False reasoning is vastly better than none, and agnosticism has its dangers as well as credulity. It was vastly better that he believe an anthropomorphic spirit dwells in every object, material and animate, than to give no thought at all to the "causes of things." Some savages have been observed at least partly in this state. When the savage lost his idea of an indwelling spirit he lost the idea of the process of continuity of phenomena. He became an agnostic—did not know and finally did not care. Of course this is only approximately true, for the tendency always is to fill the vacancy, but the "ignorant white man," devoid of pantheistic concepts, takes his faith on authority which is worse mentally than the heathen's fetish or his essential agnosticism in its lowest expression. We are not concerned with this phase of primitive mentality; it is one of the dead twigs on the stem of early mental evolution which has fallen out of the line of the evolution of thought. We should be quite ready to believe that "before the dawn of human reason evolution was a gradual unfolding of reality to the sentient consciousness,"[4] were it not

[4] Ward, Wilfred, *Edinburgh Review*, January, 1916, p. 73.

for the implication that humanity was born before human reason. One is less inclined to demur at the view that there were products of human mental activity which can not be dignified by the label of scientific, but we can hardly look upon this as a pre-evolutionary period. Despite the apparent chaos, we know well things then were taking shape—even though beyond our ken. Without allowing myself to be betrayed further into mere terminology, it is evident that this unfolding of reality to the sentient consciousness is the product of the environment in which of course other factors are integrated. One of the results of this has been the myth-making deductions which have, it seems to me, frequently led students of the evolution of human thought astray. It doubtless belongs to its inceptive stages.[5] The child shows obvious traces of it, but that very mental activity which in its exaggerated form in children leads them to lying, or more charitably to romancing, it seems to me is not a safe guide for the pre-historian in tracing out the processes of primitive thought and still less reliable in reading into the records of prehistoric man what was little more than the result of the suffusion of the gray matter of the brain with an increasing blood supply. Surrounding influences, so different usually from our own, at least the extrinsic ones, present a whole mass of inherent ideas to the individual consciousness of savages, and these find expression to some extent in mythological traditions which may indirectly furnish us with clues to matters otherwise dark to us, but when these are the only clues, it is safer to limit our conclusions simply to a belief in the marked cerebral activity of primitive man. When, however, we have concomitant hints of the direction such manifestations of primitive mentality take, we may venture further. Changes in the weather are preceded by certain appearances of the clouds and of the leaves of the trees and the grass of the plains, by certain actions of animals and birds. These are still obvious to the close observer of nature who lives in constant communion with her. Few educated people to-day do this. Even if they do, they are warped by their book knowledge and their theories and prejudices to such an extent that not only are they unable fully to profit by the observation of such phenomena, but they are unduly skeptical of what these phenomena meant to savage man.

In studying the old civilizations, we are reminded that the Mesopotamians, and those dwelling on the Nile, were able to prognosticate many things which escape us, but they resemble

[5] Wundt, Wilhelm, "Outlines of Psychology," tr. by C. H. Judd, third revised English edition, Leipzig, 1907.

us in the tendency to an optimism and a credulity which led them into theories entirely false. Because the swallows fly low before a storm and other birds have a peculiar note, because the migration of certain flocks presage an approaching change in the season, because a moderate number of future things are betrayed by the behavior of animate and inanimate nature they believed, or their priests and rulers feigned for their own necessities and purposes to believe, that they could by observing such behavior foresee fortune or misfortune in social and political affairs; their physicians believed or feigned to believe for their own necessities and purposes in theories of causation and methods of cure lacking logical foundation. It was not a lack of their power to observe, it was the lack of the critical faculty in their contemporaries or the impossibility of their exercising it and not their lack of objective knowledge which led them or tempted them astray. Here we are on common ground. Our own situation in the last century or two curiously resembles that of primitive man. The opportunities for observation, the dragging to light of new facts, has in a measure swamped the processes of logical thought. Analysis of the meaning of things in scientific records has become puerile, and the memory of the facts themselves in this futility of attempt at utilization slips rapidly away from the consciousness of civilized men. If the variation in the aspect of an animal's entrails may not, the conjunction of certain stars in the sky, the phases of the moon, *may*, at least account for certain climatological phenomena, and, perhaps oftener than in our scorn we admit, for certain etiological and pathological phenomena of disease; they may have directly or indirectly much to do in altering the pharmaceutical behavior and the therapeutic effects of the leaves and juices of plants. They may have some sort of relation to the recurrence of the rut in animals, and there may be some coincidence with the mysterious phenomena of menstruation in the human female. If that is so, modern science has not discovered it or has arrived at only a vague adumbration of the connection. They do not impress the modern man, because they do not run in certain channels which his mental faculties are now accustomed blindly to follow without the exercise of reason. When, however, certain modes of *modern* thought are followed in discourses on etiology rational exercise of the mind promptly sinks out of sight. Primitive man, no more than the most recent of modern men, tends to lend to these vague and usually fallacious hints of natural phenomena a significance often entirely illogical and absolutely devoid of rational analysis. He was no more often given to it, perhaps, but he certainly no less frequently allowed his reasoning powers to sink into abeyance, and by social inheritance he had much less material on which securely to exercise them.

We must reluctantly admit this, and to admit it is to deplore it, but to a degree we are also in a position occasionally to admit and to rejoice in the faculty of imagination vouchsafed to man as one of the gifts that differentiate him from the brutes. Inappropriately used and uncontrolled as it often is, the boundless things that appeal to the imagination and the priceless possession of it, and not alone the powers of observation and memory we share with the brutes, are the incentives and indeed the means of human progress. There is something in the appeal of the prophets to higher powers which continues to move the soul of man long after he has ceased to believe in their vaticinations. The forecasts of Isaiah and the Songs of Solomon strike a chord in the emotions of men like Byron's "Apostrophe to the Ocean" and the poems of Ossian. The more direct the contact with these primeval feelings and these forces of nature, the more acutely are the minds of men moved and the more completely are their actions controlled, which is the practical thing for ruler and priest, for prophet and physician. The Indian medicine man invoking the mighty waters to help him in his ministrations appeals to the emotional side of man and the value of it as an adjuvant, or of like things as the very sheet anchor of therapy, can not be overestimated. Yet wherever one studies these incantations, however faithfully they may be transcribed, there is always to us something incoherent about the flow of ideas. Those of primitive men and quite as much those of another civilization jar and weary us. This is not altogether due to our lack of comprehension and sympathy with ideas and an age which has long since passed away and is all but lost to us. We know that our own phylacteries do not bear analysis and we may well believe that such things may have seemed quite as incoherent in the time of Pharaoh as the outbursts of modern emotions when questioned do in our own time. We scoff at the Babylonian prayers. The scoffers at our own have quoted them in derision. Our own are music to the souls of some of us, unbelievers that we are, while around the pillars of our thought they are so entwined for others; they are so incorporated with the fiber of the feelings that most of us fail to see how absurd and inane and meaningless they are in the cold light of analysis. If that is so to-day, why should we understand such things echoing from the banks of the Nile across 4,000 years? But if for a single moment we forget their power of appeal to the emotions of the dwellers along its banks we shall surely fail to understand the course of the evolution not of history alone, but of medical thought. They are not only a valuable asset in therapy, but they profoundly influenced theory.

Man has never ceased to profit by such musings, by such exercises of the imagination. He gathers his herbs when the glint of the new moon is on them—perhaps at one of the new moons their medicinal properties are more available, but they more often remind him of something associated with the malady as he understands it. His belief and his faith inspires the patient subjectively in as helpful a way as objectively the juice of the leaf has accomplished. He summons the spirit of the rushing waters and he treasures the shining stones they have polished. They fit in with some notion which flits through or finds permanent lodgment in his brain. The association of these ideas we can seldom hope to trace, but we must neither fail to appreciate their power, nor forget the germ of truth which lies concealed, evidenced often by objective results which we are able to grasp. Fetichism and animism and many another manifestation abhorrent to our rational precepts have arisen from such imaginative musings of the physician-priest. He has transmitted them to us in the various forms of superstitions still or lately with us; ghosts, enchantments, charms are still with us or a tradition of them is familiar to us yet. These are but remnants of the earliest forms of beliefs in spirits and demons which took anthropomorphic forms in the deductions of the science of earlier times.

Not only did demons in human shape persist until long after our own traditions participated in the current of human thought, but the theriomorphic concepts of the soul have left traces with us. They go back to primitive man. I have attempted to show elsewhere how early and how widespread in its influence on medical theories was the idea of the soul. The invisible wraith or breath in its flight from the body, like smoke, their imagination pictured so vividly that in the mind's eye they caught glimpses of it as it flew upward. In the stories that have come to us from the primitive Australians and Melanesians, we find them declaring they hear the wings of the spirit of man as it flies aloft on some errand of the tribal wizard. The whir of the pinions announces its return, and the people declared that he whose soul thus flew aloft was found to have sprouted feathers on his body.[c] Now it is not difficult to see the connection of ideas, nor the reason why the affiliation persisted

[c] Smyth, R. B., "The Aborigines of Victoria," Melbourne, 1878, 2 vols.

through the queer feathered bewinged bird bodies perched as the Ba souls on Egyptian tombs, through the foul harpies of Greek mythology, through the lofty conceptions of the soul in Plato's dialogues, to the winged angels of our own Christian cult. The thought started with the fugacity, the evanescent nature of the human soul, it carried well the materialistic burden of Egyptian conceptions, it found ready acceptance in the aspirations of the human soul as Socrates unfolded them to Phædrus under the murmuring leaves of the plane tree on the banks of the Ilissus. The soaring aloft of man's spirit to mansions in the sky in the religion of Christ adapted the primitive, Egypto-Greek mechanism again to an aerial or etherial medium.

It is rarely the case, but it sometimes happens, that we can thus follow the course of human thought from its primitive source in the budding intellect of man through the vicissitudes and cataclysms of ten thousand years to our own day. It is a striking exemplification of the unchanging psychical and mental nature of man that a spiritual environment should have preserved and developed a materialistic soaring on the wing, which the wondering savage daily saw in the flight of birds from the earth to the sky over his head, into the stimulating spiritual thought of the soul of man aspiring to things not of this earth. Elsewhere also I have sought further exemplification of the pneuma, the counterpart or alter ego of the soul, springing from the primitive observation of the advent of death coincident with the cessation of respiration and the stoppage of the breath developing into a theory which created an imaginative anatomy for the Egyptians and a suggestive basis for the etiological and pathological conceptions of Greek medicine. I have tried also to show how the fatal gush of blood from foe or friend, or from the quarry in the chase, created the art of hepatoscopy with the Babylonians and their Etrusco-Roman heirs, and ultimately grew into the Galenic humoral theory. It is not necessary here to repeat the argument which brings out the physiological environment which made possible the persistence of these primitive ideas in regard to the "breath of life" and the blood as "the life," to an efflorescence within at least hailing distance of our own times. Neo-humoral theories are still reminiscent of the blood rites of brotherhood of the African and Australian wild men, which in turn were based on the phenomenon of fatal hemorrhage in man and beast.

I may now turn from these themes, more or less familiar to us all, at least in some of their aspects, illustrative of the en-

[8] *L. c.*

vironment which originated basic conceptions and favored their persistence from the infancy of mankind to an advanced age. It is not difficult to acquiesce in the view that for the few threads we hold in our hands to-day, a million strands have been broken and lost to us in this vast interval of time.

With the racial idiosyncrasies of other races we need have little concern, but it so happens that in the story of the consecutive development of thought the negro and the Greek play for us important rôles. It may be that other races, when we know more of the ramifications of thought and theory which have entered the fabric of our own civilization from them, may exhibit idiosyncrasies as striking as those which greater and more careful study of the black African and the white Aryan Greek have revealed to the student of their ethnography. It has been much the fashion among ethnologists to insist that the mental capacity does not greatly vary, that the cerebral hemispheres occupied as much cranial space ten thousand years ago as they do now, some insist even more. I can not presume to contradict this view of those much more competent than I in the matter. I may, however, seek to circumnavigate a rock in my course, which I can not help regarding with some misgivings and with some inward revolt, by suggesting there are brains and brains, in which doubtless I should receive aid from those more knowing, and by adding that there are also capacities and capacities. I may perhaps leave the question of functional efficiency in the anatomical organization of the cerebral tissue, for that is still and probably will always remain a refuge for those when hard beset who are reluctant to deny the evolution of mental capacity to a higher plane than it occupied in the time of the cavemen. Lord Avebury was of the opinion that, given the same environment, the human mind works in like fashion everywhere, and its results are all but identical.

The negro or negroid race, a very vague term I admit, is one that interests us in this connection not only as a theme to illustrate the basis of belief, but because it is directly in line with our ancestral inheritance of culture and civilization, for the primitive Egyptian and his civilization were not simply African, but negroid, and we through the Greeks are the heirs of its culture. Now, in this country, the contest as to racial cerebral efficiency rages around the negro. Ethnologists for the most part declare that his backwardness in this country is not due to racial inferiority, but to social handicap. The arguments against this view, with which I confess I sympathize, are familiar to most readers, and I do not propose to parade them here. I prefer to take the view of Miss Kingsley and many others, who have studied him in Africa and who declare he is vastly more spiritually minded than the modern predominant type of white man; but we also have many spiritually minded individuals among us. Spiritually minded people, white or black, set down in a population of an essentially materialistic turn of mind need guardians from the cradle to the grave; so with the negro; with his congeners in Africa he may indeed, as have the Hindus, evolved civilizations and built empires, but the pantheism bred in him by heredity and strengthened by environment, perhaps by selection, has placed him on a poor footing with the materialistic white man in this country. The white man invites him to take a seat at a game evolved by and for the white man. Why indeed should he not fail? It is not his game. Now I do not wish to raise the question whether the white man's game is a better game than the black man's game nor the question of the inferiority or superiority of one race over another, but while I have had little or no experience with other races, I think the black race shows radical mental differences when compared with the white race, and I can not help sympathizing with the view that there is something, not radically wrong, but radically different also in the thinking of the educated white man and of primitive man, though there can be no question that the difference has been, perhaps still is, grossly exaggerated.

In torturing ourselves to be kind and patronizing to the men of other races, in wishing to make them feel complimented by assuring them they are just like us, we assume the attitude of the most egregious and narrow-minded vanity. We tacitly assert that the captain of industry who knows how to cipher and calculate and by means thereof to bully and dominate his fellow man is the highest type of human nature conceivable. We ignore Swedenborg and the prophets, in which class the negro belongs. At different historical epochs the ideal type, as put in the foremost ranks for veneration by the white race—the warrior, the ascetic, the materialist, the idealist, the altruist—has come and gone. Representatives of each class at every epoch are always readily found and have enjoyed their heyday of popularity and have given place to a new admiration. Men differ and so does the mean type of the race from age to age, according to its stage of progress, but to say which is inferior, which is superior, smacks of intolerance and involuntarily we smell the martyr's burning fagots, we hear the chains of slaves and the creak of prison doors, we see the endless line of the crucified who have not fitted into the general scheme of things. The negro's mind is at antipodes with the Greek mind. It does not analyze, but it believes, with a faith which is entire and absolute, that crude impression which first reaches it through the senses. The negro is emotional not only in sensual fashion, but in a spiritual fashion, and as he once was portrayed on monuments now 6,000 years old so he remains to-day in Africa or in America, but who is there to deny that much which is best in our own civilization had its origin in some man's supreme capacity for spiritual emotion, which the negro has in such a marked degree?

Whether we think it of "low" or "high" mentality, the spiritually minded when pantheism was the universal theory of mankind, were its rulers, and they shaped the infancy of primitive thought. We can, therefore, not be indifferent to Averburys opinion that "the human mind works everywhere in like fashion"—to deny it is a very different thing from denying that one mind is more practically efficient in our own view as to what is worth while. We are far from being unbiased judges in deciding what is a superior and what an inferior mind. Moreover, the whole form of the discussion is grossly unscientific, because unconsciously we discuss it from a standpoint that is subjective, not objective.

In introducing the Greeks I do not do so to adduce another and a contrasting example of racial idiosyncrasy, though it is a striking one. I do it chiefly to force home the previous argument. All students of the dawn of history—all those who have pried into the practical life and the esoteric life of the ancient oriental civilizations so far as their details before the Trojan war have been revealed to us, feel that with the advent of the northern races around the Ægean Sea something almost cataclysmic happened in the smooth course of the progress of thought and emotional life, in philosophy and art and religion. The strain of adjusting oneself to these things, among the Egyptians and Assyrians is relieved as we look upon the art of Crete and read the dialogues of Plato. The cannibalism of primitive man revolts us scarcely as much as the pæderasty of the Greeks, but ancient oriental thought and emotion estrange us still more. We turn to the northern invader, we whose blood flows from his ancestors in western Europe, and we realize that "East is East and West is West." Why indeed then should we not think that the negro, whose spirit lay so heavy on the brown race that dwelt along the Nile and around the Mediterranean, is an inferior race? We understand the Greek, we are of his blood, his way of thinking, his religion, so far as he had any. His analysis and criticism, the spirit of his music, his plastic and dramatic art, flowed to us around the northern ends of the Alps before we found him again in the Mediterranean. We look down the paths of the black race and they are dark to us. It seems to me then this aspect of the question, imperfectly exposed as it is here, is an added reason for us to realize that the basis of primitive belief must have been affected not alone by environment, but by the fact that all men do *not* think alike in it either individually or racially.

The psychology of the crowd manifested by beliefs due to no individual process of reasoning, but to contagion, need find no place for discussion here, since they have less to do with the basis of belief than with its propagation. We may more profitably turn to one less discussed in current literature. In a recent book[7] on the ethnology of Africa there is a long and careful description of the art of divination by means of casting bones, the astragalus bones of various animals, domestic and wild. It is a very complex and absorbing occupation—not a child's play at all—but it requires considerable mental concentration, not a common thing apparently among primitive men. The rules are well known to all the tribe, but the mental effort to interpret, *i. e.*, to drag present, past and especially future, events into harmony with its rules and their results, is very great and necessarily at once trains the intellect, and, through the skill acquired, excites the admiration, and, through the concomitant awe and fear of approaching disaster or joy in the anticipation of agreeable experiences to come, makes the expounder and practitioner distinguished. Attention is drawn to this matter by another observer[8] of primitive man in Africa, who declares that the wizards are dupes of their own mental abstractions, their thoughts being based on natural impulses and emotions. The absorption of the attention and the concentration of thought in themselves are entirely sufficient to enlist the faith of the performer in his own assertions and prophecies; he believes in it, just as the doctor or ecclesiastic or the scientist believes in what he is working at, not through its intrinsic value as a method of arriving at the truth, but because it absorbs his attention and diverts it from a study of the environment. It is a hypnosis with the Bantu conjurer in the same sense that the doctor's art, the theologian's belief, the scientist's experiments, are to them.

[7] Junod, Henri A., "The Life of a South African Tribe," London, 1912–13, 2 vols.

[8] Leonard, A. G., "The Lower Niger and its Tribes," London, 1906.

It is Nature's revenge on man, who attempts by earnest fierce attention and energy to wring her secrets from her. She hypnotizes the assailant, or the suppliant, just as the snake charms the bird, just as the hypnotist influences the neurotic and the hysterical. It is the intensity of the preoccupation of the mind of the saint which throws him into an ecstasy or a catalepsy, the very antithesis of the detachment which the knowing seeker of the truth cultivates. He who allows himself to be mastered by his subject may indeed acquire honor and riches, but the thing he seeks eludes his grasp. Usually he passes into the twilight of mental inertia from the soothing effect of the honors and riches upon his sense of critical discrimination. When he becomes incapable of laughing at himself, he is in danger of damnation, and of course excessively disagreeable.

Contagion in the crowd and intensification of application in the cloister are somewhat aside from the basis of primitive belief, but they lie close beside it. They do not necessarily guide it into false paths, but on whatever highroad faith, true or false, is found they accentuate the pace along it. Errors of logic, on the other hand, also lying close to the foundations of belief, alter the direction of faith. Though modern errors of logic are scarcely less flagitious than the ancient, I should be presumptuous indeed if I attempted to point them out.

Hume said there is a universal tendency in mankind to conceive all beings like themselves and to transfer to every object those qualities of which they are intimately conscious. Goethe puts it in the mouth of the supernatural spirit, to whom Faust wished to liken himself, thus:

Du gleichst dem Geist
Den du begreifst
Nicht mir.

This anthropomorphism was as all-prevading in primitive medicine as it was in primitive religion. It is not for us here to inquire whether modern religion has freed itself from this motive or not. Suffice it to say if this was not one of the fundamental motives on which rested the belief of primitive man in magical medicine, it was a fertile source of error in its inception and long continued one of the glaring vices that perverted the logic of antiquity, for anthropomorphism is but one aspect of parallelism. The roots of the Babylonian astral system[9] rest on his view. The continuous sameness of the repe-

[9] Oefele, Felix von, "Janus," XII., 1907, p. 196.

titons of the courses of the heavenly bodies seemed to base its only explanation in a law of parallelism which rules nature and history alike. It was and is a blindness to the true nature of sequences, an ignorance of the laws of chance and coincidence. It is long since this fallacy of logic first dawned on the human intellect, but it is still often persistently oblivious of the falseness of the deduction "post hoc ergo propter hoc." In Babylon the observations of parallels was the chief concern. A fund of wisdom was built up on the basis of the painstaking collection and observation of facts and their sequences. The folly of disregarding the terms of logic was as little heeded then as now. The political, religious, historical events in sequence to certain stellar and cosmic happenings became a matter of voluminous record and unquestioned guidance. Vegetation dying at the conjunction of certain heavenly bodies and springing to life again when other conjunctions supervened through induction of parallels gave rise by deduction to religious and physiological conceptions of resurrection and of life after death, which still actively persist in their theocratic form at least. We see the trail of this sort of reasoning everywhere. It is doubtless very much more the process of the primitive mind than of the modern, but there it is more insistent on our attention, because we examine the mentality of remote generations much more critically and much less sympathetically than our own. I have only alluded to the astrology of Babylon, but the records of observations made on modern primitive men are pervaded with it.

If we can boast that we have almost banished from our scientific processes of reasoning the vices of anthropomorphism and parallelism in most of its other forms, this is not the case with another vice of logic, which I venture to say is quite as prominent in modern reasoning as in that of the cave man. Castelnuova is quoted[10] as saying:

> To an eye more piercing than our own the universe would seem apparently more complex than we imagine it; but fortune has willed that the imperfect senses should fail to reveal to the first observers of the world the great number of anomalies which were apparent later and has constructed, so to say, foregrounds of the picture, each succeeding the other. The building up of present-day sciences would have been vastly more slow if this perspective had failed and the successive observers had attributed the same value to near and far objects.

Now this may be so. The man of the stone age, had he realized the complexity of etiology, might well have given up in despair the project of finding the cause for anything. If it seems never

[10] "Scientia," 1, v, 1916, p. 341.

to have dawned on him that a phenomenon could have more than one cause, it was due to that kind of pantheism which he held to be the state of nature which obeys no law. He looked upon life not as a process, but as a fiat. "Let there be light; and there was light," and that was all there was about it.

Now of course this simplicity of conception is no longer the characteristic of trained and exceptional minds. Lord Kelvin when he wished to explain to himself a complicated question in physics depended upon the imagination of, or on actual construction of, a mechanical model to represent all the factors which influenced the result. A series of pulleys and levers, sometimes to a very great number, each represented to his master mind an object on which to attach a weight or exert a traction which by means of the connecting thread of causation, was acted on by other factors and all combined to give at the end of the series a totality which represented the expected answer.

By the joint action of a certain temperature, a certain amount of moisture, and a certain miasm, upon an individual of a particular diathesis, who happens to be in a particular state there may be produced the immense complication of effects constituting a disease.[11]

The great philosopher who wrote this sixty-odd years ago may have had his counterpart 6,000 years ago in Mesopotamia, but the vast majority of men then and the vast majority of men now have their minds exclusively fixed on that one word "miasm"—"devils" says the one, "plasmodium or bacillus" says the other. I am not introducing this here because it only disfigured the reasoning that clustered around the basis of belief in the stone age, but because it has failed to acquire that prominence in the discussion of primitive methods of thought which can only be explained by modern as well as by ancient oblivion to its pernicious influence.

If there is such a thing as an innate tendency of the human mind it is that instinct for the conservation of energy which finds its expression in intellectual processes in the endeavor to simplify the contemplation of causality. The common run of men are incapable or stubbornly indisposed to visualize but one of Lord Kelvin's pulleys. Spencer's modifying causes introduce a complexity which pains them and angers them.

[11] Spencer, Herbert, "The Principles of Psychology," New York and London, 1910, 2 vols.

"MAKING THE WORLD SAFE FOR DEMOCRACY"

By Professor CHARLES A. ELLWOOD
UNIVERSITY OF MISSOURI

WHEN Presient Wilson in his War Message to Congress uttered his famous phrase about "making the world safe for democracy," it is doubtful if even he, with all his social and political acumen, understood all that was involved in such a proposition. Certain it is that very few of those who use the phrase so lightly understand. It has become a rallying war-cry, a catch-word to arouse enthusiasm for our doing our "bit" in the war. It would be a pity if it should turn out that this is the only use which we are to make of such a phrase. For surely there is contained in it a program for peace as well as for war; and much more for peace than for war, because the world can not be made "safe for democracy" through war. It is a commonplace with students of social history that war through all the ages has been one of the greatest enemies of democracy. Not only has militancy tended towards the rule of force and towards despotism in general, but even a defensive warfare, such as that in which we are now engaged, has more than once resulted in the subversion of democracy both in government and in society at large. The reasons for this will be plain as we proceed. We wish at this point merely to emphasize that war can never make the world "safe for democracy," and that a much larger program than winning the war is implied in that phrase.

The masses undoubtedly think of democracy merely as a form of government, the rule of the "people." Students of society, however, know that this is only one aspect of democracy and that democracy is to be understood only as a form of social life; that the political phases of democracy rest upon social and moral foundations much deeper than mere governmental forms. Even when conceived as "the rule of the people," the question always remains, "Who are the people?" This question has been answered so variously from age to age that the answers summarize the whole history and trend of democracy. In ancient Greece the "people" were a master class imposing their authority as a sovereign group upon a population of which from one half to four fifths were slaves, and another very considerable fraction without citizenship rights. From the modern point of view Greek democracies, so-called, were not democracies at all, but were authoritarian, despotic societies, ruled by a very small oligarchic or aristocratic class. Throughout our own history, indeed, the definition of who constitutes the people has been so narrow that only a very small fraction of our population has had any actual share in the work of government. Slaves were excluded from our conception of the "people" until the Civil War, and women until very recent times.

On the other hand, in primitive times, modern anthropology tells us, as among some existing savage and barbarous peoples, there were democracies in which the "people" included all the adults recognized as belonging to a particular group. In these primitive democracies, such as those of many North American Indian tribes, clan and tribal assemblies or councils decided all matters pertaining to the group as a whole; and in such assemblies not only the men, but also the women, had a voice as a rule. There were two outstanding features of these primitive democracies, however, which sharply differentiate them from democracy as we think of it in the modern world. Majority rule was practically unknown among them but every decision which they reached regarding group action had to be a practically unanimous decision. This rule of unanimity made the the primitive democracy static, non-progressive, or at least very slow to make changes. Hence the second feature of their life which differs from ours was that democratic control with them was almost wholly the control of custom and tradition. Intelligence, after all, had a very small part to play in such habit-ridden communities.

Modern democracy is accordingly something quite unlike its classic and primitive prototypes. Democracy in classic antiquity was really aristocracy or oligarchy; in primitive times it was simply the rule of custom in a group of sympathetically likeminded individuals. Unlike ancient democracy, modern democracy is unwilling to recognize any subject or servile class, or indeed any class of adults who are excluded from political privileges. It rests rather upon the recognition of the potentially equal social worth of all individuals. Unlike primitive democracy, modern democracy does not rest upon the *customary* similarity of habits, feelings and ideas of the group, but aspires rather to rest upon the *rational*, intelligently formed judgment of every normal adult individual in the group. It is a serious sociological error to confuse the various types of social life and of government to which the term "democracy" has been applied. Modern democracy, it is evident, is a wholly new stage of social evolution, and may truly be called "the great adventure" of our civilization.

The various stages in the evolution of social control will make plain to us the nature of modern democracy, and why it is the great advanture of the modern world. A review of these stages will show, in other words, the exact significance and nature of modern democracy in relation to social evolution. The lowest form of social control of which we know is that which rests upon instinct and upon the correlated selective processes of the natural environment. Such social control, if such we may call it, is characteristic of animal groups. But the lowest human groups of which we have knowledge show a very different type of control—that of habit, of custom and tradition. All existing savage communities of mankind show this type of control and we have every reason to believe that it represents the primitive human social condition. It is the type of social control which we find in the primitive democracies just mentioned. The control exercised by them was through the sympathetic and formal likemindedness which rested largely upon the sentiment of kinship; and hence the organization of such primitive democracies was of the simplest sort.

A third form of social control is that in which the control is exercised by the despotic power of a small group of individuals over a larger group. This control sprang from the conquest of one group by another. After the conquest and subjugation of one group by another, of necessity some sort of machinery of government had to be elaborated in order to establish and maintain the unity of the whole population. Centralized control in the hands of definite authorities became inevitable. Under such circumstances the war chief usually developed into a king, with his authority more or less limited, however, by the council of the conquering tribe. In many cases despotic forms of monarchic government gradually developed; but in some groups the tradition that the freemen of the conquering tribe were the source of authority persisted, and after the subjugated elements had become reconciled to their position as slaves, the former drove out their kings and distributed authority again democratically among themselves. Thus arose the spurious "democracies" of classic antiquity. They were democratic only with reference to the members of the conquering class. In essence, however, they were authoritarian societies, since the ruling class maintained its authority and the unity of the whole population through a fear-inspired obedience. Their utter unlikeness to modern democracy is evident. They belonged to the authoritarian stage of social control and of social evolution.

Authoritarian societies of one sort or another, whether styled "democratic" or "autocratic," have characterized the greater part of the history of western civilization from the earliest times down to the present. The most prominent national groups of the modern world until very recently have been of this type. But within the last one hundred years or so a fourth and higher type of social control has been gradually emerging in the most advanced nations of western civilization —a type of control in which the unity of the group is secured not through custom and tradition based upon the sentiment of kinship, nor through coercive authority, but through the intelligent purpose and will of the whole population. We may call this new type of social control "free society" in contrast with the custom-ruled and the authoritarian societies of the past. This is modern democracy. In essence it is a form of social control in which the untrammeled opinion and will of every adult member of the group enters into the determination of group behavior. As Hobhouse says: "It founds the common good upon the common will, in forming which it bids every grown-up, intelligent person to take a part."[1] It is much more, therefore, than a form of the state or of government. It is rather a new phase of social evolution, a phase which attempts to reconcile individualism and collectivism. Social control of some sort in every complex human group is necessary; but democracy would admit to a share in that control the wills of all the adult members of the group who show any intelligent interest in the control of the behavior of the group. Evidently there is a reason for calling democracy in this sense "free society." Evidently, also, it is a new experiment in the world's history, the nearest approximation being those primitive democracies of the past which were ruled essentially by custom and swayed by sympathetic rather than by rational likemindedness.

It is now evident why democracy, in the modern sense, is at once the hope and the great adventure of our race. It is the hope of mankind, because it is to groups what self-determination and self-realization are for the individual. It represents, if it can be successfully achieved, nothing less than the final phase of social control and of political evolution, the goal

[1] "Liberalism," p. 228.

toward which all human history has been striving. On the other hand, it is an adventure, because its success obviously depends upon the possibility of vast masses of men forming rational opinions and executing rational decisions as a group. Now this is only possible when there is adequate machinery to develop rational likemindedness and a rational will in the group as a whole.

Democratic society, in other words, must find a means of selecting among all the possible opinions which the members of a large group may develop the most rational opinion and of basing group decision and group action thereon. Modern democracy depends, therefore, upon free thought, free public discussion, a free press, free assemblage, and free selection of public policies and public leaders; for if we do not have free thought and free public discussion before a policy is entered upon, we cannot have that process of mutual education by which the most rational ideas are brought to prevail. Intercommunication, according to psychology, is a method of reciprocal adaptation between individuals; and as soon as freedom of thought and of public discussion are abridged the whole machinery of adjustment in a group will be hampered—it will be impossible to compare ideas and to come to a rational judgment regarding group policies.[2] In other words, it is only through free discussion and the formation of a public opinion, untrammeled either by the prejudices and emotions of the whole group, or by the interests and power of some special class, that democracy can be a safe and efficient means of social control. In democracy, then, it is public opinion which is the force that lies back of the power of all regulative institutions; and democratic society can be efficient and successful only in proportion as it succeeds in making public opinion rational and powerful.

Some of the difficulties of democracy, as a means of social control in the great complex societies of the modern world, now become manifest. For, how can we secure in such societies the free formation of a public opinion, which is at once rational and powerful? The day of government by "town meeting," or the formation of rational opinion through face-to-face discussion in a public assemblage, is past forever. In great groups, numbering millions, the press must necessarily be the chief means of intercommunication and public discussion; accordingly, it is upon a free and untrammeled press, yet one controlled by a high sense of social obligation, that the formation

[2] For elaboration of this point, see Chapters VII. and VIII. of the writer's "Introduction to Social Psychology" (D. Appleton & Co., 1917).

of a rational public opinion depends. The press to be efficient must represent all shades of opinion in the group. If the press is in the hands of a single class, or of a few corporations, it is almost bound to fail to represent the opinions of all classes and sections. Even more would it fail if it were under the control of one socialistically organized government. Socialism, thus far, has not grappled with the problem of a free press in any convincing manner. Newspapers, periodicals and books published and distributed by the state would be very far from a free press. Yet free public criticism is the very breath of life of that "free society" which democracy is supposed to represent.

Another difficulty of democracy, especially as a form of government, is that in modern societies it can not proceed upon the basis of unanimity, but is forced to adopt the principle of "majority rule." The decisions which democratic governments reach, accordingly, can usually be, even under modern methods of "direct" government by the people, only decisions reached by a majority. In nations consisting of millions it would be foolishness to contend that any social will had been formed when a bare majority had decided some social issue. At best, such a decision is but a temporary compromise. Definite social choice has not really been reached, and hence the whole situation remains unstable. But unity of thought, feeling and will is necessary for successful action in a group. Of course it is easy to exaggerate the dangers of bare majority rule; but there can be scarcely any doubt that a great deal of the inefficiency of democracies in the past, of their lax enforcement of law, and of their internal dissensions, is due to this fact. Further discussion and a more fully developed social consciousness regarding the situation are evidently what is needed, in a majority of such cases, to obtain a social decision which is truly representative of the will of the group. The safety of modern democracy, accordingly, depends upon employing every means of public education which will fully arouse the consciousness of the group regarding any given social situation. And this, again, depends upon freedom of intercommunication and of public discussion.

Another difficulty of democracy here comes into view; and that is, how far is the control exercised by the majority to go? If it goes so far as to suppress free opinion, free speech, and free discussion, evidently it is in danger of undermining the very basis of democracy. Rather democracy, in any intelligible sense of the word, is already destroyed when free thought, free speech and free discussion in a public press are suppressed prior to the making of a social decision. But even in the case of decisions made by a majority, the possibility that the decision fails to represent the will of the group, or that it may be a mistaken decision, makes it important that free thought and free speech shall be preserved after a decision is made. Real democracy can only be safe when a minority has the right to try to convert a majority to its views by using all rational means to show that a social mistake was made. Hence the rights of majorities in true democracies can never be "absolute." There can be no absolute government in a true democracy, therefore, despite Rousseau's argument to the contrary. In practise modern democracies have not attempted, as a rule, to exercise control over the opinions, beliefs and practises of the people in many matters, as, for example, in religion. It is time that the myth of the absolute sovereignty of the state or government were exploded. Such a myth under autocracy may be very useful, but under democracy it is bound to be dangerous. It is time, therefore, that all modern democracies recognize that their principle is "limited majority rule" rather than "absolute majority rule." But the dogma of absolute majority rule prevails in most modern attempts at democracy, and perhaps nowhere more than in America. Under absolute majority rule freedom of thought, speech and conduct is bound to be lost; and democracy will turn out to be nothing more than the tyranny of a majority, which in order to maintain itself will seek refuge more and more in autocratic principles and practises.

It was perhaps the perception of this danger which led our forefathers to adopt the maxim, "that government is best which governs least." But we see that this principle of non-government is also dangerous to democracy, more dangerous perhaps, than the exercise of an absolute and rigid control by a bare majority. If modern social science has demonstrated anything in a practical sense, it has demonstrated that social control must extend over all of the activities and interests of life. The doctrine of *laissez faire* is dead because it will not work as a practical policy under modern conditions. We now see, as Mill said, that the function of government, as an agency of social control, is "coextensive with human interests." However, if government is going to embrace all human interests, and if democracy is the free formation of a social will out of all individual wills, it is evident that there must be a high development of intelligence and character in the individual citizen if democracy is to be "safe for the world." The individual citizen must understand the social consequences of bad industrial conditions, bad sanitary conditions, poor education and corrupt living. But the democratic control of social life through governmental agencies is necessarily limited, in its direct action, to relatively *external* conditions. This being so, and democracy being dependent upon the freedom of the inner life of the individual, it is evident that *the success of democratic governmental control will depend not so much upon governmental coercion of the individual as upon eliciting his spontaneous initiative and intelligent cooperation.* A democratic government, in other words, to be successful, must represent the spontaneous and intelligent cooperation of the whole mass of its citizens in what Aristotle called "well-living." Strictly speaking, it is not a government at all in the old-fashioned, authoritarian sense of the word. It is rather the free, collective control of the whole group over the conditions of its own existence.

Under what conditions can democratic control over the conditions of collective existence be successful? Manifestly, only when there is a good degree of intelligent likemindedness in the population as a whole. No one has perhaps stated the matter better than Professor Giddings. In answering the question, he says:

> Upon what basis have free communities risen and flourished? Always this: the people that have made them and maintained them have been sufficiently likeminded, sufficiently alike in their purposes, in their morals, in their ambitions and ideals, in their views of policy and method, to work together spontaneously. Naturally there has been among them what the old Roman lawyers called "a meeting of minds," so that without a whip over them, or a strong hand to hold them together, they have collectively carried on the struggle for existence and advantage, freely and effectively. They have all seen the same truth; they have all wanted the same success, they have striven by the same method for the realization of the same great purpose.[3]

But the old sympathetic and formal likemindedness which sufficed for primitive democracy will not work, as we have seen, under modern conditions; modern democracy can depend only upon *rational* likemindedness, and indeed it aspires to rest upon nothing less. But rational likemindedness depends upon the education of the whole body of citizens with reference to social and political matters. To be a success, then, modern democracy must educate the whole body of citizens in knowledge of social situations and in a sense of social obligation. Especially, must citizens be trained in the knowledge and art of self-government. This educational process should take place largely, of course, in our public schools; but every edu-

[3] Quoted by Professor Newell Sims in his "Ultimate Democracy and Its Making," p. 72.

cational institution, such as the home and the church, should also do its part; and this social education must be continued throughout the adult life of the individual by the press and by free discussions in public assemblages and in "social centers." For only when there is a proper diffusion of social knowledge among the masses and an adequate inculcation of the sense of social obligation can there be developed such a rational likemindedness as to insure the success of democracy. The whole people, in other words, must be kept in a state of continuous learning regarding social matters. The social sciences must be developed and given first place in the curriculum of our schools, and the mutual education in social matters which comes through the public discussion of social policies, either in the press or in public assemblages, must be encouraged in every way. One can not but remark here upon the foolishness, not only of placing restrictions upon the freest formation of rational likemindedness and public opinion, but also of needlessly complicating the situation in communities struggling toward democracy by introducing illiterate elements, or those who through race, language or tradition are incapable of becoming rationally likeminded with the rest of the community. If such there be, a too widely open door for such non-assimilable elements must make democracy unworkable.

The problem of democracy must not be discussed, however, too exclusively from the standpoint of government. In its essence, as we have seen, democracy is a form of the social life in general, and not simply of government. Nothing could be more opposed to democracy than such hopeless poverty as prevents the normal development of intelligence and character in citizens. As Hobhouse says, "People are not fully free in their political capacity [even] when they are subject industrially to conditions which take the life and the heart out of them."[4] There are other reasons, as we shall see, also why a form of industry which breeds poverty is essentially opposed to democracy. But as a form of social control democracy relates as much to the other institutions of social life as it does to the state and government. Democracy in the state and in government can not long succeed, indeed, unless democracy runs through the whole of the social life. We are beginning to see that a feudal or autocratic industry is a menace to democratic politics. We are also beginning to realize that the family, the school, the church and even "polite society" itself must be democratized if we are to maintain democracy in the state. Consequently, in the family life we find the old authoritarian

[4] "Liberalism," p. 249.

family to be passing and a more democratic type of the family to be evolving. A larger and larger measure of democracy is being introduced into our churches, even though older forms of ecclesiastical organization may persist. Our schools are at least beginning to try out the principles of self-government. Most of our "free associations" are striving to organize themselves democratically, while in the most intimate personal relations of social life the most advanced peoples are seeking to realize democratic ideals.

Now it is in these smaller groups, in the more intimate relations of social life, that the real nature of democracy comes most clearly into view. In these relations democracy has been slow to develop because in them democracy is seen to be something more than a mere form of relationship among individuals. It is seen to involve a social and personal attitude of individuals toward one another. This attitude is not that of absolute liberty or pure individualism. Such individualism and such liberty are the negation of social control. They lead inevitably to the exploitation of the weak by the strong and to anarchy in all of the relations of life. Democracy does not mean, then, the emancipation of the individual from social control. It is rather, as we have already said, a form of social control which attempts to reconcile the inner, moral freedom of the individual with the needs of objective social life. To accomplish this it must necessarily be careful to avoid the destruction of the sense of social obligation by the inculcation of pure individualism. The liberty for which democracy strives is therefore relative to a deeper principle.

Neither is the social attitude which democracy implies that of absolute or dead-level equality. Such equalitarianism destroys the efficiency of social control, because it prevents that coordination of the group in action, that superordination and subordination of individuals which is necessary for efficient work on the part of the group as a whole. It is often said that the spirit of democracy is essentially opposed to the existence of classes. If by classes are meant privileged castes, then there can be no objection to such a statement. But if by classes we mean simply the necessary divisions in society for the performance of economic, political or cultural tasks, then classes are no more inconsistent with democracy than organized social existence itself. Even a football team must divide itself into classes, or various specialized groups of players, in order to act efficiently. Any social group, indeed, of any size which accomplishes anything must differentiate itself into classes. Only the democratic spirit insists that these class groups in society at large shall not be artificial groups, but, like the class groups in the football squad, based upon individual merit and fitness. The classes in a democracy should greatly make, therefore, for social efficiency, rather than tend to lessen it. Absolute or dead-level equality, on the other hand, while it might temporarily gratify the egotistic feelings of those whose capacity and ability fit them only to play the part of "scrubs" in the social team, would destroy social efficiency, and so destroy the possibility of democracy becoming a success in a world where efficiency counts. Absolute or dead-level equality is, indeed, more in harmony with certain forms of autocracy than with democracy.

For these reasons the more careful writers on democracy have generally repudiated absolute liberty and absolute equality as dangerous to democracy. The liberty and equality which democracy inculcates are both relative to its fundamental principle, which, for lack of a better term, we may call "fraternity." By fraternity we mean such sympathy, understanding and good will among the members of a group that what they do collectively represents the uncoerced will of all—a spontaneous expression of the inner psychic unity of the group, or at least of a majority of its members. The liberty and equality of the members of a family group or a neighborhood group, for example, are not to be secured through the formal acceptance of liberty and equality, but only through the likemindedness, sympathy and good will of all the members of the group. Then such liberty and equality as is consistent with the total welfare of the group will emerge spontaneously. We now see why democracy is slow of realization in the general social life, while it has been so readily taken up as a form of the state or government. A doctrinaire democracy is possible in politics; but democracy will scarcely work in the face-to-face groups of men, such as the family and the neighborhood, unless it rests upon the social attitude which we have just called "fraternity."

If we are to have a democratic form of industry, for example, we shall not be able to get rid of such fundamental classes as "the chiefs" and "the people," or "the intellectuals" and "the manual workers," any more than the football team would be able to get rid of its captains, half backs, and full backs. But industry would have to be so organized that it would serve the welfare of the whole group. There would be need of such collective control of industry that the opinion and will of every individual in the group would count in the determination of industrial policies. There would have to be fraternity in the management of industrial enterprises and in the industrial life generally. Consequently, there would also have to be equal remuneration for equal service, and a democratic participation of the workers in the management of every industry, but not to the exclusion of the public which it serves. Whether such industrial democracy implies complete government ownership or not, we need not here discuss. It is sufficient to point out that many socialists have found their chief hope for the coming of socialism, not in democracy, but in working-class supremacy or dominance. Socialism has existed in many forms of society in the past which were not democratic, and the fact that the revolutionary socialists of the present are not inclined to wait for the coming of socialism through the peaceful working of democratic machinery is perhaps even more significant than that some prominent socialists have recently repudiated representative government and declared that socialism will depend for its successful development not upon a democratic, but upon a bureaucratic social and political organization. Fraternalism in industry, however, can not tolerate the individualistic and predatory tactics which we now find only too often in our business world. The menace of such practises to the spirit of democracy does not need to be enlarged upon.

We now see that democracy is a spirit more than a mere form of either government or society. It is a stage in the evolution of the social mind and of social control—that stage which is characterized by the liberty and equality which spring from fraternalism, the recognition of the social worth and brotherhood of all men. Inasmuch as the democratic spirit is unwilling to recognize the artificial distinctions created by class, race or cultural condition, we see at once that modern democracy on its ethical side is practically synonymous with that movement in ethics which we know as "humanitarianism." The safeguarding of democracy demands above all the growth of rational humanitarianism; for as soon as any individual, class, nation or race sets itself up as an end in itself apart from humanity, we must have domination, exploitation and so oligarchy or autocracy. The growth of class, national or racial interests at the expense of the interests of humanity is bound, therefore, to defeat democracy in the long run. To this extent democracy in any given nation is bound up with the triumph of internationalism. Only as we develop and maintain equality of right and of freedom among nations, as Condorcet long ago, and President Wilson recently, said, is democracy safe. As soon as one nation or one class begins to deny the rights of another nation or class it has left behind the spirit of democracy. For this reason democracy is essentially opposed to the rule of force and is trying to put an end to that rule. The great justification for this war is, as President Wilson shrewdly saw, to put an end to the rule of force and to the violation of right by aggressive might.

In other words, peace, social and international, is necessary for the safety of democracy. It has long been remarked that democratic governments are built for peace, not for war, and we now see why this is so and why war of any sort, whether international or civil, tends to the destruction of democratic government. If democracy depends upon sympathy, understanding and good will, nothing can safeguard it like the peaceful development of civilization; for it is only the peaceful development of civilization which can make for the extension of that rational likemindedness which comes through science, and that good will which comes through humanitarian ethics and religion. The great enemies of democracy are those who, whether in the name of class or nation, destroy peace and good will among men to promote their own interests.

It is now evident also why both extreme conservatism and revolutionary radicalism are foes of democracy. Conservatism wishes to preserve institutions of the past which are no longer adapted to the present. They hamper the development of some section of humanity. To maintain them under such conditions becomes a rapidly growing injustice, and injustice, long maintained, destroys good will, and so the basis for social peace. On the other hand, revolutionary radicalism refuses to wait for the peaceful development of civilization to redress real or fancied wrongs. It invokes the immediate use of force, at least as soon as the opportunity is favorable, and so destroys good will. In practice, both extreme conservatism and revolutionary radicalism are accordingly found destructive of democracy. Only a rational progressivism in social and political policies will harmonize with the true spirit of democracy. "Liberalism" is perhaps the nearest single term that we have to describe this rationally progressive spirit.

It may be said that the picture which we have drawn of democracy makes of it an impossible social ideal, and that to "make the world safe for democracy" it would have to become a Utopia. If by this is meant that the world can be made safe for democracy only through the development and perfectioning of humanitarian civilization, we would accept the criticism. But it is no impossible Utopia, no impossible development of civilization, which we have pointed to. Rather it is simply the development of that spirit of rationality and good will in all phases of collective human life which civilization at its best has always made its aim. To say that the fate of democracy is bound up with the fate of higher civilization ought, indeed, to be regarded as a truism. Two difficulties, however, do present themselves, which need yet to be cleared up. One is the old objection to democracy, that it presupposes a higher development of intelligence and of rational judgment than what the mass of individuals, even in the highest civilizations, are capable of. The other is the objection that if democratic control means only limited control over individuals we can never have social efficiency under democracy.

It may be pointed out that both of these objections fall to the ground as soon as we understand the real nature of democracy; that democracy does not preclude leadership or the highest degree of cooperation with leaders. Doubtless the mass of men can never be trained to be experts in the work of government or in social control generally; and such work, it may be admitted, in order to be efficient must always be done mainly by experts. But all the individuals of a free or democratic society can be taught to select their leaders upon the basis of adequate social knowledge and with patriotic and humanitarian rather than selfish or class ends in view; and they can be taught to coordinate their activities efficiently with the activities of their self-chosen leaders. Democracy does not necessarily mean, therefore, the control of ignorance and mediocrity, as Lecky charged, nor does it mean any necessary lack of social efficiency. The intelligence of a democracy can represent the highest intelligence of which the leaders it evolves are capable. Only it is evident that democracy, in order to be intelligent, must devote itself to the work of training social and political leaders as well as to the general diffusion among the masses of social and political information; and modern democracy has evidently not yet fully awakened to the importance of this matter of training its leaders. With trained leaders, and with the masses at large trained to take the social point of view, and to work cooperatively with their fellows, there is no reason why democratic societies should not be as efficient socially as authoritarian societies. Indeed, in the long run when the masses have been taught to play the social game and to play it well, they will be more efficient—just as the football team in which every member of the team knows so well how to play his part that he does not need to wait for directions from his captain is more efficient than the team in which every member waits upon direction from above before he plays his part.

SCIENTIFIC MANAGEMENT SIMPLIFIED

By MALCOLM KEIR, A.M., Ph.D.
UNIVERSITY OF PENNSYLVANIA

A POTTERY manufacturer of East Liverpool, Ohio, once said to me,

"I can't use scientific management in my plant, because pottery making is so utterly unlike a machine shop. We use power machinery only for mixing our clays, flint and feldspar; all the rest of our operations are hand jobs. I suppose scientific management is a good thing for those fellows in the metal trades that can employ it, but my business is different."

Almost identical opinions are expressed by textile, leather, and paper manufacturers, publishers, office managers, butchers, bakers and candlestick makers. Each claims his business is too "different" to permit scientific management, but all agree that it may be practicable in machine shops. As a matter of fact there are few activities that could not profitably make use of the principles of scientific management. Why then is there so much misconception and confusion in regard to its adaptability?

The answer lies in the history of the movement; since it arose in machine shops, when the leaders published accounts of their efforts they used illustrations drawn from their experience. Men quite naturally supposed scientific management was suited only to the business from which all the examples were taken. Furthermore, most of the writers upon the subject were practitioners rather than expounders, with the consequence that they confounded practices most bewilderingly with principles. Yet these latter are few in number, easily understood and of almost universal application. The fundamental elements of scientific management are standardization, exact knowledge, functionalization, incentive and selected personnel.

Since standardization is the most elementary principle it was first attained, and to-day is the primal step in the installation of scientific management. Upon the success of standardization depends much of the achievement wrought by the remaining principles.

The idea of standardization is easy to conceive, and its utility is readily accepted, yet when you attempt to apply the idea, you have entered upon a long nerve-racking, prejudice-smashing job. To standardize thoroughly may take two or three years and cost you your reputation for sanity. The designs of the product must be reduced to the fewest types; the raw materials must be limited to the few best suited to the purposes; the methods of storage must be subjected to uniform conduct; the entire equipment, including buildings, machines, tools, appliances, work places, light, heat, ventilation, power and the like, all must conform to the few best predetermined models; and finally the product itself must comply with fixed specifications. These general fields of standardization blaze the way for more minute studies. If a man never goes further into scientific management than taking this first step his reward will be great, for standardization pays generous dividends. There is hardly any activity that can not gain in effectiveness by the application of this principle.

After standardization as a fundamental in scientific management comes exact knowledge. As a whole, American business is run by guess; the employees act by "rules of thumb," while the employers govern their work by customs, previous records or a reliance upon "luck." From top to bottom no one has information scientifically determined. The chief reason why such haphazard methods do not wreck business is that all competitors are tarred with the same stick. In the place of "rules of thumb" a thorough investigation of the work should be made. This may involve motion study, fatigue study and time study; analysis of materials, equipment and environment; research into the laws of health, psychological experiment and community improvement. In short the effort to obtain exact knowledge may embrace a use of physics, chemistry, physiology, psychology, sociology and a few more "ologies." Yet when completed, guess work is eliminated and the work proceeds along definite assured lines.

With exact knowledge in regard to the work the employer can base his decisions upon statistics, the most important of which are found by cost accounting. Accurate determination of costs is a prime essential in deciding a business policy. Nevertheless, according to the Federal Trade Commission ninety per cent. of American corporations have no adequate cost data. Other business facts can be tabulated, put in the form of graphs, with the significant features plainly marked and then used to guide the judgment of the men who control the concern. Knowledge takes the place of "luck" in deciding the fate of a business and success becomes far less of a hazardous gamble.

When any establishment has standardized and obtained an exact knowledge of its affairs, then it is ready to consider the third principle of scientific management; namely, functionalization.

Functionalization is the application to management of the old idea of the subdivision of labor. Executive work ordinarily complex may be simplified by analysis. It consists of clerical, directive, decisive, formulative, disciplinary and selective tasks; it involves the writing and signing of documents, the giving of orders, the judgment of questions affecting the business, the planning of work and sales, the hiring, firing or fining of employees and the picking out of policies or methods. This is the outline of a hard job, but no one task is extremely difficult in itself. If there is enough of any one of these tasks to keep at least one man constantly employed, secure an individual to perform this function. By concentration upon it he can be more effective than a dozen officials who give it only a part of their time. Functionalize and then hold the functionary responsible. This rule applies to all parts of a working staff from the president to the janitor. Let the president do the one thing he is best equipped to perform, and hire a janitor for each type of janitorial service if there is enough work in that type to keep a man constantly busy. A functionalized presidency would consist of several associated presidents, one for clerical, one for directive, one for formulative work and so on. A functionalized janitorship would be made up of sweeping janitors, window-washing janitors, toilet-cleaning janitors and the like. Functionalized foremanship would include instruction, speed and repair foreman. Functionalized planning would involve instruction clerks, route clerks, time-card clerks and whatever others were necessary. Since no two businesses operate with exactly the same functions there can be no rule as to the way functionalization shall be accomplished; one concern would have one set of functions performed by functional officers while another even in the same line of business might show an entirely different line-up. Yet both would illustrate the *principle* of functionalization and that principle is an essential feature of scientific management. The subdivision of the labor of management is fully as important a step in progress as the subdivision of the direct labor of production.

It is unprofitable to spend the money needed for functionalization, exact knowledge and standardization, unless greater productivity is obtained. In order to insure increased production scientific management sets up "incentive" as the fourth principle. High wages give the workmen the spur needed to induce them to quit loafing on their jobs and to turn out more goods.

The wage systems adopted by industrial engineers usually consists of two parts: a base wage and a bonus. The base wage is customarily the same as the prevailing rate for the work in the community, while the bonus is a percentage of the base. The bonus is paid only to those men who complete a task so fixed that it ordinarily involves an output two or three times as great as prevailed before the installation of scientific management. It is possible to complete this task because by standardization, exact knowledge and functionalization the variety of work required of a man is greatly reduced. The greater output lowers costs per unit, and this gives rise to greater profits out of which the bonus wage is paid.

The establishment of a base rate is seldom scientifically done since the current day rate is accepted without investigation. The percentage allotted to bonus has been made the matter of extensive analysis, and there are at least six methods now in vogue. Some plants use several different methods according to whether the work embraces brawn or brain or combinations of these two.

The working out of the wage system is a matter of detail that need not concern us. The principle involved is that wages shall be sufficiently higher under scientific management than under ordinary management to constitute an incentive for the best workers to seek the plants where scientific management is in use, and to encourage the men employed under it to put forth their best efforts.

In addition to high wages scientific management uses as an incentive the hope of promotion. Railroad men boast that a track walker may become the president. In this respect every other business might profitably pattern after the railroads. The chance to improve one's position is oftentimes a more potent instigation to good work than high wages; especially with young, unmarried employees. Men crave power and will exert themselves if they have any hope of attaining it. Here then is a trait to which scientific management may cater.

Incentives and standardization have been more completely developed as principles of scientific management than exact knowledge or functionalization, but all four until recently had received far more attention than the fifth principle, selected personnel. Since no man can work at his best upon uncongenial tasks, an industrial misfit causes a loss to the individual concerned and also to the firm that hires him. Scientific management aims to eliminate this double loss by a careful selection of employees. If it is necessary to secure the right materials and handle them in the right ways, it is also requisite to obtain the right men. Each applicant should be analyzed as to his fitness for the occupation he seeks, and every job should be studied as to the type of man it requires. Even such matters as the repulsion or attraction of the temperament of the foreman in reference to the temperament of the applicant should be given consideration. Then hiring and firing should be thoroughly functionalized. The department that selects employees may also be responsible for their training, welfare and betterment. If all questions in regard to labor are thus centralized a real labor policy may be adopted and carried out, much cross-purpose hiring and firing eliminated, and the right men secured for all positions. Much of the friction between the employer and employee may thus be removed.

In summary the principles of scientific management may be expressed in eight words: standardization, exact knowledge, functionalization, incentive and selected personnel. A man who comprehends these principles understands scientific management. Their use is not limited to any one industry but may be applied to almost all activities with what detail the circumstances demand. Railroads, steamship companies, city governments, public service corporations, department stores, banks, publishing houses, professional work, all have made use of the principles described, as well as industrial plants. There is little reason why they can not be further extended to other work. If the principles are grasped, then practices can be adjusted to suit the conditions of each individual case.

CHEMISTRY, A TRADE OR A PROFESSION?

By Professor HANOR A. WEBB
GEORGE PEABODY COLLEGE FOR TEACHERS

The Question Asked.

With the god Mars as his press-agent, the chemist has recently been advertised until a wave of interest in his occupation has swept over the country. Young men, young women, and especially their ambitious parents, are asking us with ever-increasing frequency, "What is a chemist?"

The Problem Studied.

That this question might be answered more intelligently in connection with local conditions, a survey of the chemical industries of Nashville (exclusive of educational institutions) was begun, especial attention being given to the amount of chemical knowledge and training required of the workers, together with their opportunities for advancement along chemical lines. Conversations were had with workers and executives, and statistical data recorded on a suitable questionnaire. Many helpful suggestions were received from Professor R. W. Selvidge, department of industrial arts, George Peabody College for Teachers, based on his past experience in certain extensive government surveys.

Nashville is a city of over 150,000 population, with diversified manufacturing interests, which, at the time of this survey (winter of 1917–1918), included no overshadowing industry. The many plants visited may be grouped into 22 different types, each employing some chemical process, or operating under chemical control. It is likely that similar plants and conditions would be found in almost any city of similar size.

Two Schools for Chemists.

Some chemists go to college, others only to "the school of experience." Ten types of industries in Nashville employ the college man exclusively—nine use the man with "experience only"—in three types are both classes at work. Only two workers were found who had studied high school chemistry but no further—the nature of their work, however, placed them in the "experience only" group.

Choosing Between the Trained and Untrained Chemist.

The employment of a trained chemist depends principally upon two conditions:

1. The size of the plant. The prime function of a chemist, in controlling the operation of a plant, is to effect economies in the process. If it be true that large plants have large wastes, then smaller plants have smaller wastes in the rough proportion of their respective sizes. A plant may be so small that it is cheaper to run wastefully than to employ a chemist.

2. The attitude toward "passable quality." Much of the production observed during this survey was obviously intended for consumers with whom quality was a secondary consideration. It is undoubtedly legitimate to attempt to supply this demand. Such products need not be carefully standardized and there need be but little variation or improvement in the method of manufacture. There is, indeed, little incentive to the manufacturer to improve the quality of his product, especially if it means added expense, with no corresponding increase in selling price advisable.

None of the plants visited in this survey, in which men with "experience only" were employed as chemical workers, were of great size. But whether size made scientific management possible, or whether scientific management would produce the size, was never wholly settled by my discussions with executives,

A Comparison of the Workers.

Discussion, questioning and observation furnished a basis for a comparison of the advantages and opportunities of the workers of each group.

I. *Advantages of the Man with College or Technical School Training, Plus Experience.*

1. He can judge the efficiency of newly suggested processes, without costly experimentation. The history of industry is full of examples where men have wasted great amounts of time and material in trying to determine a formula or method by "trial and error." The trained chemist will at once detect anything which is fundamentally wrong with a new plan.

2. He can change to new methods and formulae with little confusion. No change is absolutely new to the trained chemist. He will also be able to distinguish between changes which are fundamental in the process, and those which are accessory only.

3. He can test, purify and utilize crude materials. Crude materials are never uniform, and wherever used, definite quantitative analyses are necessary. It often happens that very small amounts of certain impurities are exceedingly deleterious to a process, and just as frequently, large amounts of other impurities are of no significance. The trained chemist will know the proper methods of treatment in each case.

4. He can originate new processes and products, especially in the utilization of by-products. The spirit of research is always present in the work of a trained chemist. He has had opportunity to realize the enormous mass of chemical knowledge, and the view which he has taken of the breadth of the science has greatly widened his horizon. He is able to more clearly judge what additional products may be needed in his field of manufacture, and what materials will serve.

5. He profits rapidly and extensively from experience. A fact learned in experience is immediately measured by a principle learned in theory, and the fundamentals and accessories of a process properly judged. Related phenomena are connected with each other, no matter how different they may appear.

6. He is more likely to properly handle an emergency. Having a knowledge of the real nature of the process, he can more accurately diagnose troubles of operation, and with his wider field of information, even though much of it be theoretical, he may, if necessary, make use of more complex remedies for the difficulties than would be possible if his knowledge were limited to one line of experience.

Opportunities of the Man with College or Technical School Training, Plus Experience.

1. He is eligible for promotion to research in his field. A firm theoretical knowledge is indispensable in research, both in its planning and in its interpretation. Advanced commercial work—any chemical work, in fact, which is above pure routine —is essentially research.

2. He will find it comparatively easy to accept a position in a field different from that in which he is now engaged. The work will not be absolutely new—he knows the theory of the process already, and can rapidly gain experience.

3. He is available as an instructor in his special branch, or an allied branch of the science. A broad knowledge is fundamental to proper instruction.

4. With college or technical-school training in chemistry, he is equipped for advanced study and employment in other profitable sciences, *e. g.*, agriculture, medicine, geology, etc.

II. *Disadvantages of the Man with "Experience Only."*

1. He can not judge the efficiency of new processes, without costly experimentation. Having no theoretical conceptions, he can only "guess ahead," and determine by trial the correctness or error of his estimates.

2. He can not easily change to new formulae and methods.

Everything which he has not actually experienced is new to him. In attempting to understand a new process, he can not distinguish between the essential principles, which admit of no variation, and the lesser details, which might be radically altered to suit local conditions.

3. He can not test, purify or utilize crude materials. He must purchase purified materials, at whatever price their manufacturer may ask. The purity of his product is dependent upon the responsibility of other persons, over whom he has no control, and on whom he has no method of check. He may pay a high price for these imported articles, when quantities, almost as suitable, are at his very door.

4. He can not originate new processes and products. If he has the desire, he is likely to hesitate, because he can not be sure of his grounds. He is not familiar with his own field to its limits, much less is he willing to venture into unknown paths. This spirit was almost universal with the workers of this type in Nashville, who unhesitatingly pronounce their methods "the best," and declare that they know all they need to know.

5. He does not profit as rapidly and extensively by experience as does the trained man. He possesses nothing upon which to hang his fabric of experience—he must learn facts and manipulations in isolated sequence. He receives, after the lapse of sufficient time, a dexterity and familiarity in relation with the one process with which he is concerned which makes him an acceptable workman where the requirements are not rigorous.

6. An emergency is likely to present conditions which he will be unable to diagnose. His training is essentially one which serves only so long as the process is going smoothly. Makeshifts, substitutes and optional methods, unless obviously applicable, have probably not come within the range of his experience. In such a case, the services of an expert will of necessity be sought.

Opportunities of a Man with "Experience Only."

1. He soon reaches the limit of his scientific growth. As far as the actual manipulations of a certain process are concerned, his skill does not appreciably increase after a few months. He is not available for a position of research, as his knowledge is limited to his own experience.

2. The future for the rule-of-thumb paint mixer, the "ammonia man" at the gas factory, and others of similar employment, holds but little promise. Chemical routine is never remunerative. Why should it be? If financial reward is in any way based on the amount of intelligent effort necessary to

achieve success, what particular claims have these occupations which are quickly learned, and easily carried on—in which effort and study have been neither intensive nor extensive!

3. He is not an effective instructor, even concerning the processes with which he is familiar. He may be able to answer the question "How?" but can not explain the "Why?" of his methods. He can do a thing, while an apprentice watches and observes, but he can rarely explain clearly what he is doing. In my inquiries, this fact was noticed many times.

4. In some industries it is possible for the worker, after showing some abilities of an executive nature, to be advanced to a position of executive responsibility. But such is not the logical or the usual sequence. This is especially true of persons engaged in purely routine chemical work. The curse of rule-of-thumb training, so often, by a most egregious error misnamed "practical," is that it leads the worker into a blind alley occupation, in which he can soon reach the limit of his progress, and then go no further.

Chemistry, a Trade or a Profession?

Chemistry is distinctly a *profession*, rather than a *vocation*. It is to be classified with medicine, law and engineering, rather than with carpentry, bricklaying or plumbing. In a profession, more than an elementary study of its principles is necessary for efficiency, while in a vocation, the direct experience of labor, rather than theoretical study, makes a master of the trade. In a profession, one must show evidence of training in a recognized school, and be the possessor of degrees of proper kind, before he is accepted by his colleagues as a fellow. In a vocation, however, recognition is given to experience only—the schools which teach electroplating, photo-engraving, sign-painting, carpentry, plumbing, bricklaying, etc., being neither numerous nor largely patronized by the workers. It is apparent from the survey of the chemical industries of Nashville, that there are two recognized groups of workers—those who, after college or technical training, are properly designated as chemists, and those who, with experience only, may be recognized only as chemical artisans, more or less skilled.

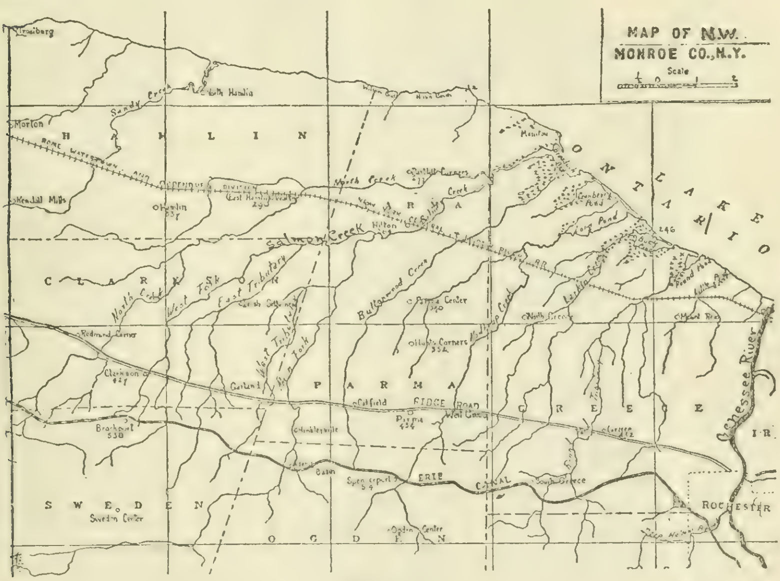
Therefore, "What is a chemist?" A man or woman of considerable educational attainments, versed in the history, literature, ethics and current progress of his cult, feeling the same pride in his life work which is common to all members of the "learned professions."

FISH SUCCESSION IN SOME LAKE ONTARIO TRIBUTARIES

By Dr. ALBERT HAZEN WRIGHT

CORNELL UNIVERSITY

IN the summer of 1904 the writer spent the whole season in surveying ten streams of Monroe County, New York, and in plotting the range of each species of fish in them according to a plan outlined in 1907.[1] The following year, 1908, tentative



MAP No. 1.

conclusions were formulated and conditions in Cayuga Lake streams contrasted with those of Monroe County. In 1912 cursory work in Ontario province caused a revision of this draft.

In 1911 an independent study of the same sort was made by Dr. V. E. Shelford,[2] in the vicinity of Chicago and our studies are in general in agreement.

These ten Monroe streams (Map 1) to which I have alluded are quite ideal for the study of fish succession because they are

[1] *The American Naturalist*, Vol. 41, June, 1907, No. 486, pp. 351–354.

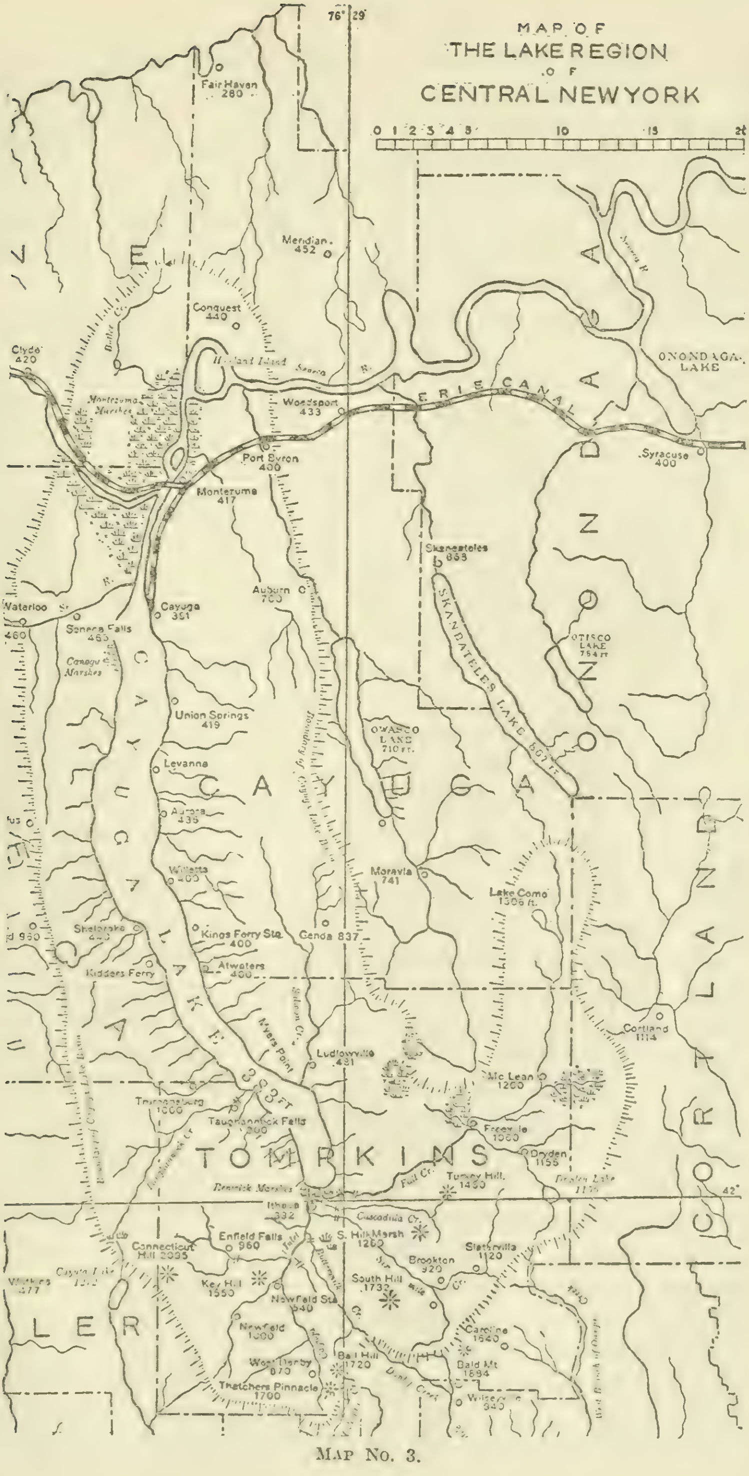
[2] "Ecological Succession. I. Stream Fishes and the Method of Physiographic Analysis," *Biol. Bull.*, Vol. XXI., No. 1, June, 1911, pp. 9–35.

in the old bed of Lake Iroquois and have come into being since its beach (Ridge Road on map) retreated to the present shore of Lake Ontario. They are then postglacial in origin and comparatively recent. For comparison, we have employed Meek's

MAP NO. 2.

results in the highlands of Ontario[3] (Map 2). He began at Hawkstone and Orilla on Lake Simcoe and followed the Grand Trunk railroad to Trout Creek (Lake Nipissing) or farther north. All the way northward this railroad bears away from Georgian Bay and the stations he successively came to were successively farther away from it in barriers, etc. Added to his results are the experiences of the writer from The Lake of Bays to Fletcher Lakes below Algonquin National Park. The northern end of Cayuga Lake (Map 3) is more comparable to

[3] Field Columbian Mus. Zool. Ser., Vols. I., No. 17; III., No. 7.



MAP OF
THE LAKE REGION
OF
CENTRAL NEW YORK
Fair Haven 280
Meridian 452
Conquest 440
Clyde 420
Montezuma Marshes
Woodsport 433
Port Byron 400
Montezuma 417
ERIE CANAL
ONONDAGA LAKE
Syracuse 400
Skaneateles 863
SKANEATELES LAKE
OTISCO LAKE
Auburn 700
Waterloo
Seneca Falls 460
Cayuga 391
Union Springs 419
Levanna
Aurora 435
OWASCO LAKE 710 FT.
CAYUGA
CAYUGA LAKE
Moravia 741
Lake Como 1306 ft.
Willetts 400
Sheldrake
Kings Ferry Sta. 400
Genoa 837
Kidders Ferry
Atwaters 400
Cortland 1114
Ludlowville 431
Myers Point
Mc Lean 1200
Trumansburg 1000
Taughannock Falls
Freeville 1060
TOMPKINS
Dryden 1155
Turkey Hill 1460
Ithaca 392
Enfield Falls 960
S. Hill Marsh 1200
Slaterville 1120
Connecticut Hill 2035
Brookton 920
Key Hill 1550
South Hill 1732
Newfield Sta. 940
Newfield 1000
Caroline 1540
Bald Hill 1720
Bald Mt 1694
West Danby 870
Thatchers Pinnacle 1700
Willseyville 940
CORTLAND
ONONDAGA
76° 29'
42°

Map No. 3.

Monroe streams and its fish inhabitants bear out the contention. Many forms are common to the two but absent at the south end of Cayuga Lake. The upper reaches of the streams at Ithaca where barriers exist near the lake are more comparable to Otter Lake or Trout Creek of Ontario. Added to the results are the comparisons from some of the Susquehanna head streams, 8–12 miles south of Ithaca. These tributaries are, however, of another drainage system and may not be so pertinent to this discussion.

In a diminutive rivulet or a developing small creek where the current is moderate and the bottom clayey, gravelly or varied the first occupants are almost sure to be the sucker (*Catostomus commersonii*), the horned dace (*Semotilus atromaculatus*) and quite likely the black-nosed dace (*Rhinichthys atronasus*). The second seems to be the original and oldest carnivore of a typical eastern stream in its first development. Thus, in central New York, in most of the hanging valleys which empty into the Finger Lakes, suckers, horned dace and black-nosed dace are about the only original occupants above the high falls and toward the sources unless the brook trout (*Salvelinus fontinalis*) be present. In our ten Monroe streams we did not record the red-bellied minnow (*Chrosomus erythrogaster*), but Evermann and Kendall took it in Salt Brook, a small creek of Webster, and in Long Pond. In many streams and lakes of the province of Ontario it is one of the first to enter and might follow close after the above three species. This may explain its presence in the Cayuga Lake Basin only in the headwaters of Fall Creek where barriers intervene between its habitat and Cayuga Lake. Another form which was taken in a little side stream of the West Fork of Salmon Creek is the fathead minnow (*Pimephales promelas*). At Ithaca, the sole record for it is in the upper waters of one of our oldest streams, namely, Fall Creek (Meek, 1889) and above the barriers near Cayuga Lake; in some of the most inaccessible lakes (Great Lakes' drainage) of Ontario it is present as it is in the headwaters of the Susquehanna. In some streams or headwaters a representative of a very pretty group of minnows may possibly be associated with the last two species. It is either the red-sided minnow (*Leuciscus elongatus*) or Cope's minnow (*Leuciscus neogæus*). In the headwaters of the Susquehanna, the former is very abundant, and Evermann and Kendall had it from several small streams at the east end of Lake Ontario, while the latter form (*L. neogæus*) occurs in some of the highland lakelets of Ontario. In the Monroe County tributaries of Lake Ontario, two minnows are amongst the species to follow after the original three as given above. These forms are the blunt-nosed minnow (*Pimephales notatus*) and the common shiner (*Notropis cornutus*). In the beginning, therefore, our small streams have in fish content a decidedly soft-rayed element. As the stream develops in width, length and diversity these forms either become our most adaptable forms and range throughout the length of the stream or betake themselves to the source or else succumb and therefore in a measure falsify the present record of fish succession.

The next incomers are usually the first of the spiny-rayed fish and are amongst the most diminutive, namely, the brook stickleback (*Eucalia inconstans*) and the fan-tailed darter (*Catonotus flabellare*). In some waters it would seem that almost concomitant with these comes the miller's thumb (*Cottus richardsoni*). Of this we are not so positive. In the smaller streams the stickleback is usually near the source and the darter may be at the source in mid-course or near the mouth. They are present, however, in almost every one of the Monroe County streams, irrespective of subsequent developments of the lower course, whether deep, muddy and marshy or swift, broad and gravelly. Following close on the heels of these spiny-rays comes the river chub (*Hybopsis kentuckiensis*) which we have recorded in all of our ten streams (small to large streams) and usually sparingly in mid-course or near the mouth. Another form which invades the new stream at about the same stage as the river chub is the stone-roller minnow (*Campostoma anomalum*), an upper course form if the lower course becomes muddy or a lower course form as well if the bottom becomes gravelly rocky or diversified. At this stage our hypothetical stream in its fish inhabitants virtually has its duplicate in Larkin Creek. Or this distribution of fish forms (river chub and stone-roller minnow not represented) is beautifully illustrated in the headwaters of Cayuga Lake Inlet. This stream is the only stream near Ithaca without obstructions or decided glaciated barriers.

The second carnivore and depredator of any size to enter is the pike (*Esox lucius*), closely associated with its smaller relative, the grass pike (*E. vermiculatus*). The former occurs in all ten Monroe streams, and it alone appears in Larkin Creek, while the grass pike occurs in seven streams. Where both are recorded the pike's range is usually greater, and it remains the longest in the oldest portions of a growing stream. This is illustrated in the Salmon Creek and in West Fork of Salmon

Creek, two stretches of the oldest stream courses under consideration. Here the pike alone remains, but in the more recent tributaries of each of these older streams both pike and grass pike occur and the former with the greater range.

About the time of the ingress of the pike, the lower course may possibly begin to deepen, the current become slower and the bottom muddy. Amongst the very first forms to appear along with such conditions is the common bullhead (*Ameiurus nebulosus*). This form is the most widespread in its distribution and most versatile in its adaptation of any of the three species of *Ameiurus* we have. Following the bullhead comes the first Centrarch, the common sunfish (*Eupomotis gibbosus*).

At this juncture our fish content compares favorably with the inhabitants of the upper reaches of Fall Creek Cayuga Lake) above the falls. The forms are: sucker, horned dace, black-nosed dace, fallfish (*Semotilus corporalis*), red-bellied minnow, fathead minnow, brook stickleback, miller's thumb, brook trout, pike, reticulated pickerel (*Esox reticulatus*), bullhead, and sunfish. Or Otter Lake above Lake of Bays (Ontario) may be comparable with its sucker, horned dace, red-bellied dace, fathead, Cope's minnow, blunthead, shiner, brook trout, bullhead, sunfish. Or Trout Creek, a small tributary of Lake Nipissing, may represent the same point with the following forms: sucker, horned dace, red-bellied dace, fathead minnow, blunthead, shiner, brook trout, brook stickleback, and sunfish. Or the very headwaters of the Susquehanna, nearest Ithaca, have a very similar fish fauna, to wit, sucker, horned dace, black-nosed dace, shiner, fathead, red-sided minnow, brook trout, miller's thumb, pike, pickerel, bullhead, and sunfish.

The golden shiner (*Abramis crysoleucas*) appears in quantity after the sunfish and is followed by a few perch (*Perca flavescens*) and the rock bass (*Ambloplites rupestris*). This summation or analysis of our ten streams has brought us unwittingly to the second youngest stream of the ten Monroe tributaries, namely, the West Tributary of the Main Fork of Salmon Creek. This tributary has only the forms recounted to this point.

The large-mouth black bass leads the way in the next associated group and occurs in eight of the ten Monroe streams. In four of the five main systems the black bullhead (*Ameiurus melas*) frequents the lower three or four miles of the stream. A close companion of the black bullhead is the tadpole cat (*Schilbeodes gyrinus*) which is recorded in five of the ten

Monroe streams and the mud minnow (*Umbra limi*) has much the same range and time of entrance. These four forms are almost synchronous in migration into the stream or the above order of the four may possibly show the succession. The first has, if anything, a longer range in the Monroe streams than the second, the second more than the third and the third more than the fourth if both occur in the same stream. We have now reached the third stage in our Monroe water courses, the state of affairs in the East Tributary of the West Fork of Salmon Creek. About this same period the Johnny darter (*Boleosoma nigrum olmstedi*) appears. It occurs in six of our streams or in five different systems, toward the gravelly, stony or clayey sources of two streams with muddy lower courses or in the mid-course of the other four more gravelly streams. In some streams the common killifish (*Fundulus diaphanus*) may enter soon after the previous forms or be associated with them. This development brings the succession to Round Pond Tributary.

A form which comes into consideration at this point is the chub sucker (*Erimyzon sucetta oblongus*). It was scarce in the West Tributary of Northrup Creek, rare in the lower part of Salmon Creek, and quite regular in the lower eight miles of North Creek, our most advanced muddy stream. Disregarding the lone bluegill (*Lepomis pallidus*) record, the West Tributary of Northrup Creek represents this stage. A common minnow (preferring a muddy sluggish course) enters. It is the Cayuga minnow (*Notropis cayuga*) and appears in the lower four miles of Buttonwood and North Creeks. The bowfin (*Amiatus calvus*) is associated with the three bullheads (*Ameiurus nebulosus, A. melas,* and *A. natalis*) in the lower part of two of the muddiest streams and occurs sparingly at the mouth of Salmon Creek. Requiring about the same conditions, the yellow cat (*Ameiurus natalis*) appears in a similar range. In one creek at one point we have the progress carried farther with the introduction of the pirate perch (*Aphredoderus saynnus*). This leaves us at the Buttonwood Creek stage. The pirate perch appeared more frequently in the more advanced muddy creek, namely, North Creek, and the succession in this stream goes even farther to the introduction of the mud darter (*Boleichthys fusiformis*). Upon the entrance of the small-mouth black bass (*Micropterus dolomieu*) at the mouth of North Creek on a few stony stretches we close this stream's development.

Thus we have from the beginning of muddy conditions the successive appearances of the common bullhead, common sunfish, golden shiner, perch, rock bass, large-mouth black bass, black bullhead, tadpole cat, mud minnow, Johnny darter, common killifish, chub sucker, Cayuga minnow, bowfin, yellow cat, pirate perch, mud darter, and small-mouth black bass.

As the stream widens its valley, cuts back into the country, these forms push up to favorable habitats above or remain at the mouth or with increasing age of the stream may enter a tributary to recapitulate the succession beyond the first forms. For example, at Ithaca we have the Monroe succession being enacted in Fall Creek. It is naturally a wide, swift, gravelly stream from source almost to the mouth, and there are no decided muddy intervals except as produced by artificial mill dams. From its source to Cornell University campus (20 miles or more) we have most of the fish associates from the sucker to the common sunfish. Through the campus comes a deep rocky ravine with a series of high falls, the last one (Ithaca Falls) being only a short distance from Cayuga Lake. The run from the Ithaca Falls to the lake is short and takes the water mass of the upper 20 miles or more. As a consequence it is gravelly or stony, very swift and very short. There are, therefore, from source to Cornell University campus no attainable muddy stretches, because the postglacial falls bar entrance to the muddy associates of the mouth. Near the mouth of Fall Creek is a small tributary or bayou, deep and muddy, and in it we have the following: common bullhead, common sunfish, golden shiner, perch, rock bass, large-mouth black bass, Johnny darter, tadpole cat, common killifish, Cayuga minnow, in abundance according to the order of the list, *i. e.*, the first three being the most common. Just outside, and slightly above the mouth of this bayou, is the swift water of Fall Creek, where the small-mouthed black bass is the most frequent large fish present. Then follows the succession of the swift gravelly or sandy group to be discussed later. Thus, we have in the source of Fall Creek the first comers to the stream; then, the second muddy group can not follow after them because of falls, but rather go off into a side-stream near the mouth or remain in the mouth; over the backs of the muddy associates or past the mouth of the new home of these enters sparingly the third assemblage, to occupy only the one eighth of a mile stretch of gravelly or sandy bottom below Ithaca Falls. As a consequence, the succession is not carried as far as in the long well-developed lower course of Salmon Creek. The mouth of the West Fork of Salmon Creek in its fish content is about intermediate between the lower courses of Fall and Salmon creeks.

Some might feel that the Johnny darter should be thought of as entering the succession after or near the small-mouthed bass, but this darter is not restricted to a gravelly bottom and swift current as many of the other darters are. Hence, its place with the previous forms. In the mouth or lower course of the West Fork of Salmon Creek we have left unmentioned in the succession silver-sided minnow (*Notropis atherinoides*), log perch (*Percina caprodes zebra*), spot-tailed minnow (*Notropis hudsonius*), and hog-nosed sucker (*Hypentelium nigricans*). Another place quite comparable is Lake Simcoe or Moon River just below Muskoka Lake (Bala). In the former Meek secured the silver-sided minnow, log perch, spot-tailed minnow, silvery minnow (*Hybognathus muchalis*), trout perch (*Percopsis omiscomaycus*), and long-nosed dace (*Rhinichthys cataractæ*); in the latter locality he secured log perch, spot-tail minnow, and silvery minnow. In the lower course of Fall Creek we have the silver-sided minnow, log perch, silvery minnow, spot-tail minnow, trout perch, satin-fin minnow (*Notropis whipplii*) and eel (*Anguilla rostrata*). In the spring the lampreys (*Petromyzon marinus unicolor*) and the calico bass (*Pomoxis sparoides*) and a stray gar (*Lepisosteus osseus*) may enter it. In Salmon Creek the succession has gone much farther. Besides the forms of Fall Creek we have in Salmon Creek the following: hog-nosed sucker, stone cat (*Noturus flavus*), green-sided dater (*Etheostoma blennoides*), straw-colored minnow (*Notropis blennius*), and the barred mad-tom (*Schilbeodes miurus*). Not infrequently a mullet (*Moxostoma aureolum*) or a bluegill may just enter the lower reaches of the stream. Rarely a sheepshead (*Aplodinotus grunniens*) or wall-eyed pike (*Stizostedion vitreum*) wanders into the mouth. Just at present the latest arrival in the lower reaches of the Salmon Creek seems to be the marine two-spined stickleback (*Gasterosteus bispinosus*). The forms above are the newest species of an older stream whose course becomes more diversified in general or at its mouth more like the Great Lake conditions. Some of the fish of this last group are as much lake species as stream inhabitants and some almost entirely lake forms. Salmon Creek has a much broader valley and longer course than any other of the Monroe watercourses previously considered and therefore has the succession farthest advanced.

The value of such an analysis as the above may not be apparent at once and may seem too speculative. But, if one considers a stream's drainage system, its size, and its geological history, he ought to be able to approximate its hypothetical fish content. Such studies may be an auxiliary in physiographic work, *e. g.*, the writer when surveying Salmon Creek (not of Monroe County) of Cayuga Lake drainage discovered fan-tailed darters near its source and at once concluded there were no natural barriers in it from the lake to its source and the conjecture was right. Or it may be that the peculiar source inhabitants of some large creeks of glaciated areas may indicate that the upper half was connected with another drainage than the present one and a comparison of fish species may help to confirm such a contention. Often one may be at a loss to explain a certain species at the source of a creek and later find that it came across a divide from another drainage system and about Ithaca we have more than one instance of two sources being on the same level and continuous at floodtime.

One important recent factor in falsifying the record of fish succession is the rôle of our canals. The Erie Canal may be responsible for the several forms which occur at the northern end of Cayuga Lake, which make its fish population more like that of Lake Ontario or Lake Erie than like its own southern end. The most recent Erie contribution in the mouths of our Ithaca streams is the gizzard shad (*Dorosoma cepedianum*) and fifteen years ago or more one or more Monroe streams had in their upper courses, carp, eel, perch and spot-tail minnow contributed by the Erie Canal.

THE PLACE OF THE MUSEUM IN OUR MODERN LIFE

By F. H. STERNS, Ph.D.

THE great world war calls upon us, more insistently than anything else has done before, to evaluate anew much of our heritage from the past. Age-old institutions can no longer justify themselves by their antiquity. The time has passed when the mere performance, however satisfactory, of a function formerly valuable can be accepted as a substitute for present-day usefulness. We hold it to be our right to require of every custom, of every art, and of every organization a demonstration of its utility in our time and of its ability to meet our needs.

This does not mean that we have become materialists. Cultural values are just as important as they ever were. The demands of the human soul are not to be sacrificed to the desires of the body. But the soul values must be real, and not fictitious. Art, for example, must have something more to commend it than tradition. "Old masters" can no longer hold their places, unless they possess the merit of some supreme appeal to a universal sense of beauty (a test destined to remove many of them from their pedestals). Science, too, must be something more than scholasticism or a compendium of universal knowledge. Our schools must give us more than pedantry, and our churches more than ceremony. Although we do not intend to use a materialistic yard-stick for spiritual things, nevertheless we insist upon measuring them rigidly.

Among the institutions which "bake no bread," but minister only to the spirit, are museums, and these we now propose to examine. They have a respectable antiquity, but do they possess that which warrants the continuation of the expenditure of vast sums of money upon them? Have they functions to perform of sufficient importance to justify their enormous costs? If they have a purpose which the modern world can accept, do they fulfil it in a degree corresponding to the energies devoted to them? Are their dividends in life-values a reasonable return from our investment? Do they show a surplus or a deficit, when their complete accounts are balanced? Do they pay?

At the foundation of all museums are collections, and men have been collectors almost since time began. The archeologist finds in the earliest village sites "caches" of multi-colored pebbles or curious fossils, while the same sort of objects occur in almost every "cabinet" in the United States to-day. Modern savages gather scalps or human heads, while the trophy instinct still exists among the hunters who make their annual pilgrimage to Maine. To-day our children collect buttons or marbles, our wives trading stamps or souvenir post cards, while we interest ourselves in coins or samples of ore.

The impelling force of curiosity has led many a man to gather and preserve unusual or mysterious objects. Specimens from foreign lands or from the depths of the sea have always had a wide appeal. Crystals, petrified objects, rocks supposed to contain precious metal, or stones weathered to a fancied resemblance to some living being or human artifact are frequent in collections. Skulls and Indian arrow heads are always saved. Things associated with the dead or with noted criminals possess a strong interest. Monstrosities and freaks seem irresistible.

Curiosity as a motive is supplemented by the sense of superiority gained from exclusive possession. The rarer the object is, the more it is to be desired. So the stamp collector seeks inverted centers and double surcharges regardless of any real significance these peculiarities may have. The art collector desires a genuine Rembrandt though it may be such an inferior product of the master's hand that it possesses little merit. The antiquarian boasts that he owns the largest accumulation of "problematical" forms in his vicinity, as if ignorance were a matter in which one could take pride.

The formation of still other collections has been promoted by intellectual interest. The scientist often preserves the objects he has gathered for study. He needs also to make "type" series for comparative purposes. So the student of art requires representative examples of each school or period of painting or sculpture. The teacher likewise must have illustrative specimens. Thus we find back of collecting the desire for knowledge, the lure of glory, or the sense of wonder.

Motives so different have necessarily led to very dissimilar results. Objects accumulated because of curiosity or the wish for exclusive possession are of one sort, while those gathered because of intellectual interest are of another sort. The one consists of the unique, the unusual, or the spectacular, while the other is made up from the normal, the typical, or the historically or scientifically valuable. The one is measured by the number or the rarity of its specimens, while the other is judged by their representativeness.

The motives which have inspired collection-making are the ones also which have given rise to museums. Popular curiosity, for example, supported the original Barnum and old Boston Museums, with their two-headed calves and three-legged chickens; and the same motive to-day keeps the dime museum alive. Our oldest American museum once had to depend for its existence on an appeal to this sense of wonder as the following advertisement will show.[1]

THE MUSEUM

OF SOUTH CAROLINA

In Chalmers' street, (near the City Square)

CONSISTING of an extensive collection of *Beasts, Birds, Reptiles, Fishes, Warlike Arms Dresses,* and other CURIOSITIES—among which are:

The HEAD of a New Zealand Chief
An Egyptian Mummy (a child)
The Great White Bear of Greenland
The Black and the Red Wolves of South Carolina
The South American Lion
The Duck Bill'd Platypus from New Holland
The Bones of an Ostrich as large as those of a Horse
The Boa Constrictor or Anaconda Snake, 25 feet long
The Grampus Whale, 20 feet long
800 Birds, 70 Beasts, 200 Fishes
4000 Specimens of Minerals.
Shoes of the Chinese Ladies, 4 inches long
The Saw Fish—Saw 4½ feet in length
A large collection of views of the Public Buildings, in Europe—and
A Fine Electrical Machine

The whole elegantly arranged in glass cases, open every day from 9 o'clock, and brilliantly illuminated every evening, with occasionally a Band of Music.

☞ Admittance 25 cents. Season ticket $1.; Children half price. f Jan. 6

It would be hard to exaggerate the part played in the founding of museums by the sense of superiority derived from ex-

[1] This appeared in January, 1826, in the Charleston *City Gazette.* I copy it from the *Proceedings of the American Association of Museums,* Vol. 9, 1915, p. 59.

clusive possession. Collections made under the lure of such a motive attain their end in the fullest measure only when they are shown to some one. So what is more natural than that their owner should have them forever exhibited in a museum to a wondering public, with the name of the donor in a prominent place? Or that a museum should be started expressly to house such a collection? Or that this museum should bear the name of its rich patron? Need we mention the number of collections and museums called after wealthy men, or the number of tablets to the memory of those who financed some expedition, to show the importance of this motive in the history of museums?

In recent years, intellectual interest has become a prominent factor in the founding and continuation of museums. To demonstrate the truth of this statement, it is necessary only to cite the development of museums supported by universities and colleges, depending upon grants from city, state, or nation, founded and maintained by learned societies, or existing solely as educational institutions for children. These bodies propose to preserve articles of artistic, historic, or scientific worth, to advance research, or to diffuse knowledge as widely as possible.

Thus curiosity, the sense of superiority derived from exclusive possession, and intellectual interest are the foundations of museums as well as of collections. In the past, they supplied the motives for the building and supporting of such institutions. Is this true to-day? Do these organizations believe their functions to be the satisfaction of the sense of wonder, the desire for glory, or the passion for knowledge? Does the public which eventually pays the bills subscribe to these aims? What is the attitude, in regard to the old-time purposes, of the museums and their patrons?

If general tendencies may be regarded as evidence, the museums have repudiated the satisfaction of curiosity as their end. Undoubtedly it is still a motive for the visitor, and so appeal must still be made to it; but no well-organized modern institution will cater to it. They no longer find a place for freaks and monstrosities. One will search in vain for three-legged chickens or two-headed calves. Fakes, such as Barnum's mermaid which once excited so much attention, are rigidly barred. Museum curators devote much energy to the elimination of everything of doubtful authenticity, no matter how interesting it may be. Some places still cling to the old ways, but those of the better class tell us by their actions that they no longer consider it to be their function to satisfy idle curiosity.

Our museums must do something more for us than the movies or the circus. We will not be satisfied with petrified menageries. Nor do we care to support side-shows of freaks. The unusual and the meaningless can no longer occupy much of a place in our lives. To amuse is not now the function of a museum.

The sense of superiority derived from exclusive possession has likewise been discarded as an aim. The respectable museum no longer boasts of the uniqueness of its specimens. Things whose worth depends largely on their unusualness are not wanted at all. Objects of great rarity, but of real value, are freely shared with less fortunate institutions, either by the making of copies or by actual loan exhibits. No museum now would reserve for its own members the use and enjoyment of its collections. Self-glorification is no longer an approved motive.

Nor is the exaltation of the rich patron deemed any more commendable. Museums and collections are still called after founders or donors in many cases; but because of the increase of fine institutions and splendid accumulations of specimens which bear the name of no individual, this practice gives but little honor. Men are still impelled by the wish for fame to contribute to museums, but to-day their rewards are small. The promotion of the sense of superiority derived from exclusive possession, either of the museum or of its patron, has ceased to be a legitimate function.

The satisfaction of intellectual interest, on the other hand, as the aim of a museum has now received the sanction both of these institutions themselves and of the public which supports them. More and more are government agencies in city, state, and nation contributing to aquariums, zoological gardens, art galleries, and natural history museums, because they regard them to be essentially a part of the public school system. Universities and learned societies maintain many such institutions for research. There is an increased desire to interest the public, and to make the collections as useful as possible to investigators, to craftsmen, to the schools, and to the casual visitor. The ideal now is have every one who enters the museum building go out with a broader outlook on life, a deeper conception of the universe in which he dwells, or a keener appreciation of the true and the beautiful.

The accepted function now of a museum is to satisfy the thirst for knowledge or the love of beauty, especially by the use of specimens, models, or other objects appealing directly to the senses. But for whom is it to do this? For the student of the future? Or for the investigator to-day? Or shall it be done for the general public? If for the first, we will store and care for the perishable materials of to-day that they may be ready for his use to-morrow. For the second, we should need to supply workrooms and equipment for research. For the third, there would be required proper installation and labeling of collections for exhibition purposes. Is the museum to be a warehouse, a laboratory, or a school, or all three? Is its function to preserve, to develop, or to disseminate the true and the beautiful.

We all recognize the necessity for the careful preservation of those objects which are desirable as records. Time is a great destroyer. Moths and rust corrupt, and thieves are apt to steal. Deterioration, such as is always taking place, progresses much faster when specimens are neglected. It is so easy to misplace things that it seldom happens that they can be found when they are wanted unless they have been cared for. Even if such an object is found, its parts may be so displaced that they can not be restored to their original arrangement, or its record may be lost, so that its exact value or even its authenticity may be open to question. Some person or some institution must make it a business to preserve anything of artistic, historic, or scientific value.

Certain commercial bodies exist for this very purpose. They possess the facilities necessary to do it. They have, for example, fire-proof vaults, in which the temperature and moisture may be properly regulated. They have locks and watchmen to guard against thieves. They are equipped to treat objects with preservatives and disinfectants, to minimize the destructive action of time and the elements, and of insect pests. They serve the public well.

Museums, on the other hand, often fail to perform this function as satisfactorily. The possibility of fire or theft is increased by the presence of visitors. Constant exhibition of an object allows injury due to sunlight. Handling by investigators and students exposes the specimen to misplacement, disarrangement of parts, or the loss of the accompanying data.

A museum can not remedy these faults without becoming a mere warehouse. Its whole nature is changed if it has no exhibits, no visitors, and no students. Professor T. H. Montgomery once described such a condition thus, "A museum that consists mainly of collections and of simple caretakers of the same has a speaking resemblance to a graveyard."

There can be no question but that a museum must store some specimens. It can not exhibit everything it has at once. If it is to be a place for students and investigators, it can not be without large accumulations of "type" objects. But this necessary preservation for use is a very different matter from that sort of storage which would make the institution a "cemetery of bric-à-brac." A museum must store and care for perishable specimens, but this must not be its chief function. A museum is not primarily a warehouse.

This conclusion was once stated very aptly by Mr. F. A. Lucas as follows:

> A collection of specimens does not make a museum any more than a collection of paints and brushes makes an artist. It is not what we have, but what we do with what we have that produces results, and the true value of the museum does not lie in its specimens alone, but what it does or what is done with them.

Another writer tells us that "the museum should be more than a mere collection of specimens. It should be a house of ideas." This suggests very strongly that a museum's chief function is research. For how else do worth-while ideas arise? Is there any other way than by careful observation that we can obtain true conceptions of nature? Knowledge is advanced only by systematic investigations. So if a museum is to be more than a mere collection, if it is to be a house of ideas, some sort of research is imperative.

If a museum were a mere "old curiosity shop," if its place depended entirely on what its accumulation of objects was worth, or if it were merely a warehouse of valuables, still research would be important to it, because thus the value of its specimens would be enhanced. For even the curious demand a name and an explanation of what they see. If you can classify the object, and list its striking peculiarities, then it becomes still more a matter of interest. Even Barnum's famous establishment would not have survived if it had not labeled its curiosities with titles and descriptions.

When the specimens are documents of science or of history, their value depends upon what some one can read in them. Now if no one takes the trouble to read them, if no one by classification attempts to assign them to their proper position, if no one tries to relate them to others of their kind or to differentiate them from these, if no one cares to investigate their place or their authenticity, if no one believes that their evidence is worth the getting, then it will be difficult to persuade any one that they have worth-while evidence to give.

So it is with a work of art. If its beauty is such that no one takes the trouble to see it, if no one cares which artist made it, if no one is concerned as to its age or genuineness, if its lessons in the history of art or in technique are of no value to any one, then no one will regard the specimen to be of worth.

Now all these things require some measure of research. Whether it be naming, description, classification, or explanation which is attempted, still some one must make some sort of investigation to accomplish it. Thus we find research important, even when the aim is merely the possession of valuable specimens.

The same is true when the object of a museum is education. Before any one can teach, he must first learn. If the institution is to disseminate knowledge, it must first acquire it; and this can be done only by careful investigation. The student requires labels giving names, description, classification and explanation; but the preparation of sound labels demands research. The more the museum has discovered, the more it can tell others; the sounder its own knowledge is, the more valuable will be its contribution to public education.

Further, the institution engaged in research can command the services of the most eminent and able men. It can thus have on its staff to arrange its exhibits, to label its specimens, and to educate its visitors, men whom it could not otherwise engage. To advance teaching, the best teacher possible must be obtained, and only by encouraging careful investigations can this be done. Thus research is a necessary function of a museum regardless of what its other aims may be.

Sometimes there has been a tendency to exaggerate the legitimate demand for research in a museum until it becomes the whole object of the institution. Often appeal is made exclusively to the learned and the specialist. Even to-day there are curators who cater entirely to a limited class of visitors. This attitude was voiced not so many years ago in the Association of American Museums thus:

> I consider the chief aim of a museum the advancement of science. This is its function; it must not go to the public; it must lead.

Now there is a certain danger here—even for the advancement of science. Research, the results of which are not applied or made available to the general public, but which are written up only for technical journals, has a narrowing influence. When one's audience consists exclusively of specialists, where one's entire effort is confined to one limited field, one is apt to lose a broad view-point; and then even the research work becomes sterile.

Besides, research is better carried out in other places. The great fields of nature are the places to study nature's ways. Museums at their best contain but a human selection of the things of the universe, and any conclusion based on their specimens is liable to errors due to the personal bias of the selector. Collections should represent the organized results of systematic investigations rather than their sole basis. Museums should be more of a record of researches successfully completed and now made available for all, than of places to carry on such work.

There is an increasing demand both on the parts of the museums and of the general public that the results of museum work should be made available for all, as the following quotation from Mr. Cheshire Lowton Boone will show.

> Now the mere collection and systematic study of things of nature and the doings of people is an occupation leading nowhere, profiting no one, and obviously ending in a cultural cul-de-sac, unless the student uses his research to illuminate some race problem. . . . I grant you the delight in personal vocations, because I have this in common with other men. But the most enthusiastic interest in science or art or literature as a justification for the maintenance of museums must, it seems to me, imply the advancement of culture, of social richness, and adjustment. In other words, those vast stores of reference material called museums must not only be indexed, classified, and studied, but exploited, and their significance laid bare for the benefit of the generations now and later. To this end the museum of whatever kind must, it appears, get into sympathy with the people, who are the ones to finally digest the results of expert study and perhaps lift themselves a peg intellectually.

This idea was brought out at one time even more strongly by W J McGee.

> The issue is between scientific research on one hand and education on the other. I think the prime function of a modern museum is education. The way in which science is best advanced is through research in the fields of nature and not in the museum. In order, however, that we may have naturalists forever with use and have an appreciation of the outside world we must educate the growing minds. The functions of a great public museum are education, the implanting in the minds of children and laymen of interpretative nuclei, interpretations of nature as it is represented, perhaps pictorially, but calculated to create an appreciation of nature in such a manner that the mind is stimulated and set to work.

That education is an important function of a museum, if not the main function, needs no further argument. The museums are rapidly coming to this position, and certainly the general public approves of it.

However, there still remains the question of the type of education to be given. Most of these institutions seem to be to-day in the position the universities were fifty years ago. They believe their function to be educational, but the public must have no say in what it will be taught. The museums have a "required course of study," and this is cultural rather than practical. A few great museums are now trying the "elective system," they have added technical and occupational "classes," and they are even going in for "university" extension. In this democratization of the museums, the needs and desires of the people are being taken more into account, and room is being found even for the craftsman. A museum's chief function is educational, in the widest sense of that term.

The purposes of a museum are: first, to disseminate knowledge, second to advance it by research, and third to do such other things as are necessary to the forwarding of its two chief aims (for example, the storing and preserving of objects of scientific, historic, or artistic value).

We are now ready to subscribe to the motto of the American Museum of Natural History, as expressed in its charter of 1869, "for the purpose of . . . encouraging and developing the study of Natural Science; of advancing the general knowledge of kindred subjects, and to that end of furnishing popular instruction," or, as it is printed on the museum's publications, "a free institution, for the people, for education, for science."

THE PHYSICAL TOLSTOI

By Dr. JAMES FREDERICK ROGERS

NEW HAVEN, CONN.

In the hidden bond between the soul and the body lies the solution of opposing aspirations.—Tolstoi.

THE physical biography of Tolstoi is easily written. The material has been abundantly furnished by reliable biographers, and we have the assistance also of our subject who, from an early date, was self-conscious and self-recording in regard to matters of the body as of the mind. It is interesting to observe the attitude toward the body which accompanied his varying views of life. Moreover, the influence of the physical upon the philosophical man stands out significantly.

Tolstoi inherited a body well fitted to house a colossal genius, and his early surroundings were such as to further his physical unfolding to the utmost. As a boy he was "interested in his father's dogs and horses," accompanied him in his hunting expeditions, and took a lively interest in all the "games and masquerades" in which the robust family amused itself.

His sensitiveness and self-concern early cropped out in distress over his homeliness and he tried to improve his appearance by clipping his eyebrows. He had "an ardent desire to fly," and persuaded himself that it was possible to do so. It was "only necessary to sit down light on your heels, clasping your arms firmly round your knees, and the tighter you held them the higher you would fly." Once when on a journey "he got out of the sleigh and ran, and was not overtaken until he had gone about two miles. He was lifted back into the carriage gasping for breath, perspiring and quite exhausted. Any one not endowed with the remarkable physical vigor," comments his biographer Maude, "that in spite of frequent attacks of ill health, has characterized Tolstoi through life, would probably have done themselves serious injury had they taxed their vital resources as recklessly as he often did."

When his brothers were sent to a riding school, Leo, although his father and the riding master insisted that he was too small, was also allowed to accompany them. "At the first lesson he duly tumbled off, but begged to be replaced in the saddle, and he did not fall off again, but became on expert horseman."

In his college days Tolstoi says: "I perfected myself physically, cultivating my strength and agility by all sorts of exercises and accustoming myself to endurance and patience by all sorts of privations," *but* "his animal passions were strong, and the looseness of morals of society lent them rein. He gave himself freely to drinking, smoking, gambling, though these and other bad habits were easier to overcome than the desire for women." "I lead an animal life," he said, "though not quite debauched," for he saw the ugliness of his sins.

His dissipations brought his college life to an end with little apparent benefit. At nineteen, "on account of ill-health, and for private reasons," he left the university and returned to his estate. Fired with ambition to better the lives of the serfs, he entered upon the task of their reformation, but his enthusiasm was dampened by the slowness of results, and after a few months he abandoned his task and with his brother gave himself up to "hunting, gambling and carousing with Zigani dancers."

Debts and other results of his conduct brought a reaction. At twenty-two he tried to "simplify" life. He rented a cottage in the Caucasus for three dollars a month. "I dine at home," he writes, "on cabbage soup and buckwheat porridge, with which I am quite content." His years of bodily abuse had told upon him. "My health is not good. I am not ill, but I often catch cold and suffer from sore throat or from toothache or from rheumatism, so that I have to keep my room at least two days in the week."

He joined the army at twenty-two, and this entry in his diary for the next year shows his efforts toward a sober life. "Refrain from wine and women . . . the pleasure is so small and the remorse so great." If suffering more or less from minor ailments, Tolstoi, as a soldier, exhibited great physical strength and endurance. "One who entered his battery in the Crimea," just after Tolstoi left it, "says he was remembered there as an excellent rider . . . and an athlete who, lying on the floor could let a man weighing thirteen stone be placed on his hands and could lift him up by straightening his arms. At a tug of war (with a stick) no one could beat him."

If there were rifts in the clouds, the end of his "twenty years [from fourteen to thirty-four] of coarse dissipation" were not yet. At twenty-seven it was again "sprees, gipsy girls, and cards all night long," and he was frequently ailing in body and in soul. "Gymnastics were fashionable in Moscow in those days and any one wishing to find Tolstoi between one and two o'clock in the afternoon could do so at the gymnasium in the Great Dmitrovka street, where, dressed in gymnastic attire, he might be seen intent on springing over the vaulting-horse without upsetting a cone placed on its back. He always," continues his biographer, "was expert at physical exercises: a first-rate horseman, quick at all games and sports, a swimmer and an excellent skater."

Fearless in the hunt, while pursuing a bear through snow, waist deep, the animal, to escape other hunters, took a cross path and came upon Tolstoi unexpectedly. When the bear was about six yards from him he fired and missed. "It was only two yards from him when his second shot hit her in the mouth but did not stop her onset. She fell upon him and Tolstoi felt his face being drawn into her mouth. He could only draw his head between his shoulders and try to present his cap instead of his face to the bear's teeth. Piercing the cap the teeth entered his flesh above and below his left eye. At this moment Ostachkof, armed with a small switch, came running up shouting at the bear, 'Where are you getting to? Where are you getting to?' at which the beast took fright and rushed off." When the wound was washed with snow and sewn up it proved to be trifling, though it left a scar.

At thirty-two, "a strongly built, broad-shouldered man," he delighted in bodily exercise and entertained his brother's children with gymnastic feats. "He would lie at full length on the floor, making them do the same, and then all would try to arise without using their hands." "He also contrived an apparatus out of rope which he fixed in the doorway; and on this he performed summersaults, to the great delight of his juvenile audience."

In establishing schools for the peasants "he had parallel bars and horizontal bars put up, and gave the children physical training." Like many other pioneers in gymnastic teaching, Tolstoi aroused suspicion, and to the effects of the novel exercises the peasant mothers did not fail to attribute any digestive troubles that befell their children from time to time; especially when the long Lenten fasts were succeeded by a return to more appetizing food, or when, after luxuries had long been lacking, fresh vegetables again came into use in summer."

Behrs, in his "Recollections," gives us a lively picture of the Tolstoi of this period. "With me, he liked to mow, or use the rake; to do gymnastics, to race, and occasionally to play leap frog, or gorodki, etc. Though far inferior to him in strength, for he could lift 120 pounds with one hand, I could easily match him in a race, but seldom passed him, for I was always laughing. That mood accompanied all our exercises. Whenever we happened to pass where mowers were at work, he would go up to them and borrow a scythe from one who seemed most tired. I of course imitated his example. He would then ask me why we, with well-developed muscles, can not mow six days on end, though a peasant does it on rye bread, and sleeping on the damp earth? 'You just try to do it under such conditions," he would add in conclusion. When leaving the meadow, he would take a handful of hay from the haycock and sniff it, keenly enjoying the smell."

Though possessed of great strength and endurance, Tolstoi seldom enjoyed very long periods of uninterrupted health. His previous abundance of health had made habits of bodily care well-nigh impossible. "In early manhood he seems to have distended his stomach by imprudence in eating, and for the rest of his life he was subject to digestive troubles." At thirty-four we find him suffering from a cough and taking for it the "koumys cure." At fifty he writes: "A week ago I caught cold and fell ill, and only to-day have I come to life again;" and the next year—"Caught cold and was ill for a week."

Tolstoi had a contempt for doctors. "Like Rousseau he considered that the practice of medicine should be general and not confined to one profession; and this opinion inclined him to approve of the folk-remedies used by peasants. But he did not go the length of refusing to call in a doctor when one of the family was seriously ill."

The mental unrest to which, after middle life, he became a prey, told seriously upon his health. At fifty-seven his wife was much concerned, for "he has quite overworked himself. His head is always aching but he can not tear himself away" from his study.

At fifty-nine, for ethical reasons, he became a vegetarian. He gave up hunting for like reasons and abandoned tobacco as a harmful luxury. The latter renunciation was very difficult, but he finally lost all longing for it. He craved the mental peace of the peasant and sought it in manual labor. "What a delight it is," he exclaims, "to rest from intellectual occupations by means of simple physical labor! Every day, according to the season, I either dig the ground, or saw and chop wood, or work with scythe, sickle, or some other instrument. As to ploughing, you can not conceive what a satisfaction it is to plough. . . . It is not very hard work, as many people suppose; it is pure enjoyment! You go along lifting up and properly directing the plough, and you don't notice how one, two, or three hours go by. The blood runs merrily through your veins; your head becomes clear; you don't feel the weight of your feet; and the appetite afterwards, and the sleep! For me daily exercise and physical labor are as indispensable as the air. In summer in the country I have plenty of choice. I can plough, or cut grass; but in autumn in rainy weather it is wretched. In the country there are no sidewalks or pavements, so when it rains I cobble and make shoes. In town, too, I am bored by simple walking, and I can not plough or mow there; so I saw or split wood. If for a single day I do not walk or work with my legs and hands, I am good for nothing by evening. I can't read or write, or even listen to any one with attention; my head whirls; there seem to be stars in my eyes, and I have a sleepless night."

Widow Anisyas's barn collapsed and Tolstoi helped to build another. He cut aspens in the forest, and "stripped and smoothed them with axe and plane." He was always first in the work—digging, preparing timbers, etc. He toiled from morning to night, proud to have done his work "with pains" and to have learned to execute some feat of handicraft.

Though he was proud of the work of his hands, it could not, in the nature of things, be as perfect as that of one who had made it his business and been trained from earlier life. Of the shoes over which he toiled for so many hours, a competent judge was so unkind as to remark that they "could not be worse."

That this period of hard muscular labor was also one prolific in valuable mental product indicates the enormous nervous energy at his command. We are reminded of that saner and happier though less robust philosopher, Emerson, who likewise sought the benefits of manual labor, but soon found that "when the terrestrial corn, beets, onions and tomatoes flourish, the celestial archetypes do not." "If I may judge from my own experience, I should unsay all my fine things, I fear, concerning the manual labor of literary men. . . . To be sure he may work in the garden, but his stay there must be measured, not by the needs of the garden, but of the study."

The following incident, occurring in his fifty-eighth year, offers a supreme example of Tolstoi's bodily powers. He wished to make the journey from Moscow to Yasnaya, a distance of a hundred and thirty miles. Disapproving of railways, but partly for the sake of economy and from love of out-door exercise, he decided to walk the distance. "Over his shoulder he took a linen sack for his food, and in it he also took a pair of broad shoes, a soft shirt, two pairs of socks, some handkerchiefs, and a small vial of stomach drops, as he often suffers from indigestion. He started with three young men. Two of them broke down on the road and the count and his companion, after sleeping in hovels, reached their destination on the third day." On their arrival Tolstoi was "lively and merry" and expressed himself as having never enjoyed anything so much in his life.

Though Tolstoi appreciated the benefit of fresh air, muscular exercise and plain food, his hygienic knowledge or practise was not otherwise perfect. He ate "like a pig," and a famished pig at that. His son, Count Ilya, writes: "My father was very hungry as a rule and ate voraciously whatever turned up. My mother would stop him, and tell him not to waste all his appetite on *kasha,* because there were chops and vegetables to follow. 'You'll have a bad liver again,' she would say, but he paid no attention to her and asked for more and more, until his hunger was satisfied." Such a mighty machine needed plenty of fuel, but it is little wonder that with such stoking, there was frequent need of stomach drops.

Mental states had a profound influence on Tolstoi's bodily condition. Nor did his peasant practise long bring him mental peace. He was but a count masquerading as a serf. In his earlier years he had spent considerable time with music, had attained some proficiency as a pianist, and his appreciation was sane and his enjoyment of the art great until the dawn of his morbidly religious and socialistic phase. During this period Rubenstein played in Moscow. By natural desire Tolstoi wished to hear him and sent for a ticket. But on second thought he found that the attendance upon the concert was out of keeping with his lately expressed views of art. The distress of doubt as to the right conduct to pursue, and his desire to be sincere, brought on a "nervous attack" which prostrated him.

The same year in which he took his long journey afoot, Tolstoi was very sick with erysipelas, which developed from an injury to his leg. In spite of the pain and weakness, he persisted in following the plough. Pretending to have neuralgia, the Countess went to Moscow and brought back a physician. Tolstoi received him with much dissatisfaction, but finally allowed an examination which revealed a temperature of 104° and a badly swollen leg, from which pieces of dead bone came away. He was laid up for nine weeks, and in times of pain not only did not forbid the coming of the physician, but more than once was glad to have him sent for at night.

At the age of sixty-six Tolstoi took boyish delight in learning to ride the bicycle. He acquired the feat without difficulty and could even ride without holding the handle bar. On May 2, 1896, he wrote in his diary, "I have stopped riding the bicycle. I wonder how I could have been so infatuated." But the joy of doing a physical feat with ease was not to be resisted and the next summer, at sixty-nine, he writes, "Went on my bicycle to Yasenki. I love the motion very much. But I am ashamed." He had always been fond of his horse, and at this time he often, after his literary work, took a ride of twenty miles, ending with a bath in the river. He was an expert swimmer and also a remarkably good tennis player.

After seventy his health became precarious. He suffered from angina pectoris, and following a severe attack at seventy-three he said to his daughter: "The sledge was at the door, and I had only to get in and go; but suddenly the horses turned round, and the vehicle was sent away. It's a pity, for it was a good sledge road, and when I'm ready to start again, it may be rough."

In the following year he suffered from inflammation of the lungs, and later, from typhoid fever. Always skeptical about medicine, he was surprised to note the stimulating effects of injections of camphor, and speaking in his humorous way he said: "Well, gentlemen, I have always spoken badly of doctors, but now that I have got to know you better, I see that I did you great injustice. You are really very good men, and know all your science teaches: the only pity is," he added, "that it knows nothing." A resident physician for Yasnaya was obtained on his account; but Tolstoi stipulated that the doctor must also be at the disposal of the neighboring peasants. His health improved greatly and in August of this year he was able to walk for two hours a day. Riding, the day after his seventy-fifth birthday, and wishing to spare his horse for a season, he got off and led it by the bridle. The animal trod on his foot and he was prevented from walking for some time.

At eighty-one he was still able to ride horseback, though vigor and certainty of mental and bodily processes were failing, and his death from pneumonia came in the following year, when, like an animal, he sought to retire from the haunts of his fellows to end his days alone.

The physical Tolstoi is the mirror of the mental and moral colossus that he was. It is interesting to observe the sway which, for so long, his primitive somatic nature, by its very strength, held over him. He recognized the higher, though he followed the leadings of his lower nature. Though he knew the shallowness of pleasure and depth of regret which followed his conduct, his moral aspirations were continually swamped by his bodily automatism. If, like Saint Francis, he had early experienced a prostrating illness, his career might have been greatly altered. That his health was so little injured by the prolonged period of excess proves how wonderfully strong he was. The large crop of the golden grain of genius was, however, sadly mixed and marred by a late and abundant yield of wild oats.

It is especially noteworthy that Tolstoi, in his better moods, and after his emancipation from its sway, had the highest regard for the body and went to the utmost pains to bring it to and keep it at its best. To do so was an essential part of his religion.

JACOBUS HENRICUS VAN'T HOFF

VAN'T HOFF was born in Rotterdam in 1852, the son of a physician. He died in 1911. After completing his work in the Unversity of Leiden, he studied under Kekulé in Bonn and Würtz in Paris and obtained the doctor's degree at Utrecht in 1874.

When only twenty-two years old van't Hoff showed that certain unexplained cases of isomerism would be accounted for if structure formulas were so written as to represent the arrangement of atoms in space and not merely relations in a plane. The importance of this new point of view lay in the fact that it enabled chemists to classify substances which rotate the plane of polarized light and to predict what substances will possess this property. The branch of chemistry known as stereochemistry is the outgrowth of the paper published by van't Hoff in 1874 and of the independent statement of the same idea by LeBel a few months later.

In 1878 van't Hoff was appointed professor of chemistry, mineralogy and geology at the new University of Amsterdam. From this time forward his work has been in physical chemistry rather than in organic chemistry. In the next six years he rediscovered the law of mass action; he worked out the generalized theory of reaction velocities; he showed that the quantitative relation between chemical affinity and heat effect has the same form as the relation between electrical energy and heat effect deduced by Helmholtz. In addition to this he established the theorem which bears his name, on the quantitative displacement of equilibrium with change of temperature.

In 1885 a new period begins. Some experiments by the botanist, Pfeffer, were the starting-point. Pfeffer had been studying the rise of sap in trees and had found that a high pressure is necessary to prevent the diffusion of water through a membrane of colloidal copper ferrocyanide into a solution of sugar in water. Van't Hoff showed that the results of Pfeffer could be predicted if it were assumed that a dissolved substance exercises an osmotic pressure equal to the pressure which it would exert if converted completely into a gas occupying the volume of the solution and having the same temperature. This assumption not only explained Pfeffer's results, but also those of Racult on the vapor-pressures, boiling-points and freezing-points of solutions. When the osmotic pressure theory of solutions was supplemented by Arrhenius's theory of electrolytic dissociation, it needed only the energy and enthusiasm of Ostwald to raise physical chemistry in the short space of twenty years to the position which it now holds.

In 1894 van't Hoff was offered the chair of physics at Berlin, made vacant by the death of Kundt. This was declined; but the ideal position offered by the Prussian Academy in the following year was accepted and van't Hoff left Amsterdam in 1896 for Berlin. Since that time he has worked systematically at a problem which had interested him off and on for many years previously. The special form of the problem was a systematic study of the conditions of equilibrium in their bearing on the salt deposits at Stassfurt, but the general results are applicable to all cases in which the deposits consist chiefly of any mixtures of the chlorides and sulphates of sodium, potassium, magnesium and calcium. Although not yet finished, the work is a masterpiece and shows what can be expected from an application of physical chemistry to geology and mineralogy.

The work of van't Hoff can be divided crudely into four parts: 1872–1877, organic chemistry; 1878–1884, chemical affinity; 1885–1895, theory of solutions; 1896–1904, oceanic deposits. Much of the organic chemistry of to-day is the direct outcome of the work done in the first period; the second and third periods made physical chemistry possible; the fourth period has probably introduced a new era in geology. It was because van't Hoff is a great exponent both of organic chemistry and of physical chemistry that he was the first man to be awarded the Nobel prize in chemistry.

VAN'T HOFF IN AMERICA

By Dr. BENJAMIN HARROW

COLUMBIA UNIVERSITY

ON the occasion of its tenth anniversary, the University of Chicago invited some distinguished foreign scholars to attend its celebration. Among these was Van't Hoff. Whilst on his journey Van't Hoff kept a brief diary which has since found its way into Ernest Cohen's life of the great Dutch chemist (in German).

No sooner were the necessary arrangements completed with Nef, representing the University of Chicago, than further invitations began to pour in from the American Chemical Society, from Yale, from Richards at Harvard, from Bancroft at Cornell, from Loeb at Wood's Hole, etc.

With his wife by his side, and with a dose of sodium cyanide in his pocket, to be used in case of accident—a typical European custom—Van't Hoff set sail from Rotterdam on May 21, 1901. Being a Dutch celebrity, the directors of the Holland-American Line set aside a stateroom for his use, and at table he sat with the captain on the one side and the Dutch Consul to St. Paul on the other.

The voyage, aside from a day of rough weather, was, on the whole, a pleasant one. Professor Webster Wells, of Boston, and Dr. Pettijohn, of Chicago, whom he met on board, proved agreeable companions. During the spare moments when talk and play did not occupy him, Van't Hoff busied himself with Loeb's work.

After landing in New York, where his pockets were searched by a custom-house official as though he were a pickpocket (!), Van't Hoff registered at the Savoy Hotel. Here troubles soon began. The taxi-man proved exorbitant. The wash basin in his room had unexpected possibilities. The shades simply could not be moved, as though defiant of European authority. And the trunk, without which outdoor life was not to be thought of, simply would not show up.

In good time things righted themselves somewhat. With the arrival of the trunk a brief stroll was undertaken. Everything was greeted with open-mouthed astonishment. Much was found that was beautiful; much that was ugly; but everywhere something very distinctively American was encountered. Upon his return, cards from Professor Chandler, from his son-in-law, Pellew, and from a reporter of the *New York Tribune*, together with an invitation to the Century Club, awaited him. This was evidently the beginning of American hospitality.

At luncheon there was a welcome introduction to ice-water —an unknown luxury in Europe. After the mid-day meal, Miss Maltby, of Barnard, whom Van't Hoff had met in Göttingen, called on him and his wife, and the trio started out on a stroll through Central Park and the Zoo, thence by bus to the "glorious" Hudson and Grant's Tomb, and finally to Barnard and the girls for supper.

The following day visits to Hale, to Chandler and to Pellew were planned. Brooklyn proved too complicated a center, and Hale could not be located. However, a sight of Brooklyn Bridge partially repaid his disappointment, for this structure aroused much admiration from the artistic scientist. The homes of Chandler and Pellew, "with their well-dressed ladies" were easier to find.

Not being expected in Chicago for some days, Van't Hoff decided to visit some places of interest in this country. The first to be selected was Baltimore, with its Ira Remsen and Johns Hopkins. The country, as viewed from a Pullman, did not excite him much. One feature was the large posters along the road, announcing such items as "Baker's 5c Cigars, Generously Good," or "Omega Oil For Sore Feet, Stops Pain, For Headaches, For Everything." That, at least, was America with a vengeance! Passing into Philadelphia over the Delaware recalled the story of the famous crossing and the chain of dramatic events that followed it.

Baltimore was much more after his own heart. There was none of that breathless living so characteristic of the Empire City. Here people lived more on the style of the Rotterdammers and Amsterdammers.

At the University he met his old pupil, Harry C. Jones, whose open-hearted laughter, with his "all right" and "first-rate" and "that's it" won Van't Hoff completely. Here he was shown the first of the series of classical researches on osmotic pressure, so intimately associated with the name of Morse.

The greeting by President Remsen and the faculty in the Senate House was most cordial. "Really great" was a phrase used, and Van't Hoff felt satisfied. The lunch at Remsen's which followed it, however, was too exclusively American; particularly the grape-fruit, which Van't Hoff had not, as yet, cultivated a taste for.

On to Washington! More south! More negroes!! Fans!!!

Here the trusty Baedeker did yoeman service—whether at the Capitol, or at Howard University (a university for negroes!), or at the Geological Survey, or at the Smithsonian Institution, or at Mount Vernon. There was much to admire. And Day, and Clarke, and Hillebrandt, of all of whom he had heard much, he was glad to meet.

Over the Lehigh Valley to Mauch Chunk, the "American Switzerland," with its immense coal-fields, and thence to Ithaca. Here some delightful hours were spent with Bancroft and his wife. An introduction to President Schurman gave occasion for a discussion on the influence of the money-kings on the development of American universities. This was apropos of the dismissal of a professor who professed leanings towards socialism. Their next stop was in Buffalo, where the Pan-American Exposition and the grand Niagara Falls were visited.

From Buffalo Van't Hoff proceeded direct to Chicago. The Pullman arrangements were an unpleasant surprise to him. He recalled how traveling from Paris to Strassburg each passenger had his own little room with his own wash-stand. But these common sleeping quarters, stiflingly hot and uncomfortable, with one wash-stand for all!

At Chicago Nef had undertaken to look after his comfort, and the result was everything that could be desired. His suite at the Hotel Windemere was ducal in pretentiousness.

The first part of the celebration consisted of a reception tendered by Mr. Rockefeller. Here he made the acquaintance of Stieglitz and Alexander Smith. In the afternoon Van't Hoff delivered the first of his promised addresses, and this duly made its appearance in *Science*. Later on, Nef took him to a baseball game which was to be played between Chicago and Michigan, and here, for the first time, Van't Hoff really understood just what baseball is. It would seem that while in Washington he had one day watched a steamer crowded with lively young girls depart for a baseball game. At that time our learned professor was of the opinion that baseball was some sort of a dance!

In the evening the president tendered a dinner to his guests. Van't Hoff was seated between M. Cambon, the French Ambassador, and Professor Goodwin, of Harvard. Goodwin considered Van't Hoff's speech on the occasion—"American Ideals"—the best, because it was the shortest! Rockefeller's presence made wine or beer out of the question.

Following this came the general reception, which was most noteworthy for the immense crowd which had been gathered there. Van't Hoff retired to a quiet corner with Alexander Smith, "an extraordinary tall colleague."

The following day—June 18—began with the laying of the foundation stone. The heat was terrific, and poor Van't Hoff fell quite asleep during the long-drawn-out speeches.

Then came the awarding of degrees. All the honorary recipients were there, with the exception of the Russian, who had got his dates confused because of sticking too close to his Russian Calendar!

Fully one half of the students who received degrees were girls. This was an excellent augury for the future, thought Van't Hoff, and the thought he conveyed to an acquaintance sitting near-by. This man explained the university's point of view by saying that the authorities did not greatly encourage the girl graduates to seek positions, but did like to see these same girls marry rich men. Why? Because it would then be the duty of these girls to interest their *rich* husbands in the needs of the university. Was the man serious?

Van't Hoff was among a few to receive the honorary degree of Doctor of Laws.

At 1 P.M. came the alumni dinner, and Van't Hoff was honored by being seated next to Rockefeller. Very little conversation was carried on with the oil magnate, because this gentleman seemed much too preoccupied with his coming speech. When Rockefeller's turn did come, he commenced with a story about a negro who was asked what he thought of Jesus, to which the negro replied, "I have nothing against Him." With this, Rockefeller turned to the public and said, "I have nothing against you." Van't Hoff does not tell us how the millionaire further developed his speech.

Again not a drop of alcohol on the table! Again Rockefeller's influence!

The next four or five days were mainly occupied with the preparation and deliverance of the lectures—since published and translated into English by Alexander Smith.

On the 24th of June Van't Hoff departed for Cambridge. At Boston he was met by Richards, who had provided for his comfort as liberally as had Nef at Chicago.

On the 26th, which was the day of Harvard's Commencement, Van't Hoff was presented for his honorary degrees as "the greatest living physical chemist," a statement which was received with much applause. The lunch at Memorial Hall which followed was chiefly memorable because of Roosevelt's presence. The well-advertised teeth showed prominently. The evening was spent at the homes of Richards and Münsterberg. The following day, with Jackson and Richards as guides, Boston's sights were carefully inspected. In the evening he was the chief guest at a dinner which included President Eliot, Richards, Jackson, Pickering, Trowbridge, Hill, Michael and Bancroft. Gibbs and Crafts sent regrets. Van't Hoff was seated next to Eliot, who discussed with him the possibility of losing Richards, at that time considered as a probable successor to the chair of chemistry at Göttingen—an unusual distinction for an American!

Van't Hoff took his departure from this country highly impressed with all that he had seen. He prophesied that within fifty years American universities would seriously rival those in Europe. It is but seventeen years since he has been here, but his prophecy has already come true.

THE PROGRESS OF SCIENCE

ANDREW DIXON WHITE

THE death of Andrew Dixon White at the close of his eighty-sixth year completes a life of fine performance. Three great university presidents, White at Cornell, Angell at Michigan and Eliot at Harvard, were the leaders in the development of our system of higher education. Theirs is not the blame if the office has been magnified by their qualities so as to become dangerous in the hands of lesser men.

White and Ezra Cornell were members of the New York State Senate in 1863, when the question of the disposal of the land grant for colleges of agriculture and the mechanic arts was under discussion. As the result of conferences between them, Cornell gave $500,000 to establish Cornell University in cooperation with the land-grant college. White was elected president of the new university, and served in that office for twenty years. Through his influence there was established an institution for advanced instruction and research in which science, pure and applied, had an equal place with letters, and in which the students were in large measure released from pedantry and routine. It was provided at the outset that "no professor, officer, or student shall ever be accepted or rejected on account of any religious or political views which he may or may not hold."

White once told the present writer the story of how nearly he had repeated the experience with Mr. Cornell. A prominent benefactor had provisionally accepted his plans for a national university at Washington with an endowment of forty million dollars, but was finally dissuaded by those who looked askance on such an institution.

White was professor of history and English literature at the University of Michigan from 1857 to 1863, having been appointed to his chair at the age of twenty-five years, after his return from three years' study in Europe. During that time he had been an attaché of the American legation at St. Petersburg and at Moscow. In 1867 he was made minister to Germany, which post he occupied as ambassador from 1897 to 1902, having from 1897 to 1914 served as minister to Russia. He was also active in diplomatic and political affairs at home. Even last summer at the age of eighty-five years he spent several weeks in Washington as an adviser of President Wilson.

White was also an author of distinction. In this place it is becoming to state that he was one of three men whose contributions did the most to make *The Popular Science Monthly*, on the editorial lines of which this journal is conducted, a leader in the emancipation of science and of thought in this country. It is difficult for us to understand the bitterness with which Darwin and the theory of evolution were opposed when the *Monthly* began publication in 1872. To it White contributed twenty-eight articles, Herbert Spencer ninety-one and Huxley forty-four. Those of White's articles concerned with the struggle of science for freedom were subsequently published in book form under the title "A History of the Warfare of Science with Theology," a work of fine scholarship and wide influence. White was the author of a number of books concerned with

Andrew Dixon White.

economics, history, education and social conditions. In 1905 he published the autobiography of a life of unusual usefulness and distinction.

FREEING THE FOREST RESERVES FROM PREDATORY ANIMALS.

SKILLED hunters in the employ of the government are waging persistent warfare against the predatory animals that prey on sheep and cattle in the western states. Their efforts are encouraging stockmen to increase live-stock production on the federal forest reserves as well as in the range country, and they are protecting the sources of supplies of meat, leather and wool now in the western grazing districts.

Hunters of the Biological Survey of the United States Department of Agriculture have killed 70,713 predatory animals during the last three years, which has resulted in a direct saving estimated at nearly $5,500,000 a year to the stockmen of the Rocky Mountain section. The total number killed since the fall of 1915, when the work was started, includes 60,473 coyotes, 8,094 bobcats, 1,829 wolves, 201 mountain lions and 137 bears. The government experts estimate that the annual depredations among cattle and sheep effected by single predatory animals are as follows: wolf, $1,000; stock-killing grizzly bear, $500; mountain lion, $500; bobcat, $50; and coyote, $50.

Stockmen in sections where the predatory animals are obnoxious are aided by the government in ridding the ranges. In some localities the stockmen's associations cooperate with the state and federal authorities in the extermination campaign, professional hunters being employed to detect and kill the animals that prey on sheep and cattle. Illustrative of the scope of this work, the total income from pelts of predatory animals killed by government hunters last year amounted to approximately $100,000. In addition many other animals whose skins could not be reclaimed were killed by poisoning. Ordinarily the United States Biological Survey has from 250 to 350 professional hunters permanently in its employ. The area wherein predatory animal control is practiced includes ten districts: Montana; Idaho; Washington and Oregon; Nevada and California; Utah; Wyoming and South Dakota; Colorado; Arizona; New Mexico; and Texas.

During the last twelve months 26,226 coyotes, 3,458 bobcats, 849 wolves, 85 mountain lions, and 41 stock-killing bears have been disposed of at an annual saving of approximately $2,400,000 in domestic stock. Recently a government hunter shot two male wolves which had killed 150 sheep and 7 colts on two Wyoming ranches, while another trapper bagged a pair of old wolves which had a record of killing $4,000 worth of live stock a year. A third trapper destroyed 85 coyotes and 2 bobcats in one month, using 6 horses and 200 traps over a trap line varying from 50 to 100 miles in length. A coyote was recently captured which had destroyed $75 worth of sheep in one week. Two wolves, seven mountain lions, and a grizzly bear, the largest of its species ever killed in the Yellowstone Park section, were shot by another sharpshooter. These results are typical of the campaign destined to free the Rocky Mountain range country of predatory animals.

THE BALTIMORE MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE meeting of the American Association for the Advancement of

Skins of some of the larger predatory Animals on an Oregon National Forest.

Science and of the national scientific societies affiliated with it, which it has been planned to hold this year in Boston, has been transferred to Baltimore in order to reduce as much as possible the need for traveling and to be near Washington, which has become the center of scientific activity of the country. It is planned that the programs of the association and of the affiliated societies shall be mainly directed to questions of national welfare, national efficiency and national defense; they will demonstrate the value of science and of the work of scientific men to the country. Dr. L. O. Howard, the permanent secretary of the association, under the date of October 16, addressed the following letter to the secretaries of the affiliated societies:

Something of a complication has arisen in connection with the meetings of the American Association for the Advancement of Science and the affiliated societies.

The Johns Hopkins University has taken on the Students Army Training Corps and, therefore, its courses are largely revised and its faculty is very busy. Their Christmas vacation runs only from the 22d to the 29th of December, both dates inclusive.

I had expected to be able to utilize the facilities of Goucher College, but this institution has now been closed by the epidemic of influenza and will probably have to be in session during Christmas week.

The present situation leaves for our meeting dates the 23d and 24th (then comes Christmas Day) and the 26th to the 28th, these being the only dates in which certain of the lecture rooms of Johns Hopkins can be used by us.

The committee on policy of the association has decided to adhere to its decision to meet in Baltimore, but there must be some change in plans, both on account of the small size and number of lecture rooms available and the fact that there are practically no hotel accommodations. Members will have to rely almost entirely upon lodging-houses.

It is obvious that for certain of the affiliated societies the 23d and 24th should be selected and, for others, the 26th to the 28th, since rooms vacated on the night of the 24th can be used by members of the affiliated societies meeting on the 26th to the 28th.

It is planned to have the opening meeting of the American Association on the night of Thursday, December 26, although meetings of the sections may be held during the day of the 26th.

SCIENTIFIC ITEMS

We record with regret the death of Major Alfred Reginald Allen, instructor in neurology in the University of Pennsylvania, killed in France; of Captain George S. Mathers, of the McCormick Institute for Infectious Diseases, and of Lieutenant Admont Halsey Clark, M.C., U. S. Army, assistant professor of pathology in Johns Hopkins University.

The Prince of Wales has accepted the position of patron of the Ramsay Memorial Fund, founded in November, 1916, to raise £100,000 as a memorial to the late Sir William Ramsay. The committee has already collected £37,000, and subscriptions from oversea committees will probably bring the total to £50,000. It is proposed to raise the remaining £50,000 by a million shilling fund, now opened with a donation of 1,000 shillings from the Prince of Wales. Already over 10,500 shillings have been subscribed. The fund will provide Ramsay Research Fellowships and a Ramsay Memorial Laboratory of Engineering Chemistry in connection with University College, London. Donations from one shilling upwards should be sent to the honorable treasurer, Lord Glenconner, at University College, London.

According to a press dispatch from Paris Dr. Alexis Carrel, of the Rockefeller Institute for Medical

Research, was recently seeking a building at Saint Cloud suitable for a laboratory and workshop near certain hospital centers. He found the house he wanted in a park full of splendid trees. The property belonged to André Bernheim, who had refused all offers to rent it on account of the family souvenirs it contained and the art treasures. When Mr. Bernheim heard of Dr. Carrel's wish to lease his house he said: "Tell Dr. Carrel that I am greatly flattered at his choice and that the Verger and its surroundings are at his service." When the question of rent was raised, Mr. Bernheim declared, "No, no, a scientist owes nothing to anybody. It is I who am honored."

INDEX

NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS

BINDING LIST SEP 1 1947

Q
1
S817
v.7
Physical &
Applied Sci.
Serials

The Scientific monthly

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY